Date and Time Terms and Definitions

Brooks Harris Version 35 2016-05-17

Introduction

Many documents describing terms and definitions, sometimes referred to as “vocabulary” or “dictionary”, address the topics of timekeeping. This document collects terms from many sources to help unify terminology and to provide a single reference document that can be cited by documents related to date and time.

The basic timekeeping definitions are drawn from ISO 8601, its underlying IEC specifications, the BIPM Brochure (The International System of Units (SI)) and BIPM International vocabulary of metrology (VIM).

Especially important are the rules and formulas regarding TAI, UTC, and “civil”, or “local”, time. The international standards that describe these fundamental time scales, the rules and procedures of their maintenance, and methods of application are scattered amongst many documents from several standards bodies using various lexicon. This dispersion makes it difficult to arrive at a clear understanding of the underlying principles and application to interoperable implementations. This document collects and consolidates definitions and descriptions from BIPM, IERS, and ITU-R to clarify implementation.

There remain unresolved issues in the art and science of timekeeping, especially regarding “time zones” and the politically driven topic of “local time”. This document does not attempt to resolve those dilemmas but describes the terminology and the current state of the art (at the time of publication) to help guide implementation.

Table of Contents

1 Scope

This document specifies terms and definitions for use in engineering documents related to date and time.

2 Conformance Notation

This draft is the author's work and not yet under any official SDO authority. Any standards document must include some form of conformance notation and IETF RFC 2119 is used as a starting point or placeholder.

Key words for use in RFCs to Indicate Requirement Levels

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

3 Normative References

BIPM The International System of Units (SI) 8th edition 2006 (commonly called the SI Brochure)
http://www.bipm.org/en/publications/si-brochure/

BIPM JCGM 200:2012, International vocabulary of metrology – Basic and general concepts and associated terms (VIM)
http://www.bipm.org/en/publications/guides/vim.html

ISO 8601 2004-12-01, Data elements and interchange formats — Information interchange — Representation of dates and times
http://www.iso.org/iso/iso8601

IEC INTERNATIONAL STANDARD, 60050-11, Amendment 1 International Electrotechnical Vocabulary – Part 111: Physics and chemistry
http://www.mz3r.com/fa/wp-content/uploads/2012/02/books/standards_of_IEC/60050-111.pdf

IEC INTERNATIONAL STANDARD, 60050-11, Amendment 1 International Electrotechnical Vocabulary – PART 713: RADIOCOMMUNICATIONS: TRANSMITTERS, RECEIVERS, NETWORKS AND

OPERATION
http://www.iea.lth.se/internt/IEC_Dictionary/Base/713.pdf

BIPM Annual Report on Time Activities 2012
http://www.bipm.org/en/scientific/tai/time_ar2012.html

ITU-R TF.460-6 (02/02), Standard-Frequency and Time-Signal Emissions
http://www.itu.int/rec/R-REC-TF.460/en

ITU-R TF.457-2 (10/97), Use of the Modified Julian Date by the Standard Frequency and Time-Signal Services
http://www.itu.int/rec/R-REC-TF.457-2-199710-I

INTERNATIONAL EARTH ROTATION AND REFERENCE SYSTEMS SERVICE (IERS), Leap_Second_History.dat
ftp://hpiers.obspm.fr/iers/bul/bulc/Leap_Second_History.dat

IERS RESOLUTION B1 ON THE USE OF JULIAN DATES
The XXIIIrd International Astronomical Union General Assembly,
http://www.iers.org/nn_10382/IERS/EN/Science/Recommendations/resolutionB1.html

Title: International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884. Protocols of the Proceedings
http://www.gutenberg.org/cache/epub/17759/pg17759.txt

IERS Conventions (2010)
IERS Technical Note No. 36
http://www.iers.org/IERS/EN/Publications/TechnicalNotes/tn36.html
Also at ftp://tai.bipm.org/iers/conv2010/tn36.pdf

World Geodetic System 1984
http://www.unoosa.org/pdf/icg/2012/template/WGS_84.pdf

IEEE Std 1588-2008, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems[1]

ISO 80000-3 2006 Quantities and units – Part 3: Space and time

4 Date and time text formatting notation

Date (calendar) and time text formatting notation in this document follows the recommendations of ISO 8601 as closely as possible with certain restrictions and modifications to clarify meaning within this document.

Date and time notation will generally use only the extended form "YYYY-MM-YY hh:mm:ss". See ISO 8601, *4.1.2 Calendar date, 4.1.2.2 Complete representations*, and *4.2.2 Local time, 4.2.2.2 Complete representations*.

Date and time on the UTC time scale at the IERS Reference Meridian, that is *UTC of day*, will use the extended form including the "T" time designator with the addition of a "(UTC)" suffix. For example "1972-01-01T00:00:00Z (UTC)". See ISO 8601, *4.2.2.5 Representations with time designator* and *4.2.4 UTC of day*.

Date-time on a local time scale will use the extended form including the "T" time designator and the "+-xx:xx" difference from UTC indicator, with addition of a "(UTC)" suffix. For examples "1972-01-

[1] IEEE-1588 is a registered trademark of the Institute of Electrical and Electronics Engineers, Inc.

01T00:00:00-08:00 (UTC)", "1972-01-01T00:00:00+01:00 (UTC)". See ISO 8601, *4.2.5.1 Difference between local time and UTC of day*.

NOTE 1 Representations of the UTC and local time scales indicate accurate UTC date and time according to the rules of UTC including application of Leap Seconds.
NOTE 2 The "difference from UTC indicator" portion of a representation of local time scales may or may not include a factor for Daylight Savings ("summertime" v.s. "wintertime"). This RP makes no attempt to specify how this ambiguity is to be resolved. See section *standard time.*

Date and time on the TAI time scale will use the extended form *without* the "T" time designator and with the addition of a "(UTC)" suffix. For example "1970-01-01 00:00:00 (TAI)".

NOTE 3 The "difference from UTC indicator" is not applicable on the TAI timescale.
NOTE 4 Representation of the TAI time scale is not an accurate UTC date and time because it does not include Leap Seconds; the duration of all days is 86400 seconds.

5 Basic terms and concepts

Basic Term and Concepts follows ISO 8601 definitions as closely as possible, often quoting directly. This includes the normative references used by ISO 8601 where needed, especially IEC 60050. It also adopts the style of ISO 8601 where square braces "[]" contain the specific reference.

5.1 International System of Quantities (ISQ)

The International System of Units (abbreviated SI from French: Le Système international d'unités) is the standardized system of units of measurement.

The 11th CGPM (General Conference on Weights and Measures (French: Conférence générale des poids et mesures - CGPM)) of 1960 laid down rules for the prefixes, the derived units, and other matters for a recommended practical system of units of measurement.

The base units are a choice of seven well-defined units, which by convention are regarded as dimensionally independent: the metre, the kilogram, the second, the ampere, the kelvin, the mole, and the candela. Derived units are those formed by combining base units according to the algebraic relations linking the corresponding quantities. The names and symbols of some of the units thus formed can be replaced by special names and symbols which can themselves be used to form expressions and symbols of other derived units. The SI is not static but evolves to match the world's increasingly demanding requirements for measurement.

See BIPM The International System of Units (SI) 8th edition 2006 (commonly called the SI Brochure).

Table – SI base units

Unit name	Unit symbol	Quantity name
Metre	m	length
Kilogram	kg	mass
Second	s	time
Ampere	A	electric current
Kelvin	K	thermodynamic temperature
Mole	Mol	amount of substance
Candela	Cd	luminous intensity

5.2 Quantity

property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference. NOTE2 - A reference can be a measurement unit, a measurement procedure, a reference material, or a combination of such.
[BIPM VIM, 1.1]

5.3 kind of quantity, kind

aspect common to mutually comparable quantities

[BIPM VIM, 1.2]

5.4 scalar
real or complex number
[IEC IEV 102-02-18]

5.5 measurement unit, unit of measurement, unit
real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the two quantities as a number NOTE 1 Measurement units are designated by conventionally assigned names and symbols.
[BIPM VIM, 1.9]

5.6 quantity-value scale, measurement scale
ordered set of values of quantities of a given kind used in ranking, according to magnitude, quantities of that kind
[IEV 112-01-36]

5.7 ordinal value scale
quantity-value scale for ordinal quantities
[IEV 112-01-37]

5.8 conventional reference scale
quantity-value scale defined by formal agreement
[IEV 112-01-38]

5.9 conversion factor between units
ratio of two measurement units for quantities of the same kind
EXAMPLE km/m = 1 000 and thus 1 km = 1 000 m.
NOTE The measurement units may belong to different systems of units.
EXAMPLE 1 h/s = 3 600 and thus 1 h = 3 600 s.
EXAMPLE 2 (km/h)/(m/s) = (1/3.6) and thus 1 km/h = (1/3.6) m/s.
[BIPM VIM, 1.24]

5.10 quotient
result of the division of two numbers or quantities
[IEV 112-03-01 Quantities and units]

5.11 rate
quotient of a quantity by a duration
[IEC 112-03-18 Quantities and units]

5.12 nominal
1: of, relating to, or constituting a name
2: existing or being something in name or form only
3: of, being, or relating to a designated or theoretical size that may vary from the actual: approximate

5.13 space-time
conceptual model having properties of a four-dimensional mathematical space and used to describe everything existing physically.
[IEC 60050-111, 111-16-01]

5.14 time
one-dimensional mathematical space, which is a subspace of space-time and which is locally orthogonal to space
[IEC 60050-111, 111-16-03]

5.15 event
something that happens in time (1)
NOTE In pure physics, an event is considered as a point in space-time.
[IEC 60050-111, 111-16-04]

5.16 instantaneous
adj, pertaining to an event that is considered as having no extension in time (1).
[IEC 60050-111, 111-16-05]

5.17 process
sequence in time (1) of interrelated events
[IEC 60050-111, 111-16-06]

5.18 time axis
mathematical representation of the succession in time of instantaneous events along a unique axis
NOTE According to the special relativity theory, the time axis depends on the choice of a spatial reference frame.
[ISO 8601, 2.1.1]
[IEC 60050-111, 111-16-07]

5.19 instant
point on the time axis
[ISO 8601, 2.1.2]
[IEC 60050-111, 111-16-08]

NOTE An instantaneous event occurs at a specific instant.
[ISO 8601, 2.1.2]

5.20 instantaneous
pertaining to an event that is considered as having no extension in time
[IEC 60050-111, 111-16-05]

5.21 simultaneous
pertaining to two or more events having the same initial instant and the same final instant
NOTE According to the special relativity theory, the concept of “simultaneous” depends on the choice of a spatial reference frame.
[IEC 60050-111, 111-16-09]

5.22 period
- a length of time during which a series of events or an action takes place or is completed
- a chronological division
- a division of geologic time longer than an epoch and included in an era

5.23 time interval
part of the time axis limited by two instants

NOTE 1 A time interval comprises all instants between the two limiting instants and, unless otherwise stated, the limiting instants themselves.

NOTE 2 A time interval can be specified by the dates marking the initial instant and final instant or by one of these dates and the duration of the time interval.

[ISO 8601, 2.1.3]
[IEC 60050-111, 111-16-10]

5.24 time scale
system of ordered marks which can be attributed to instants on the time axis, one instant being chosen as the origin

NOTE 1 A time scale may amongst others be chosen as:
- continuous, e.g. international atomic time (TAI) (see IEC 60050-713, item 713-05-18);
- continuous with discontinuities, e.g. Coordinated Universal Time (UTC) due to leap seconds, standard time due to summer time and winter time;

- successive steps, e.g. usual calendars, where the time axis is split up into a succession of consecutive time intervals and the same mark is attributed to all instants of each time interval;
- discrete, e.g. in digital techniques.

NOTE 2 For physical and technical applications, a time scale with quantitative marks is preferred, based on a chosen initial instant together with a unit of measurement.

NOTE 3 Customary time scales use various units of measurement in combination, such as second, minute, hour, or various time intervals of the calendar such as calendar day, calendar month and calendar year.

NOTE 4 A time scale has a reference point which attributes one of the marks of the time scale to one of the instants, thus determining the attribution of marks to instants for the time scale.

[ISO 8601, 2.1.4]
[IEC 60050-111, 111-16-11]

5.25 time point

date
time
mark attributed to an instant by means of a specified time scale

NOTE 1 On a time scale consisting of successive steps, two distinct instants may be expressed by the same time point (see Note 1 of the term “time scale”).

NOTE 2 For many time scales with quantitative marks, the numerical value of the time point of an instant may also be considered to be equal to the duration between the origin of the time scale and the considered instant.

NOTE 3 In IEC 60050-111 this definition corresponds with the term “date”.

NOTE 4 The term “time” is often used in common language. However, it should only be used if the meaning is clearly visible from the context, since the term “time” is also used with other meanings.

[ISO 8601, 2.1.5]

5.26 duration

non-negative quantity attributed to a time interval, the value of which is equal to the difference between the dates of the final instant and the initial instant of the time interval, when the dates are quantitative marks

NOTE 1 Different time intervals may have the same duration, e.g. the period of a time-dependent periodic quantity is a duration that is independent of the choice of the initial instant.

NOTE 2 The duration is one of the base quantities in the International System of Quantities (ISQ) on which the International System of Units (SI) is based. The term “time” instead of “duration” is often used in this context and also for an infinitesimal duration.

NOTE 3 For the term “duration”, the word expressions as “time” or “time interval” are often used, but the term “time” is not recommended in this sense and the term “time interval” is deprecated in this sense to avoid confusion with the concept of “time interval”.

NOTE 4 The SI unit of duration and time (2) is the second.

NOTE 5 In common language, the word “time” is used with several different meanings. In technical language, however, more precise terms, e.g. date, duration, time interval should be used.

[ISO 8601, 2.1.6]
[IEC 60050-111, 111-16-13]

5.27 nominal duration
duration expressed amongst others in years, months, weeks or days

NOTE The duration of a calendar year, a calendar month, a calendar week or a calendar day depends on its position in the calendar. Therefore, the exact duration of a nominal duration can only be evaluated if the duration of the calendar years, calendar months, calendar weeks or calendar days used are known.

[ISO 8601, 2.1.7]

5.28 date
time point representing a calendar day on a time scale consisting of an origin and a succession of calendar days
[ISO 8601, 2.1.8]

5.29 calendar date
date representing a particular calendar day by its calendar year, its calendar month and its ordinal number within its calendar month
[ISO 8601, 2.1.9]

5.30 ordinal date
date representing a particular calendar day by its calendar year and its ordinal number within its calendar year
[ISO 8601, 2.1.10]

5.31 week date
date representing a particular calendar day by the calendar year to which its calendar week belongs, the ordinal number of its calendar week within that calendar year and its ordinal number within its calendar week
[ISO 8601, 2.1.11]

6 Time units

6.1 second
base unit of measurement of time in the International System of Units (SI) as defined by the International Committee of Weights and Measures (CIPM, i.e. Comité International des Poids et Mesures)
[ISO 8601, 2.2.1]

second (symbol s): "duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom"
[ISO 80000-3 2006]

BIPM The International System of Units (SI) 8th edition 2006, 2.1.1.3 Unit of time (second).

6.2 minute
unit of time, equal to 60 seconds
[ISO 8601, 2.2.3]

6.3 nominal minute
Unit of time equal to 60 seconds or 60 seconds plus 1 second in the case of a positive Leap Second insertion.
Unit of time equal to 60 seconds or 60 seconds minus 1 second in the case of a negative Leap Second deletion.

6.4 hour
unit of time, equal to 60 minutes
[ISO 8601, 2.2.4]

6.5 nominal hour
Unit of time equal to 60 minutes or 60 minutes plus 1 second in the case of a Leap Second insertion (positive Leap Second).
Unit of time equal to 60 minutes or 60 minutes minus 1 second in the case of a Leap Second deletion (negative Leap Second).

6.6 day
(unit of time) unit of time, equal to 24 hours
[ISO 8601, 2.2.5]

6.7 day
(duration) duration of a calendar day

NOTE The term "day" applies also to the duration of any time interval which starts at a certain time of day at a certain calendar day and ends at the same time of day at the next calendar day.
[ISO 8601, 2.2.7]

6.8 calendar day
time interval starting at midnight and ending at the next midnight, the latter being also the starting instant of the next calendar day

NOTE 1 A calendar day is often also referred to as day.

NOTE 2 The duration of a calendar day is 24 hours; except if modified by: - the insertion or deletion of leap seconds, by decision of the International Earth Rotation Service (IERS), or -the insertion or deletion of other time intervals, as may be prescribed by local authorities to alter the time scale of local time.
[ISO 8601, 2.2.6]

6.9 length of day
duration of a calendar day

Note - The IERS uses the term as related to the UT1 timescale:
The difference between the astronomically determined duration of the day and 86400 SI seconds is also called excess of length of day (LOD).
https://hpiers.obspm.fr/eop-pc/earthor/ut1lod/UT1.html

6.10 nominal day
On time scales with counting methods supporting Leap Second insertions and deletions and Daylight Savings Time ("summertime") adjustments the length of the Day will be altered by the presence of one or both of these factors. In the general case there are 9 possible lengths.

Note - It is unlikely Leap Seconds will occur on the same day as a Daylight Savings adjustment, but its theoretically possible, either because of increasing rate of Leap Second introduction in the distant future or because some local time jurisdiction makes a careless choice for DST rules.

- 23 Hours minus 1 second in the case of initiation of Daylight Savings Time and a negative Leap Second Insertion
- 23 Hours in the case of initiation of Daylight Savings Time
- 23 Hours plus 1 second in the case of initiation of Daylight Savings Time and a Leap Second Insertion
- 24 Hours minus 1 second in the case of a negative Leap Second Insertion
- 24 Hours if no Leap Second insertion and no initiation of Daylight Savings Time or initiation of return to Standard Time are in effect

- 24 Hours plus 1 second in the case of a Leap Second Insertion
- 25 Hours minus 1 second in the case of initiation of return to Standard Time from Daylight Savings Time and a negative Leap Second Insertion
- 25 Hours in the case of initiation of return to Standard Time from Daylight Savings Time
- 25 Hours plus 1 second in the case of initiation of return to Standard Time from Daylight Savings Time and a Leap Second Insertion

Table Nominal Day Length

Positive Leap Second Insertion	Negative Leap Second Insertion	Daylight Onset	Daylight Retreat	Seconds length of Nominal Day
	X	**X**		82799
		X		82800
X		**X**		82801
	X			86399
				86400
X				86401
	X		**X**	89999
			X	90000
X			**X**	90001

6.11 mean solar day

The period of time between two successive transits of the mean sun, a hypothetical sun defined as moving at a uniform rate along the celestial equator at the mean speed with which the real sun apparently moves along the ecliptic.

6.12 recurring time interval

series of consecutive time intervals of the same duration or nominal duration
NOTE If the duration of the time intervals is measured in calendar entities, the duration of each time interval depends on the calendar dates of its start and its end.
[ISO 8601, 2.1.17]

7 General Terms

7.1 epoch

The origin of a time scale.
[IEEE 1588/PTP, 3.1.9]

7.2 origin

ordered mark chosen as the beginning of a time scale.

7.3 proleptic

1. Of a calendar, extrapolated to dates prior to its first adoption;
2. A proleptic calendar is a calendar that is applied to dates before its introduction
3 . A calendar or era that is extrapolated to dates prior to its first adoption; used to adjust to or from the Julian calendar or Gregorian calendar.

Etymology - from prolepsis –
1. the assignment of something to a period of time that precedes it.
2. the representation of something which has occurred before its time.

7.4 resolution

smallest change in the measurand, or quantity supplied, which causes a perceptible change in the indication.
[IEC 60050-311-03-10]

7.5 time resolution

limit of accuracy of chronology
the minimum time by which two events must be separated in order that the corresponding time tags be different
Note – The time resolution cannot be shorter than the separating capability.
[IEC 60050-371-05-03]

7.6 precision

(1) (general). The quality of being exactly or sharply defined or stated. A measure of the precision of a representation is the number of distinguishable alternatives from which it was selected, which is sometimes indicated by the number of significant digits it contains.
(2) (measurement process). The quality of coherence or repeatability of measurement data, customarily expressed in terms of the standard deviation of the extended set of measurement results from a well defined (adequately specified) measurement process in a state of statistical control. The standard deviation of the conceptual population is approximated by the standard deviation of an extended set of actual measurements.
[IEEE Dictionary of Electrical and Electronic Terms]

7.7 accuracy

(instrumentation and measurement).
The quality of freedom from mistake or error, that is, of conformity to truth or to a rule.
Notes.
(A)Accuracy is distinguished from precision as in the following example: A six-place table is more precise than a four-place table. However, if there are errors in the six-place table, it may be more or less accurate than the four-place table.
(B) The accuracy of an indicated or recorded value is expressed by the ratio of the error of the indicated value to the true value. It is usually expressed in percent. Since the true value cannot be determined exactly, the measured or calculated value of highest available accuracy is taken to be the true value or reference value. Hence, when a meter is calibrated in a given echelon, the measurement made on a meter of a higher-accuracy echelon usually will be used as the reference value. Comparison of results obtained by different measurement procedures is often useful in establishing the true value.
[IEEE Dictionary of Electrical and Electronic Terms]

8 Modified Julian Date (MJD)

The Modified Julian Date time scale is a linear sequence of day numbers, which equals the Julian Date less 2,400,000.5 days. The origin of MJD equals 00:00 hours UTC time, 17 November 1858. MJD is specified by a number with five significant figures. (The Julian Date has its origin at 1200 hours UTC and its value consequently was 2,400,000.5 at the time of MJD origin.)

[The Modified Julian Day (MJD) is defined as MJD = JD - 2400000.5 , where JD is the Julian Day. Start of the JD count is from 0 at 12 noon 1 JAN -4712 (4713 BC).

Note: MJD is used when a continuous numbering of days is more convenient than the use of the civil calendar. Fractions of the day can be added to indicate the exact time of the day. The counting starts at midnight.]

The Modified Julian Date time scale was introduced by Smithsonian Astrophysical Observatory in 1957
http://adsabs.harvard.edu/full/1960SAOSR..40.....M

RECOMMENDATION ITU-R TF.457-2
USE OF THE MODIFIED JULIAN DATE BY THE STANDARD-FREQUENCY
AND TIME-SIGNAL SERVICES
http://www.itu.int/rec/R-REC-TF.457/en

8.1 Julian Date, (JD)
The Julian Date (JD) is the interval of time in days and fraction of a day since 4713 B.C. January 1, Greenwich noon. The Julian Day Number (also JD) is the integer part of the Julian Date.

8.2 Julian calendar
Introduced by Julius Caesar in 46 BC

9 Gregorian Calendar

The Gregorian Calendar time scale describes the traditional use of the Gregorian calendar in common use. It does *not* describe or account for the use of Coordinated Universal Time (UTC), Leap Seconds, time zones, or Daylight Savings Time.

9.1 Gregorian calendar
calendar in general use, introduced in 1582 to define a calendar year that more closely approximated the tropical year than the Julian calendar
[ISO 8601]

The Gregorian calendar is the internationally accepted time scale for the identification of calendar days.

The Gregorian calendar distinguishes common years of 365 consecutive calendar days and leap years of 366 consecutive calendar days. A leap year is a year whose year number is divisible by four an integral number of times. However, a centennial year is not a leap year unless its year number is divisible by four hundred an integral number of times. [ISO 8601]

In the Gregorian calendar each calendar year is divided in 12 sequential calendar months, each consisting of a specific number of calendar days as indicated in Table Days of Week

9.2 Day
(unit of time) unit of time, equal to 24 hours
[ISO 8601]
(duration) duration of a calendar day
[ISO 8601]

24 Hours or 86400 Seconds, except where a Leap Second may apply.

9.3 Calendar week
time interval of seven calendar days starting with a Monday [ISO 8601, 3.2.2]

Table - Calendar days

Name	ISO 8601 Ordinal day number in the week	Common software #
Monday	1	1
Tuesday	2	2
Wednesday	3	3
Thursday	4	4
Friday	5	5
Saturday	6	6
Sunday	7	0

9.4 Month
12 Months of the Year with names and durations as defined in Table - Calendar Months

Table - Calendar Months

Month Number	Name	Days in month	Ordinal dates of days in common years	Ordinal dates of days in leap years

Month Number	Name	Days in month	Ordinal dates of days in common years	Ordinal dates of days in leap years
1	January	31	001-031	001-031
2	February	28 or 29 in Leap Year	032-059	032-060
3	March	31	060-090	061-091
4	April	30	091-120	092-121
5	May	31	121-151	122-152
6	June	30	152-181	153-182
7	July	31	182-212	183-213
8	August	31	213-243	214-244
9	September	30	244-273	245-274
10	October	31	274-304	275-305
11	November	30	305-334	306-335
12	December	31	335-365	336-366

9.5 Year

duration of 365 or 366 calendar days depending on the start and/or the end of the corresponding time interval within the specific calendar year
[ISO 8601]

9.6 Common year

calendar year in the Gregorian calendar that has 365 calendar days
[ISO 8601]

9.7 Leap year

calendar year in the Gregorian calendar that has 366 calendar days
[ISO 8601]

A leap year is a year containing one additional day, February 29, in order to keep the calendar year synchronized with the astronomical or seasonal year.

Pseudo-code to determine whether a year is a leap year or not in either the Gregorian calendar since 1582 or in the proleptic Gregorian calendar between 1 and 1582:

```
if year is divisible by 400 then is_leap_year
else if year is divisible by 100 then not_leap_year
else if year is divisible by 4 then is_leap_year
else not_leap_year
```

10 Coordinated Universal Time (UTC)

Coordinated Universal Time (UTC) is a time scale used to compensate the representation of date and time for the difference between TAI atomic time and the observed rotational position of the Earth with respect to the Sun, that is, the mean solar day. Many local authorities and jurisdictions use UTC as the basis of civil time.
Methods, mechanisms, and rules governing the implementation of UTC are explained in the following sections.

10.1 International Atomic Time (TAI)

International Atomic Time, (acronym “TAI” from the French name Temps Atomique International) is a time scale established and maintained by the BIPM to standardize an absolute time reference scale. TAI is measured as a continuous uninterrupted count of seconds from the origin 1958-01-01 00:00:00 (TAI) based on the combined readings from many standardized atomic reference clocks in laboratories around the world.

Time scale established by the International Bureau of Weights and Measures (BIPM) on the basis of data from atomic clocks operating in several establishments conforming to the definition of the second, the unit of time of the International System of Units (SI).
[IEC 60050-713, 713-05-18]

The international reference scale of atomic time (TAI), based on the second (SI), as realized on the rotating geoid, is formed by the BIPM on the basis of clock data supplied by cooperating establishments. It is in the form of a continuous scale, e.g. in days, hours, minutes and seconds from the origin 1 January 1958 (adopted by the CGPM 1971).
[ITU-R TF.460-6]

See Coordinated Universal Time (UTC)
See Annex A International Atomic Time (TAI), Coordinated Universal Time (UTC), and Civil Time (Informative) for more detail.

10.2 UT1 Time scale (Universal Time)

UT1, or Universal Time, is a time scale maintained by the IERS based on the observed current rate of the rotation angle about the Earth pole. It can be regarded as a non-uniform time scale determined by the rotation of the Earth. UT1 is used as an intermediate time scale in determining the maintenance of UTC.

See Coordinated Universal Time (UTC)
See Annex A International Atomic Time (TAI), Coordinated Universal Time (UTC), and Civil Time (Informative) for more detail.

10.3 Leap Second

A one second unit count inserted into the UTC counting method to compensate for the difference between TAI atomic time and the observed rotational position of the Earth as represented by UT1.

See Coordinated Universal Time (UTC)
See Annex A International Atomic Time (TAI), Coordinated Universal Time (UTC), and Civil Time (Informative) for more detail.

10.4 IERS Reference Meridian (IRM)

IERS Reference Meridian (IRM) is the prime meridian (0° longitude) maintained by the International Earth Rotation and Reference Systems Service (IERS). It is the reference meridian of Global Navigation Satellite Systems (GNSS) and the UT1 and UTC timescales.

See Coordinated Universal Time (UTC)
See Annex A International Atomic Time (TAI), Coordinated Universal Time (UTC), and Civil Time (Informative) for more detail.

10.5 Coordinated Universal Time (UTC)

Coordinated Universal Time (UTC) is a time scale used to compensate the representation of date and time for the difference between TAI atomic time and the observed rotational position of the Earth with respect to the Sun, that is, the mean solar day.

The initialism “UTC” is a compromise between international names of the time scale and is not strictly an acronym or abbreviation.

Many local authorities and jurisdictions use UTC as the basis of civil time but UTC itself does not address “local time” – it applies only at the IERS Reference Meridian, that is, at the “00:00 UTC offset”, or “zulu time zone”. See Local Time.

The representation of civil time is expected in the form YYYY-MM-DD hh:mm:ss and that this should indicate the time of day with respect to the position of the Sun in the sky. Society relies on this ancient tradition.

TAI atomic time provides an absolute uniform time scale incrementing in monotonic seconds suitable for precise timekeeping, but it diverges from the traditional methods of timekeeping based on the solar day.

The Earth's rotational position with respect to the Sun is unpredictable due to many natural causes and it is continuously slowing mainly because of tidal forces induced by the orbit of the Moon. These cause the length of the mean solar day to vary slightly, tending to become longer. The length of a day as indicated by TAI atomic time is 86400 seconds, but a mean solar day as observed and realized by the IERS UT1 time scale is slightly longer and slowly increasing.

To correct for this difference, UTC employs a counting method to compensate the uninterrupted monotonic count of TAI atomic time for the unpredictable rotation of the earth with respect to the sun to arrive at a representation of calendar-time that respects the observed position of the sun during the day. This is accomplished by inserting a Leap Second adjustment into the UTC count such that the difference between midnight as indicated by TAI atomic time and midnight as determined by the observed positions of the Sun and Earth is not more than 0.9 seconds.

Note that UTC is a counting method applied to the underlying TAI; therefore it is by definition incrementing at exactly the same rate as TAI.

For historical reasons of calibration, the reference point between TAI and UTC is established as 1972-01-01T00:00:00Z (UTC) = 1972-01-01 00:00:10 (TAI), that is, UTC = 1972-01-01 00:00:10 (TAI) – 10s, at the reference meridian. Calendar-time after this reference point may be expressed as UTC = TAI – Leap Seconds.

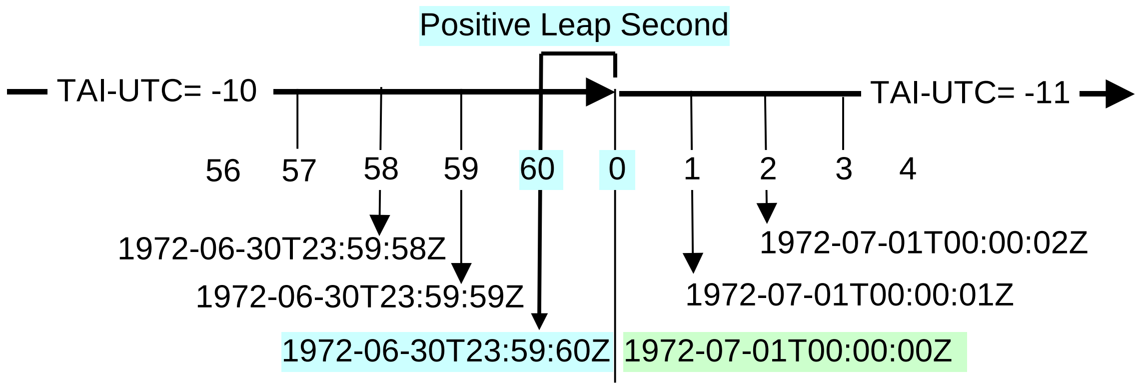
A Leap Second is inserted into the UTC count at the end of the day *preceding* the date on which the Leap Second is decreed to be in effect. A Leap Second can be either positive or negative

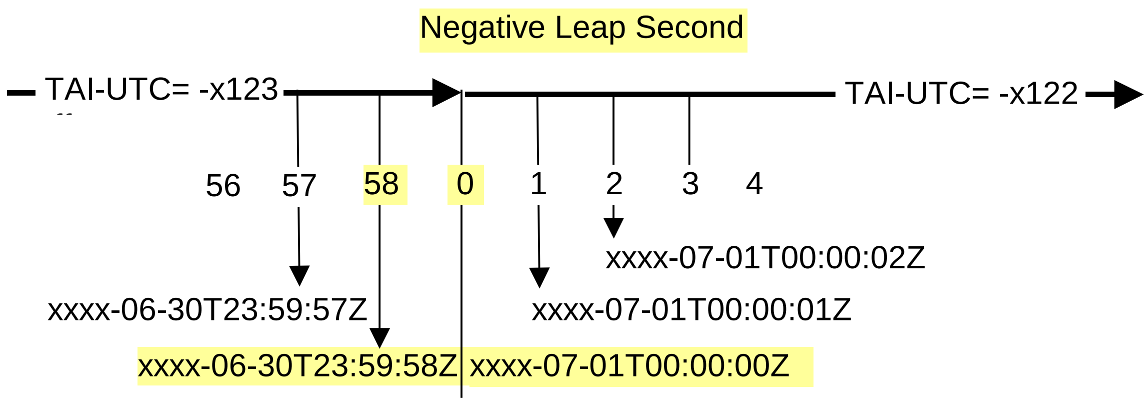
A positive Leap Second insertion is represented as 23:59:60 following the last second of the day, 23:59:59. The day it occurs will be counted as 24 hours plus one second (86401 seconds) (ignoring the effects of possible Daylight Savings onset or retreat).

A negative Leap Second insertion is represented by omitting the last second of the common day 23:59:59 so that the last represented second is labeled 23:59:58. The day it occurs will be counted as 24 hours minus one second (86399 seconds) (ignoring the effects of possible Daylight Savings onset or retreat). No negative Leap Seconds have occurred and are considered possible but unlikely.

Figure xxx illustrates the counting methods near the Leap Second insert. The positive Leap Second is illustrated with the example of the first Leap Second, introduced at 1972-01-01T00:00:00Z. The negative Leap Second is illustrated as the insert at the end of June of some undetermined year in the future. Note that the value of the TAI-UTC offset updates *after* the Leap Second insert itself.

Figure xxx Leap Second insertion and TAI-UTC values.





The IERS monitors the rotation of the Earth to maintain the UT1 time scale and is responsible for deciding to issue a Leap Second when UT1-UTC may exceed 0.9 seconds. IERS announces the Leap Second insertions in Bulletin C.

The first Leap Second was inserted at the end of the day on 1972-06-30T23:59:60Z (UTC) so that the total difference between TAI and UTC was 11 Seconds on 1972-07-01T00:00:00Z (UTC). Since then, more Leap Seconds have been inserted when required. *Annex E Historical Values of Leap Seconds* shows a listing of Leap Seconds inserted since 1972 until the publication of this document.

The standards bodies most directly responsible for TAI and UTC are:

- The BIPM defines and maintains TAI and coordinates definitions and information regarding UTC.
- The IERS monitors Earth position, maintains UT1, and is responsible for declaring Leap Seconds.
- The ITU is responsible for definitions of UTC for systems and applications for dissemination of standard time and frequency signals.

Definitions of UTC are found in:

- BIPM Annual Report on Time Activities.
- IERS Conventions
- ITU-R TF.460, Standard-Frequency and Time-Signal Emissions

Leap Second announcements are released by the IERS as
INTERNATIONAL EARTH ROTATION AND REFERENCE SYSTEMS SERVICE (IERS), Bulletin C

Historical records of UTC and Leap Seconds can be found in

- BIPM Annual Report on Time Activities, Table 1 and Table 2.

- INTERNATIONAL EARTH ROTATION AND REFERENCE SYSTEMS SERVICE (IERS), Leap_Second_History.dat

A Leap Seconds table can also be obtained from many NTP time servers via FTP as “leap-seconds.list”.

[A list of NIST time servers is available at: http://tf.nist.gov/tf-cgi/servers.cgi
time.nist.gov is a global load balancer and may not be available. Go directly to a server instead. For instance: ftp://nist1-ny.ustiming.org/pub/ or ftp://utcnist.colorado.edu/pub/
/pub/leap-seconds.list should always point to the most recent available leap-seconds file.
For example: ftp://utcnist.colorado.edu/pub/leap-seconds.list]

See Annex A International Atomic Time (TAI), Coordinated Universal Time (UTC), and Civil Time (Informative) for more detail.

10.6 TAI1972

Name given to the TAI side of the UTC/TAI calibration time point.
TAI1972 = 1972-01-01 00:00:10 (TAI) = 1972-01-01T00:00:00Z (UTC).
This is the same instant as the time point UTC1972, that is TAI1972 = UTC1972.

10.7 UTC1972

Name given to the UTC side of the UTC/TAI calibration time point.
UTC1972 = 1972-01-01T00:00:00Z (UTC) = 1972-01-01 00:00:10 (TAI).
This is the same instant as the time point TAI1972, that is UTC1972 = TAI1972.

10.8 UTC of day

quantitative expression marking an instant within a calendar day in accordance with UTC
[ISO 8601, 2.1.13]

NOTE UTC of day refers to UTCT, that is, the UTC time at the IERS Reference Meridian. *See ISO 8601, 4.2.5.1 Difference between local time and UTC of day*

10.9 UTCZ

Name given an abstract “time zone” at the IERS Reference Meridian. It has no size – only the position of meridian itself. It does not have any date-time meaning; see UTCT. The “Z” of the name is derived from “time Zone”, or “Zulu”, or the “Z” in ISO 8601 character representation.

10.10 UTCT

Name given the date-*time* at the UTCZ time zone. UTCT is the same as UTC of day.

10.11 Zulu

Used to refer to the location or time at the UTC reference meridian.

11 Civil Time (Local Time)

“Civil time”, often called “local time”, refers to time scales established by law or custom in some jurisdiction at some geographic location.

The use of local time is prescribed by a local jurisdiction’s “competent authority”, often meaning laws of the government as administrated by some department of government. The details of how these laws describe local time are typically guided by several standards, defacto-standards, and common practice. There is no universally applicable set of formulas that strictly define local time.

Generally, there are two considerations to local time: the time zone, and whether and when Daylight Savings Time may be observed.

Time zones are generally based on the idea that the 360° of the globe can be divided into 24 15° segments of longitude each representing 1-hour of the Earth’s 24-hour rotation. This is a simplification since the Earth is not a perfect sphere and the Earth’s rotation is not exactly 24-hours, but it creates a convenient one-to-one approximate relationship between the offset to UTCT and longitude.

There are two types of time zone in use: civil (land) and nautical. Civil time zones are usually designated as a time offset from the UTCT. Nautical time zones are specified by longitude.

See Annex B Civil Time (Local time), Time Zones, and Daylight Savings Time

11.1 Civilian Time Zone

A civilian time zone is a region of land and territorial waters to which a local time has been assigned by a competent authority for legal, commercial, and social purposes.

A time zone is generally made up of:

- The longitude location and geopolitical boundaries of the local jurisdiction.
- A fixed offset from UTCT to the region as defined by the local jurisdiction's competent authority. The offset applies to all geographic points in the designated area. Typically positive offsets represent places and local time west of and earlier than UTCZ/UTCT while negative values represent places and local time east of later than UTCZ/UTCT.
- A time zone name - There is no standard naming convention. Some jurisdiction use names of the location, such as "New York" or "Europe/London". Others use names like "Eastern Standard Time" and "Eastern Daylight Time" which combine both location and local time with Standard and Daylight Savings Time.

It is still common for laws to refer to the reference meridian and time by the now obsolete "Greenwich Meridian" or "Greenwich Mean Time (GMT)". This is usually taken to mean UTCZ and UTCT but caution should be exercised in implementation.

There are several sources of time zone data. Unfortunately not all are compatible with each other and caution must be taken. Two important sources of time zone data are:

IANA (Internet Assigned Numbers Authority) Time Zone Database
http://www.iana.org/time-zones

Microsoft Windows TimeZone
http://technet.microsoft.com/en-us/library/cc749073(v=ws.10).aspx

11.2 Nautical Time Zone

Time zones as used in nautical and aviation navigation and in some militaries differ from civilian local time and time zones. The time zone location is specified in terms of longitude from the reference meridian rather than offset from UTCT.

Each time zone has a single letter name from the NATO phonetic alphabet. The time zone at the reference meridian is called "Z" (from "Zulu"). West and earlier as "A, B, C, D, E, F, G, H, I, K, L, and M". East and later as "N, O, P, Q, R, S, T, U, V, W, X, and Y".

Time offsets for each of the named time zones are given in terms of "Universal Time" or "Standard Time". Daylight Savings is not observed.

Note the implied signs (positive or negative) of the time zones are inverted from the civilian time zone convention.

Nautical time zones are published in the Nautical almanacs as tables called "Standard Time". A sample can be found at:

The Nautical Almanac 2005
Her Majesty's Nautical Almanac Office
STANDARD TIMES (corrected to November 2003) pp 262
http://books.google.com/books/about/The_Nautical_Almanac_2005.html?id=CHhMf3UPoTkC

Nautical almanacs also often publish the "World Time Zone Map". A sample can be found at:

USNO

World Time Zone Map jpg
http://www.usno.navy.mil/USNO/astronomical-applications/images_aa/TimeZoneMap0210.jpg

11.3 international date line

The term “international date line” is a common-use name for an imaginary line of longitude on the Earth’s surface that marks the divide between one calendar day and the next. The date to the west of the date line is one day later than the date east of the date line.

It is located at approximately 180° from the UTC reference meridian. It runs roughly North to South through the middle of the Pacific Ocean but deviates to pass around some territories and island groups. The position given on most maps is the line drawn by the British Admiralty in 1921.

The date line is taken to mean the divide from negative to positive of the “offset from UTC(Zulu)”. This is usually at the point of –12:00 to +12:00 offset from UTC(Zulu), however two time zones, +13:00 and +14:00, were artificially constructed in the Polynesia region.

Despite its name there is no specification or any international agreement that officially defines it. It has been recognized as a matter of convenience and has no force in international law. Its common use probably follows from a proposal to the *International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884.* (This conference is often *improperly* referred to as the “International Meridian Conference”). That proposal, offered by the Delegate of Sweden read:

"The Conference recommends as initial point for the universal hour and the cosmic day the mean mid-day of
Greenwich, coinciding with the moment of midnight or the beginning of the civil day at the meridian 12 hours or 180° from Greenwich. The universal hours are to be counted from 0 up to 24 hours."

Contrary to popular understanding, that proposal was *defeated*, or “lost”, in the words used at that conference, and no official proclamation of these facts has since been proposed or approved (at the publication date of this document). Nonetheless, the idea of “beginning of the civil day at the meridian 12 hours or 180° from Greenwich” has found its way to common use.

See Annex C The International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884.

11.4 local time

locally applicable time of day such as standard time of day, or a non-UTC based time of day
[ISO 8601, 2.1.16]

11.5 Offset from UTCT

Difference between local standard time and UTC of day.

11.6 standard time

time scale derived from coordinated universal time, UTC, by a time shift established in a given location by the competent authority
[IEC 60050-111]
NOTE This time shift may be varied in the course of a year.
[ISO 8601, 2.1.14]

NOTE Examples are Central European Time (CET), Central European Summer Time (CEST), Pacific Standard Time (PST), Japanese Standard Time (JST), etc.
[IEC 60050-111, 111-16-16]

The term “standard time” refers to local time either *with* or *without* Daylight Savings Time adjustments applied. In Europe, for example, both Central European Time (CET) and Central European Summer Time (CEST) are “standard time”. This is consistent with the international definitions, as above.

In some areas, such as the United States and Australia, the common use of the term is in direct conflict with the formal international definition. Here, the use of “standard time” typically refers to the “the local time in the time zone *without* daylight savings”, for examples “Eastern Standard Time” in the USA, and “Australian Eastern Standard Time”. “Daylight Savings Time”, in contrast, means “the local time in the time zone *with* daylight savings”, for examples “Eastern Daylight Time” in the USA, and “Australian Eastern Daylight Time”.

Remarkably, in the USA, common use of the term “standard time” is in direct conflict with United States law regarding time zones. The USA law is, in fact, consistent with the international definition.

Australian law (at least in New South Wales) regarding time zones and “daylight saving”, or “summer time”, appears more consistent with common use and thus in conflict with the international definitions.

11.7 standard time of day

quantitative expression marking an instant within a calendar day by the duration elapsed after midnight in the local standard time
[IEC 60050-111]
NOTE Standard time of day is called “clock time” in IEC 60050-111.
[ISO 8601, 2.1.15]
NOTE: See comments regarding common use of the term “standard time” in section *standard time*

11.8 Daylight Saving Time (DST)

Daylight Saving Time (DST), also called “summer time” in some places, is the practice used in some localities of advancing clocks by some duration, typically one hour, so that sunrise occurs earlier, and sunset later. Clocks are usually adjusted forward in the spring and backward in autumn.

The choice to observe Daylight Savings, and selection of the time of Daylight Savings Time onset and retreat dates and time is defined by the local jurisdiction’s competent authority.

11.9 clock time

quantitative expression marking an instant within a calendar day by the duration elapsed after midnight in the local standard time.
NOTE Usually, clock time is represented by the number of hours elapsed after midnight, the number of minutes elapsed after the last full hour, and, if necessary, the number of seconds elapsed after the last full minute, possibly with decimal parts of a second.
[IEC 60050-111, 111-16-17]

11.10 12-hour clock

The 12-hour clock is a time convention in which the 24 hours of the day are divided into two periods:[1] a.m. (from the Latin ante meridiem, meaning "before midday") and p.m. (post meridiem, "after midday").[2] Each period consists of 12 hours numbered: 12 (acting as zero), 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11.

11.11 24-hour clock

The 24-hour clock is the convention of time keeping in which the day runs from midnight to midnight and is divided into 24 hours, indicated by the hours passed since midnight, from 00:00 to 23:00.

11.12 time of day

clock time

11.13 wall clock

clock time

12 Acronyms, Abbreviations, and Initialisms

12.1 BIPM
Bureau International des Poids et Mesures. French acronym for International Office of Weights and Measures.

12.2 CGPM
Conférence Générale des Poids et Mesures. French acronym for General Conference of Weights and Measures

12.3 DST
Daylight Savings Time

12.4 IEEE
Institute of Electrical and Electronic Engineers. This is a professional association and Standards Development Organization.

12.5 IERS
International Earth Rotation Service

12.6 ITU
International Telecommunications Union. This is a specialized agency of the United Nations that is responsible for issues that concern information and communication technologies

12.7 LOD
Length of day

12.8 MJD
Modified Julian Date

12.9 IRM
IERS Reference Meridian

12.10 TAI
International Atomic Time

12.11 UTC
Coordinated Universal Time

12.12 CGPM
Conférence Générale des Poids et Mesures. French acronym for General Conference of Weights and Measures.

Annex A International Atomic Time (TAI), Coordinated Universal Time (UTC), and Civil Time (Informative)

The history of timekeeping stretches back to antiquity. Many calendars and clocks were developed all over the world. Most were related to the motion of the stars and planets, the Sun, the seasons, and the day.

Today the form of calendar-time, YYYY-MM-DD hh:mm:ss, is a combination of timekeeping traditions through the ages.

- The Egyptians subdivided daytime and nighttime into twelve hours each since at least 2000 BC.
- After 300 BC, the Babylonians subdivided the day sexagesimally, that is by 1⁄60, by 1⁄60 of that, by 1⁄60 of that, etc., giving rise to the tradition of minutes of the hour and seconds of the minute.
- Julius Caesar commissioned the Julian calendar in 46 BC, inaugurating the development of the modern calendar with 12 months.
- The Hellenistic astronomer Ptolemy used 1⁄24 day as the mean hour in 150 AD.
- The Anno Domini was devised in 525 AD by Dionysius Exiguus in Rome, establishing the traditional use of decimal (base-10) counting of years and the “birth of Christ” as the origin of the calendar. It was not in wide use until 800 AD.
- In 1000 AD the Persian scholar al-Biruni gave the times of the new moons of specific weeks as a number of days, hours, minutes, and seconds in his “Vestiges of the Past”. His definition of the length of a second remained in use until Newcomb’s Tables – for nearly 1000 years.
- The medieval scientist Roger Bacon reinforced the adoption of days, hours, minutes, and seconds in *Opus Majus*, 1267. He famously criticized the Julian calendar’s inaccuracy and set the stage for the eventual Gregorian reform nearly 300 years later.
- Johannes Werner proposed determining time by measuring the position of the moon relative to the background stars in 1514. This became known as the lunar distance method.
- The Pope Gregory VIII the created the Gregorian calendar in 1582 based on a design by Aloysius Lilius (also known as Luigi Lilio) as modified by Christopher Clavius. The “Gregorian reform” improved the Julian calendar’s accuracy of the length of years. This is still the basis of today’s familiar calendar.
- The “longitude problem” receives increased attention when Spain's Philip II offered a prize for the discovery of a solution in 1567. Holland offers a prize 1636.
- The Académie Royale des Sciences is formed in 1666 and the Observatory of Paris opens in 1667
- In 1669 Jean Picard measures the size of the Earth at the Paris Observatory.
- The Royal Greenwich Observatory is commissioned in 1675.
- The British form the Board of Longitude in 1714 offering another prize for the “longitude problem”. From 1715 France’s Académie Royale des Sciences offers two Prix Rouillés for navigation.
- Nevil Maskelyne publishes the first Nautical Almanac in 1767 suitable for lunar distance method based on observations at the Royal Greenwich Observatory.
- John Harrison’s H-4 chronometer passes sea trials in 1773.
- Greenwich Mean Time (GMT) is adopted by the Railway Clearing House in Britain in 1847.
- By 1850 the lunar distance method is replaced by time-based longitude as inexpensive chronometers become widely available.
- Her Majesty's Nautical Almanac Office continues publication of the almanacs and the U.S.A begins the American Ephemeris and Nautical Almanac in 1855 with Greenwich as the prime meridian.
- GMT is legally adopted in Great Britain in 1880.
- The *International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day*. October, 1884, provided several important agreements at the foundation of modern timekeeping. Excerpts from resolutions that were adopted:
  - I. ... a single prime meridian for all nations
  - II. ... Observatory of Greenwich as the initial meridian for longitude

- III. ... from this meridian longitude shall be counted in two directions up to 180 degrees, east longitude being plus and west longitude minus.
- IV. ... a universal day ... which shall not interfere with the use of local ... time
- V. ... a mean solar day ... at the moment of mean midnight of the initial meridian, coinciding with the beginning of the civil day ... and is to be counted from zero up to twenty-four hours.

NOTE: Contrary to popular understanding, this conference did *not* adopt the resolution to establish a “date line” or “time zones”. See Annex C *The International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884*.

- Newcomb's *Tables of the Sun* is published in 1895, defining the second as “the fraction 1/31,556,925.9747 of the tropical year for 1900 January 0 at 12 hours ephemeris time”
- Newcomb’s Tables are incorporated into the U.S.A and U.K Almanacs from 1900.
- International Astronomical Union (IAU) is formed in 1919 “To facilitate the relations between astronomers of different counties where international cooperation is necessary or useful.” The IAU is still the governing authority for much of modern timekeeping standards.

This history establishes the basic shape of modern timekeeping:

- The Gregorian calendar with its “Leap Years” is the basic calendar-time counting method.
- Years are counted in decimal with an origin, or reference point, at “the Common Era”.
- The boundary between days is Midnight.
- The day is divided in into 24 hours, sometimes as two 12 hour periods.
- Hours are divided into 60 minutes, and minutes into 60 seconds.
- The length of a day is based on the mean solar day
- The length of a second is based on the mean solar day
- The prime meridian for longitude is at the Observatory of Greenwich

The common form YYYY-MM-DD hh:mm:ss of calendar-time is a mixed radix number born of tradition.

Table Mixed Radix Calendar-time

Denomination	Year	Month	Day	Week	Hour	Minute	Second	decimal fraction
Radix	10	12	28, 29, 30, 31	7	24	60	60	10
Numerical system	decimal	duodecimal	Its complicated	septenary	tetravigesimal	sexagesimal	sexagesimal	decimal
Origination	Anno Domini	Julian	Julian Gregorian	Babylonian Hebrew Julian	Egyptian	Babylonian	Babylonian	

This sets the stage for the development of atomic clocks and the refinement of astronomical observation and measurement of the mean solar day during 1950s and 1960s.

Clock makers had strived for an absolute time reference for centuries. For much of this time the most of accurate time keeping mechanism was the Earth rotation itself, yet it was well known that the length of the day did not divide evenly into a year. With the development of Relativity and atomic science it became possible to build atomic clocks. Essen and Parry at the UK NPL are credited with creating the first chronometer using the cesium resonance in 1955.

Into the 1960s atomic timekeeping and astronomical observation evolved quickly. As expected, it became clear that any measurement of the length of day was diverging from the absolute time reference of atomic time. It was necessary to develop intermediate time scales to represent this difference quantitatively. The development of the TAI, UT1, and UTC time scales emerged through the collaboration of many international standards bodies. *Metrologia, The leap second: its history and possible future* gives a detailed history of the efforts. The following summarizes important milestones:

The standards bodies responsible include:

- International Union of Pure and Applied Physics (IUPAP)
- General Conference on Weights and Measures (CGPM)
- International Committee for Weights and Measures (CIPM)
- Bureau International de l'Heure (BIH)
- International Astronomical Union (IAU)
- International Union of Radio Science (URSI)
- International Radio Consultative Committee (CCIR)
- International Telecommunication Union (ITU)
- ITU Radiocommunication Sector (ITU-R) (formally CCIR)

Notable developments in the official definitions of TAI and UTC:

- 1948 IUPAP request to CGPM for a practical system of units covering all branches of metrology
- 1954 CGPM selects a limited set of base units, including the second SI
- 1956 CIPM compiles a representative list of derived units
- 1960 11th CGPM officially ratifies the definition of SI; "the fraction 1/31 556 925.9747 of the tropical year for 1900 January 0 at 12 hours ephemeris time".
- 1965 BIH attaches UTC to atomic time. This was the origin of the link between TAI and UTC.
- 1967 13th CGPM adopts the atomic second as the fundamental unit of time
- 1967 IAU 13th General Assembly formally approves the name "Coordinated Universal Time (UTC)"
- 1970 CCIR XIIth Plenary Assembly in New Delhi approves a decision to begin the new UTC system on 1 January 1972
- 1971 14th CGPM approves the establishment of International Atomic Time (TAI).
- 1971 CCIR Recommendation 460 draft refines the definition of UTC.
- 1972 1972-01-01T00:00:00Z, the appointed moment, arrives.

The culmination of the efforts was the standardization of International Atomic Time (TAI), Universal Time (UT1), and Coordinated Universal Time (UTC).

International Atomic Time (TAI) is an uninterrupted count of integral seconds (SI) based on the combined readings from many standardized atomic reference clocks in laboratories around the world.

Universal Time (UT1) is the angle of the Earth's rotation about the CIP axis defined by its conventional linear relation to the Earth Rotation Angle (ERA). It is related to Greenwich apparent sidereal time through the ERA. It is determined by observations (currently from VLBI observations of the diurnal motions of distant radio sources). UT1 can be regarded as a time determined by the rotation of the Earth.

Coordinated Universal Time (UTC) is the time scale used to compensate the representation of date and time for the difference between TAI atomic time and the observed rotational position of the Earth with respect to the Sun.

For historical reasons of calibration, the reference point between TAI and UTC is established as 1972-01-01T00:00:00Z (UTC) = 1972-01-01 00:00:10 (TAI), that is, UTC = 1972-01-01 00:00:10 (TAI) – 10s, at the reference meridian. Calendar-time after this reference point may be expressed as UTC = TAI – 10 - Leap Seconds.

In the words *of Recommendation ITU-R TF.460-6*: "UTC is the time-scale maintained by the BIPM, with assistance from the IERS, which forms the basis of a coordinated dissemination of standard frequencies and time signals. It corresponds exactly in rate with TAI but differs from it by an integer number of seconds. The UTC scale is adjusted by the insertion or deletion of seconds (positive or negative leapseconds) to ensure approximate agreement with UT1."

From the *BIPM Annual Report on Time Activities, Volume 7 2012*, Leap seconds:
"Since 1 January 1988, the maintenance of International Atomic Time, TAI, and of Coordinated Universal Time, UTC (with the exception of decisions and announcements concerning leap seconds of UTC) has

been the responsibility of the International Bureau of Weights and Measures (BIPM) under the authority of the International Committee for Weights and Measures (CIPM). The dates of leap seconds of UTC are decided and announced by the International Earth Rotation and Reference Systems Service (IERS), which is responsible for the determination of Earth rotation parameters and the maintenance of the related celestial and terrestrial reference systems. …"

Today, TAI, UT1, and UTC are cooperatively authorized, maintained, and disseminated by 3 organizations:

International Bureau of Weights and Measures (BIPM), provides the basic specifications of TAI and UTC, oversees the maintenance of TAI, and coordinates information and activities amongst cooperating organizations. It publishes specifications and activities in the BIPM Annual Report on Time Activities.

BIPM Annual Report on Time Activities 2012
http://www.bipm.org/en/scientific/tai/time_ar2012.html

International Earth Rotation and Reference Systems Service (IERS) oversees the astronomical observations used for Earth position and, in cooperation with BIPM, maintains DUT1, the intermediate time scale relating TAI to Earth position. IERS is responsible for the decision when a Leap Second will occur.
The IERS was established in 1987 by the International Astronomical Union and the International Union of Geodesy and Geophysics. The IERS Conventions explains its activities.

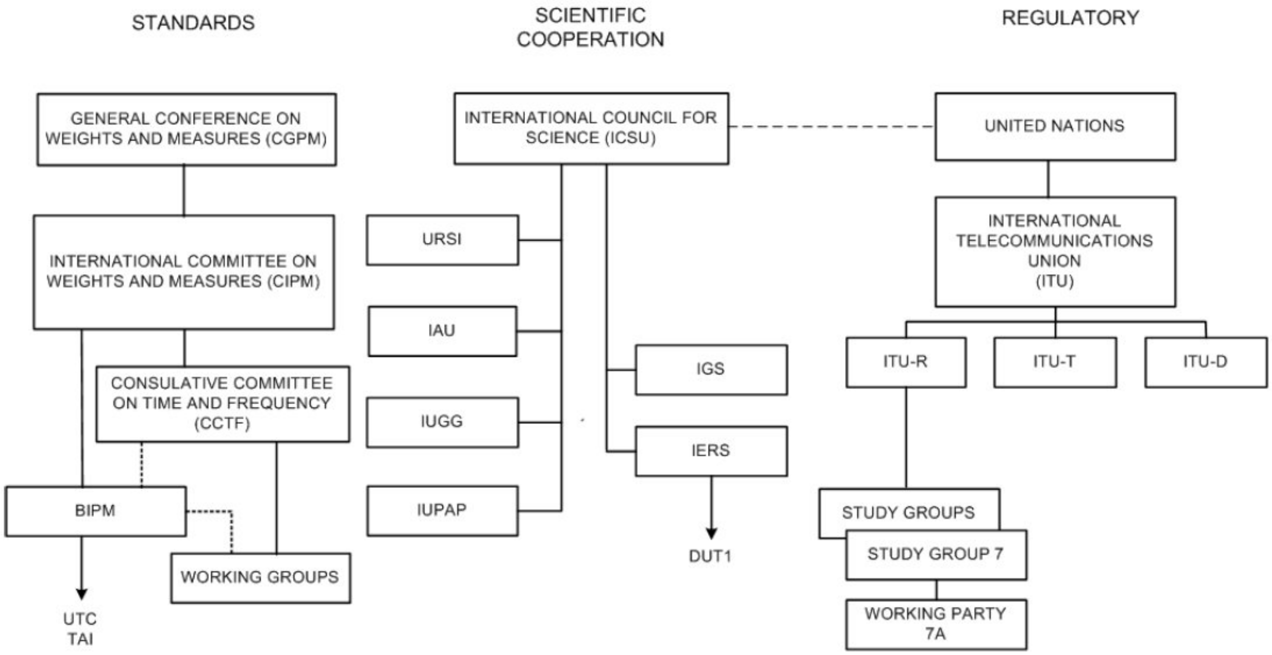
IERS Technical Note 36, IERS Conventions (2010)
ftp://tai.bipm.org/iers/conv2010/tn36.pdf

International Telecommunication Union (ITU) is responsible for time disseminations. Recommendation ITU-R TF.460 defines UTC for purposes of Standard-frequency and time-signal emissions.

ITU-R TF.460-6 (02/02), Standard-Frequency and Time-Signal Emissions
http://www.itu.int/rec/R-REC-TF.460/en

The relationships amongst the many organizations responsible for timekeeping and related science are complex. The illustration, drawn from a document at the ITU shows the basic relationships. This is followed by a list of the organizations, a description of their missions, and links.

From *Role of the ITU-R in Time Scale Definition and Dissemination*
http://www.itu.int/dms_pub/itu-r/oth/0a/0e/R0A0E0000960016PDFE.pdf



CGPM General Conference on Weights and Measures
The General Conference receives the report of the International Committee for Weights and Measures (CIPM) on work accomplished; it discusses and examines the arrangements required to ensure the propagation and improvement of the International System of Units (SI); it endorses the results of new fundamental metrological determinations and various scientific resolutions of international scope; and it decides all major issues concerning the organization and development of the BIPM, including the dotation of the BIPM.
http://www.bipm.org/en/convention/cgpm/

CIPM International Committee for Weights and Measures
The CIPM is made up of eighteen individuals, each of a different nationality. Its principal task is to promote world-wide uniformity in units of measurement and it does this by direct action or by submitting draft resolutions to the General Conference (CGPM).
The CIPM meets every year (since 2011 in two sessions per year) and, among other matters, discusses reports presented to it by its Consultative Committees. Reports of the meetings of the CGPM, the CIPM, and all the Consultative Committees, are published by the BIPM.
http://www.bipm.org/en/committees/cipm/

CCTF Consultative Committee for Time and Frequency
Present activities concern matters related to the definition and realization of the second, establishment and diffusion of International Atomic Time (TAI) and Coordinated Universal Time (UTC), and advice to the CIPM on matters related to time and time scales.
http://www.bipm.org/en/committees/cc/cctf/

BIPM Bureau International des Poids et Mesures (International Bureau of Weights and Measures)
The task of the BIPM is to ensure world-wide uniformity of measurements and their traceability to the International System of Units (SI).

It does this with the authority of the Convention of the Metre, a diplomatic treaty between fifty-five nations, and it operates through a series of Consultative Committees, whose members are the national metrology laboratories of the signatory States, and through its own laboratory work.

The BIPM carries out measurement-related research. It takes part in, and organizes, international comparisons of national measurement standards, and it carries out calibrations for Member

States.
http://www.bipm.org/

ICSU International Council for Science
The 31 international Scientific Union Members provide the disciplinary backbone of ICSU. They play a central role in bringing together scientists from all parts of the world to consider the issues of particular interest to individual disciplines
http://www.icsu.org/about-icsu/our-members/?icsudocid=scientific-unions

IUPAP International Union of Pure and Applied Physics
To assist in the worldwide development of physics, to foster international cooperation in physics, andto help in the application of physics toward solving problems of concern to humanity.
http://www.iupap.org/

URSI International Union of Radio Science
Radio science encompasses the knowledge and study of all aspects of electromagnetic fields and waves. The International Union of Radio Science (Union Radio-Scientifique Internationale), a non-governmental and non-profit organisation under the International Council for Science, is responsible for stimulating and co-ordinating, on an international basis, studies, research, applications, scientific exchange, and communication in the fields of radio science.
http://www.ursi.org/en/ursi_mission_statement.asp

IUGG International Union of Geodesy and Geophysics
The International Union of Geodesy and Geophysics (IUGG) is the international organization dedicated to advancing, promoting, and communicating knowledge of the Earth system, its space environment, and the dynamical processes causing change. IUGG is one of the 31 scientific Unions presently grouped within the International Council for Science (ICSU).
http://www.iugg.org/

IAU International Astronomical Union
Its mission is to promote and safeguard the science of astronomy in all its aspects through international cooperation.
http://www.iau.org/

IERS International Earth Rotation and Reference Systems Service
The primary objectives of the IERS are to serve the astronomical, geodetic and geophysical communities by providing data and standards related to Earth rotation and reference frames.
http://www.iers.org/nn_10880/IERS/EN/Organization/About/about.html?__nnn=true

IGS The International GNSS Service (Global Navigation Satellite Systems (GNSS))
The International GNSS Service (IGS) provides Global Navigation Satellite Systems (GNSS) orbits, tracking data, and other high-quality GNSS data and data products on line in near real time. Currently the IGS includes two GNSS, the Global Positioning System (GPS) and the Russian GLONASS, and intends to incorporate future GNSS.
http://www.iers.org/IERS/EN/Organization/TechniqueCentres/IGS/igs.html

ITU International Telecommunication Union
United Nations specialized agency for information and communication technologies (ICTs)
http://www.itu.int/en/about/Pages/default.aspx

ITU-R Radiocommunication Sector (ITU-R)
Our mission is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including those using satellite orbits, and to carry out studies and approve Recommendations on radiocommunication matters.
http://www.itu.int/en/ITU-R/Pages/default.aspx

ITU-R Study Group 7 (SG 7)
Science Services
1. Systems for space operation, space research, Earth exploration and meteorology, including the related use of links in the inter-satellite service.
2. Systems for remote sensing, including passive and active sensing systems, operating on both ground-based and space-based platforms.
3. Radio astronomy and radar astronomy.
4. Dissemination, reception and coordination of standard-frequency and time-signal services, including the application of satellite techniques, on a worldwide basis.
http://www.itu.int/en/ITU-R/study-groups/rsg7/Pages/default.aspx

ITU-R Working Party 7A (WP 7A) - Time signals and frequency standard emissions
Systems and applications (terrestrial and satellite) for dissemination of standard time and frequency signals.
http://www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rwp7a&lang=en

ITU-R Electronic facilities
http://www.itu.int/ITU-R/index.asp?category=information&rlink=e-facilities&lang=en

ITU Document Management System
Recommendations
http://www.itu.int/rec/rec.asp

ITU-R Recommendations
The ITU-R Recommendations constitute a set of international technical standards developed by the Radiocommunication Sector (formerly CCIR) of the ITU. They are the result of studies undertaken by Radiocommunication Study Groups.
http://www.itu.int/pub/R-REC/en

ITU-R Recommendation TF.460
Rec. ITU-R TF.460-6, Standard-frequency and time-signal emissions
http://www.itu.int/rec/R-REC-TF.460/en

Observatoire de Paris
The Paris Observatory has three main missions:
research - contributing to the advancement of knowledge of the universe initial and continuing training dissemination of knowledge
http://www.obspm.fr/?lang=fr

Earth Orientation Center
Missions of the EOP Product Centre of International Earth Rotation Service and Reference Systems Collect through the world the time series of the Earth Orientation Parameters (EOP): polar motion (x,y), universal time (UT1-UTC, UT1-TAI), Celestial pole offsets (Dpsi, Deps)
Archive EOP and make them available through FTP/WEB
Analyze EOP and in particular monitor their consistencies with respect to the international terrestrial and celestial reference frames.
Compute a combined standard solution for EOP (Bulletin B) in the (IERS) C04 solution.
Compute and make available DUT1 (Bulletin D) and leap second announcements (Bulletin C).
http://hpiers.obspm.fr/eop-pc/index.php?index=mission&lang=en

BULLETINS B, C, D
http://hpiers.obspm.fr/eop-pc/index.php?index=bulletins&lang=en

REATIONSHIP BETWEEN TAI AND UTC
http://hpiers.obspm.fr/eop-pc/earthor/utc/TAI-UTC_tab.html

Annex B Civil Time (Local time), Time Zones, and Daylight Savings Time (Informative)

Annex *A International Atomic Time (TAI), Coordinated Universal Time (UTC), and Civil Time (Informative)* chronicles the development of timekeeping, culminating in the establishment of TAI, UT1, and UTC. The relationship of time to position on Earth was an important aspect of this effort and leads to the idea of time zones, a central concept in civil and local time. This annex summarizes the history of time zones and current practice.

The development of timekeeping proceeded together with geography, cartography, and navigation.

- The Babylonians produced some of the oldest surviving world maps in the 9th century BCE.
- The Persian Achaemenid Empire (550–330 BC) used a solar calendar with 360 days.
- In the 2nd century BC Greeks astronomers and mathematicians divide the circle in 360 degrees of 60 arc minutes.
- The Greek Eratosthenes of Cyrene invented the armillary sphere around 255 BC. He became the Chief Librarian of Library of Alexandria in 245 BC where he measured the circumference of the Earth and created the discipline of geography. He also proposed a system of latitude and longitude for a map of the world.
- From 162 BC to 127 BC the Greek Hipparchus of Nicaea founded trigonometry and used latitude and longitude to specify places on Earth. He also proposed a system of determining longitude by comparing the local time of a place with an absolute time. This is the first recognition that longitude can be determined by accurate knowledge of time.
- Ptolemy produced his treatise on cartography, Geographia, in the 2nd century AD.
- Working around 1000 AD the Persian scholar al-Biruni debated that the earth rotated on its axis, viewing it favorably, and made accurate calculations of latitude, longitude and time. (al-Biruni also measured radius of the Earth, putting it at 3928.77 miles The modern value is 3959 miles.).
- Railway Time was first adopted as a standard time in 1840 by the Great Western Railway in Great Britain using Greenwich Mean Time (GMT) kept by portable chronometers.
- Time signals were first transmitted by telegraph from the Royal Observatory, Greenwich in 1852.
- In1868 New Zealand officially adopted a standard time to be observed throughout the colony, It was based on the longitude 172°30'East of Greenwich, 11 hours 30 minutes ahead of GMT. This was known as New Zealand Mean Time.
- Canadian Sir Sandford Fleming proposed a worldwide system of time zones in 1879.
- Britain makes GMT legal time in 1880.
- American railroads inaugurate the use of four time zones in 1883.
- The International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October 1884 establishes Greenwich as the prime meridian and longitude counted in two directions up to 180 degrees. It does *not* resolve to create time zones, this being beyond the conference's purveyance.
- Her Majesty's Nautical Almanac and the American Ephemeris and Nautical Almanac include tables of “Standard time”, listing many international locations as an offset from GMT.
- The New Zealander George Vernon Hudson first proposed daylight savings time in 1895. Thomas Sidey of New Zealand put forward a private member's bill for putting clocks forward an hour in summer every year from 1909.
- In 1916 Germany and its World War I allies use daylight savings to conserve coal. Britain and many European countries follow.
- The U.S. Congress implements standard time and daylight saving time in the Standard Time Act of 1918.
- International Astronomical Union (IAU) is formed in 1919 “To facilitate the relations between astronomers of different counties where international cooperation is necessary or useful.” The IAU is still the governing authority for much of modern timekeeping standards.

The histories of astronomy, navigation, geography, cartography, and timekeeping have converged to provide extraordinarily accurate location and timing technology exemplified in GPS. Yet there remain many difficulties with the use of time zones and local time.

With the prime meridian set at Greenwich, longitude defined as counting east and west to 180° from the prime meridian, and with the mean solar day being (very nearly) 24 hours it is obvious and natural to divide the globe into 24 15° segments, each representing an hour, with the 180° median marking the divide between consecutive calendar days. This is generally the organization the railways and the nautical almanacs adopted and many nations and jurisdictions followed suite. This established a common practice, but there was no formal definition or international agreements governing it.

This convenient organization did not fit all situations ideally and many jurisdictions did not follow these practices faithfully, if at all. Many places elected to use ½ hour and ¼ hour offsets. Others applied a single time zone to areas much larger or smaller than 15°. Some smaller countries elected to follow their larger neighbors sometimes resulting in inconvenient and illogical jumps to other adjacent areas.

This inconsistency has led to a separation of time zone usage between “nautical time” and “land time”. Nautical, aviation, and military chose to use the more uniform 24 time zone formulas as shown in the Nautical and Aviation almanacs for operations, ignoring “civil” or “land” time except when necessary.

Further complication is added by the non-uniform application of Daylight Savings Time. The custom is only observed in “western” countries: most places do not. Of course the length of the day depends on latitude and time of year due to the tilt of the Earth with respect to the Sun, so any reason for DST depends on a place’s north-south location. For an extreme example, in Barrow Alaska the Sun doesn’t rise at all during December and January and never sets during June, July, and August. A one-hour Daylight Savings Time offset doesn’t mean much there. This is one obvious consideration in any choice to observe daylight savings, yet other reasons, such as conformity with adjoining areas may over ride it.

Adding to the predicament is an inconsistent use of nomenclature related to dates and time in technical standards. By 1972 TAI, UT1, and UTC were well defined and implemented as applied to the reference meridian (Zulu time). But the use of time zones was not officially defined anywhere and the common terminology was inexact.

In 1988 ISO published the ISO 8601 standard. This was a very important document for several reasons. It most famously defines date-time character representations in the form YY-MM-DD hh:mm:ss. It also defines the terms and formulas of the elements to be represented.

ISO 8601 has one glaring omission – it is silent on how daylight savings is handled. In 8601, “standard time” may or may not include daylight savings (or “summer time”) offsets and has no way to signal the difference.

ISO 8601 formatting has an option to include the difference between local time and UTC by appending a value of the UTC offset, but this may or may not include any daylight offset. For example, in the U.S.A there are the common-use terms “Eastern Standard Time” and “Eastern Daylight Time”. Both refer to the “time zone” of the east coast region of the U.S.A. while also signaling if daylight savings is in effect or not. Thus, in this common-use, “standard time” means the fixed UTC offset of the region while “daylight time” means “standard time with daylight savings in effect”.

The UTC offset to the U.S.A. East Coast is –05:00. A date-time represented in ISO 8601 form for “Eastern Standard Time” would be, for example, “1982-01-01T00:00:00-05:00”. For “Eastern Daylight Time”, “1982-01-01T00:00:00-04:00”. Note the UTC offsets are–05:00 vs.–04:00. There is no way to determine if daylight savings is in effect and no way to know the region the date-time applies to. It could be interpreted as shifting the “time zone” by one hour, but that is not the intended meaning.

The ISO 8601 specification derives from earlier standards, including ISO Recommendation R 2014 issued in 1971. These, in turn, rely on International Electrotechnical Commission (IEC) standards, for example 60050-111, International Electrotechnical Vocabulary – Part 111: Physics and chemistry. Those standards have long histories of their own, and the concepts of “local time ” and “time zone” were not, apparently, considered in those disciplines. ISO 8601 reflects this legacy, unfortunately not explicitly addressing the meanings of common-use terminology in timekeeping.

In summary, there are several overlapping difficulties with implementation of local time and time zones:

- No standard defines the division of the globe into 24 15° subdivisions.
- No standard defines the 180° median as demarking the calendar day.
- Nautical, aviation, and military sectors use different common-use time zone schemes from the civilian (land) jurisdictions and these do not often coincide.
- Nautical, aviation, and military common-use time zones employ the 24 15° subdivision design but it is not as symmetrical or uniform as the scheme may suggest..
- Civilian (land) common-use and political expediency have resulted in thousands of similar but different laws and definitions in jurisdictions all over the world.
- There is no uniform convention for naming locations, time zones, or local time.
- Common-use often differs from technical standards.
- Common-use and custom often differs from the applicable laws.

Of course many of these problems are recognized and there are ongoing efforts to overcome them.

Annex C The *International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884* (Informative)

The International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884 adopted several resolutions at the foundation of modern timekeeping. (Note this conference is often improperly referred to as the “International Meridian Conference”). http://www.gutenberg.org/ebooks/17759

The conference was held at the behest of and under the authority of President Chester A. Arthur. It was the crucial meeting where important agreements were finalized following several other international conferences on timekeeping, most notably Paris and Italy. (See Report upon the Third International Geographical Congress and Exhibition, Venice Italy, 1881. War Department - Corps of Engineers, US Army)

The text from the Final Act lists the adopted resolutions:

Final Act

I. "That it is the opinion of this Congress that it is desirable to adopt a single prime meridian for all nations, in place of the multiplicity of initial meridians which now exist."

II. "That the Conference proposes to the Governments here represented the adoption of the meridian passing through the centre of the transit instrument at the Observatory of Greenwich as the initial meridian for longitude."

III. "That from this meridian longitude shall be counted in two directions up to 180 degrees, east longitude being plus and west longitude minus."

IV. "That the Conference proposes the adoption of a universal day for all purposes for which it may be found convenient, and which shall not interfere with the use of local or other standard time where desirable."

V. "That this universal day is to be a mean solar day; is to begin for all the world at the moment of mean midnight of the initial meridian, coinciding with the beginning of the civil day and date of that meridian; and is to be counted from zero up to twenty-four hours."

Contrary to popular understanding, this conference did not adopt the resolution to establish a “date line” or “time zones”. The following proposal was defeated:

"The Conference recommends as initial point for the universal hour and the cosmic day the mean mid-day of Greenwich, coinciding with the moment of midnight or the beginning of the civil day at the meridian 12 hours or 180 degrees from Greenwich. The universal hours are to be counted from 0 up to 24 hours."

That proposal was defeated, or “lost”, in the words used at that conference, and no official proclamation of these facts has since been proposed or approved (at the publication date of this document). Nonetheless, the idea of “beginning of the civil day at the meridian 12 hours or 180° from Greenwich” has found its way to common use.

Annex D United States Law regarding Standard time and Time Zones (Informative)

United States law concerning time zones, standard time, and daylight savings time is influential in timekeeping standards worldwide.

The United States Naval Observatory (USNO) provides many timekeeping services for the U.S. specifically, but its importance has global reach especially in publication of astronomical and navigational almanacs and its responsibilities to maintaining and disseminating GPS.

The National Institute of Standards and Technology (NIST) also provides time services and in cooperation with USNO it maintains UTC(NIST) to within 20 nanoseconds of UTC(USNO).

This annex provides a summary of important parts of the history of U.S. law, relevant statues, and time services by USNO and NIST. The full history is of these laws is complex and beyond the scope of this document.

Standard time, Daylight Savings, and Time Zones

The first and original U.S. law establishing standard time, time zones, and daylight saving time was published in 1918. Many subsequent laws reference this statute.

40 Stat. 450
THE STATUTES AT LARGE OF THE UNITED STATES OF AMERICA 1918
CONCURRENT RESOLUTIONS OF THE TWO HOUSES OF CONGRESS
March 19, 1918.
[S. 1854] [Public, No. 106.]

CHAPTER 24 An Act To save daylight and to provide standard time, for the United States.
[the author is unable to locate this document at the U.S. Government Printing Office]
http://www.webexhibits.org/daylightsaving/usstat.html

The daylight savings provision was repealed in 1919 and reestablished in 1942.

56 Stat. 9
LAWS AND CONCURRENT RESOLUTIONS ENACTED DURING THE SECOND SESSION OF THE SEVENTY-SEVENTH CONGRESS OF THE UNITED STATES OF AMERICA 1942
CHAPTER 7 AN ACT To promote the national security and defense by establishing daylight saving time.
[the author is unable to locate this document at the U.S. Government Printing Office]
http://www.webexhibits.org/daylightsaving/usstat.html

The modern version of time standards was published in 1966 as the "Uniform Time Act of 1966". The act makes the Interstate Commerce Commission responsible for oversight of time standards and law. Many subsequent laws reference this statute.

80 Stat
Public Law 89-387
AN ACT To promote the observance of a uniform system of time throughout the United States.
April 13, 1966
[S. 1404]
U.S. Government Printing Office (GOP)
http://www.gpo.gov/fdsys/pkg/STATUTE-80/pdf/STATUTE-80-Pg107.pdf

An act in 1983 substituted "Secretary of Transportation" for "Interstate Commerce Commission". Since then the responsibility to time standards rests with Department of Transportation.

United States Code, 2006 Edition, Supplement 5
Title 15 - COMMERCE AND TRADE
CHAPTER 6 - WEIGHTS AND MEASURES AND STANDARD TIME
SUBCHAPTER IX - STANDARD TIME (sections 260 - 267)
U.S. Government Printing Office (GOP)
http://www.gpo.gov/fdsys/granule/USCODE-2011-title15/USCODE-2011-title15-chap6-subchapIX

U.S. Government Printing Office (GOP)
Tilte 49 Transportation
Part 71 – STANDARD TIME ZONE BOUNDARIES
http://www.gpo.gov/fdsys/search/pagedetails.action?collectionCode=CFR&searchPath=Title+49%2FSubtitle+A%2FPart+71&granuleId=&packageId=CFR-2009-title49-vol1&oldPath=Title+49%2FSubtitle+A%2FPart+1%2FSubpart+A%2FSection+1.1&fromPageDetails=true&collapse=true&ycord=1556

The United States Naval Observatory (USNO)

"The United States Naval Observatory (USNO) provides a wide range of astronomical data and products, and serves as the official source of time for the U.S. Department of Defense and a standard of time for the entire United States."

Naval Oceanography Portal, The United States Naval Observatory (USNO)
http://www.usno.navy.mil/USNO

Naval Oceanography Portal, The United States Naval Observatory (USNO), Precise Time
The U. S. Naval Observatory is charged with maintaining the DoD reference for Precise Time and Time Interval (PTTI). That reference is UTC(USNO).
http://www.usno.navy.mil/USNO/time

National Institute of Standards and Technology (NIST)

The Time and Frequency Division, part of the NIST Physical Measurement Laboratory, maintains the standard for frequency and time interval for the United States, provides official time to the United States, and carries out a broad program of research and service activities in time and frequency metrology.

The National Institute of Standards and Technology (NIST) is an agency of the U.S. Department of Commerce.

Time and Frequency Division
http://www.nist.gov/pml/div688/index.cfm

Explanation of UTC(NIST), TAI, UTC, and UTC(USNO)
NIST Frequently asked questions (FAQ)
http://www.nist.gov/pml/div688/utcnist.cfm#usno

Annex E Historical Values of Leap Seconds

The International Earth Rotation & Reference Systems Service (IERS) publishes the current value of TAI-UTC and Leap Second announcements in IERS Bulletin C - ftp://hpiers.obspm.fr/iers/bul/bulc/bulletinc.dat

Historical values of TAI-UTC are published in IERS Leap_Second_History.dat
http://hpiers.obspm.fr/eoppc/bul/bulc/Leap_Second_History.dat

IERS Bullitin C – Sample retrieved 2015-01-06
ftp://hpiers.obspm.fr/iers/bul/bulc/bulletinc.dat

```
     INTERNATIONAL EARTH ROTATION AND REFERENCE SYSTEMS SERVICE (IERS)

SERVICE INTERNATIONAL DE LA ROTATION TERRESTRE ET DES SYSTEMES DE REFERENCE

SERVICE DE LA ROTATION TERRESTRE DE L'IERS
OBSERVATOIRE DE PARIS
61, Av. de l'Observatoire 75014 PARIS (France)
Tel.      : 33 (0) 1 40 51 22 26
FAX       : 33 (0) 1 40 51 22 91
e-mail    : services.iers@obspm.fr
http://hpiers.obspm.fr/eop-pc

                                              Paris, 5 January 2015

                                              Bulletin C 49

 To authorities responsible for the measurement and distribution of time


                                   UTC TIME STEP
                            on the 1st of July 2015


 A positive leap second will be introduced at the end of June 2015.
 The sequence of dates of the UTC second markers will be:

                          2015 June 30,     23h 59m 59s
                          2015 June 30,     23h 59m 60s
                          2015 July  1,      0h  0m  0s

 The difference between UTC and the International Atomic Time TAI is:

  from 2012 July 1,    0h UTC, to 2015 July 1  0h UTC  : UTC-TAI = - 35s
  from 2015 July 1,    0h UTC, until further notice    : UTC-TAI = - 36s



 Leap seconds can be introduced in UTC at the end of the months of December
 or June, depending on the evolution of UT1-TAI. Bulletin C is mailed every
 six months, either to announce a time step in UTC or to confirm that there
 will be no time step at the next possible date.


                                              Daniel Gambis
                                              Head
```

```
                                                    Earth Orientation Center of
IERS
                                                    Observatoire de Paris, France
```

IERS Leap_Second_History.dat - Sample retrieved 2015-01-06
http://hpiers.obspm.fr/eoppc/bul/bulc/Leap_Second_History.dat

```
#  Value of TAI-UTC in second valid beetween the initial value until
#  the epoch given on the next line. The last line reads that NO
#  leap second was introduced since the corresponding date
#  Updated through IERS Bulletin C49 issued in January 2015
#
#
#  File expires on 31 December 2015
#
#
#    MJD        Date        TAI-UTC (s)
#           day month year
#    ---    --------------   ------
#
    41317.0    1  1 1972       10
    41499.0    1  7 1972       11
    41683.0    1  1 1973       12
    42048.0    1  1 1974       13
    42413.0    1  1 1975       14
    42778.0    1  1 1976       15
    43144.0    1  1 1977       16
    43509.0    1  1 1978       17
    43874.0    1  1 1979       18
    44239.0    1  1 1980       19
    44786.0    1  7 1981       20
    45151.0    1  7 1982       21
    45516.0    1  7 1983       22
    46247.0    1  7 1985       23
    47161.0    1  1 1988       24
    47892.0    1  1 1990       25
    48257.0    1  1 1991       26
    48804.0    1  7 1992       27
    49169.0    1  7 1993       28
    49534.0    1  7 1994       29
    50083.0    1  1 1996       30
    50630.0    1  7 1997       31
    51179.0    1  1 1999       32
    53736.0    1  1 2006       33
    54832.0    1  1 2009       34
    56109.0    1  7 2012       35
    57204.0    1  7 2015       36
```

Annex F Bibliography (Informative)

ITU-R BT.656-4 (02/98), Interfaces for Digital Component Video Signals in 525-line and 625-line Television
Systems Operating at the 4:2:2 Level of Recommendation ITU-R BT.601 (Part A)

Internet Engineering Task Force (IETF) rfc 5905, Network Time Protocol Version 4: Protocol and Algorithms Specification

The Open Group Base Specifications Issue 7 IEEE Std 1003.1™-2008 POSIX.1-2008

IEEE Std 1588™-2008, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

IS-GPS-200G 05 Sep 2012, Global Positioning Systems Directorate Systems Engineering & Integration Interface Specification

ITU-R BT.470-6 (11/98), Conventional Television Systems

IERS Technical Note 36, IERS Conventions (2010)
ftp://tai.bipm.org/iers/conv2010/tn36.pdf

MJD original specification by
SAO/NASA Astrophysics Data System (ADS)
Title: Satellite Orbital Data
http://adsabs.harvard.edu/full/1960SAOSR..40.....M

Inter gravissimas (papal bull) (1582), Pope Gregory XIII,
http://en.wikisource.org/wiki/Inter_gravissimas

International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884
http://www.gutenberg.org/ebooks/17759

Report upon the Third International Geographical Congress and Exhibition, Venice Italy, 1881. War Department - Corps of Engineers, US Army. Includes a summary of The International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884
http://books.google.com/books?id=J0wSAQAAMAAJ&pg=PA33&lpg=PA33&dq=proceedings+of+the+1884+international+meridian+conference&source=bl&ots=URBOYocPnM&sig=pdtvjpLzwQ88LQdWzOtIUq7zRGA&hl=en&sa=X&ei=sYbLUs7FLo-IogT9roLYDw&ved=0CF4Q6AEwCA#v=onepage&q=proceedings%20of%20the%201884%20international%20meridian%20conference&f=false

metrologia, The leap second: its history and possible future, R. A. Nelson, et al
http://www.cl.cam.ac.uk/~mgk25/time/metrologia-leapsecond.pdf

Report on the organization of the International Astronomical Union, presented for the American Section, International Astronomical Union by W.W. Campbell, chairman, and Joel Stebbins, secretary. Contains "Statutes of convention" organizing the International Astronomical Union, and reports of committees of the American Section of the International Astronomical Union.
http://catalog.hathitrust.org/Record/002092244

UNITED STATES NAVAL OBSERVATORY
CIRCULAR NO. 179
U.S. Naval Observatory, Washington, D.C. 20392 2005 Oct 20
The IAU Resolutions
on Astronomical Reference Systems,

Time Scales, and Earth Rotation Models
Explanation and Implementation
http://www.usno.navy.mil/USNO/astronomical-applications/publications/Circular_179.pdf/view

The Nautical Almanac and Astronomical Ephemeris for the year 1922 For the Meridian of the Royal Observatory at Greenwich published by order of The Lords Commissioners of the Admiralty
http://books.google.com/books?id=DMpVAAAAYAAJ&printsec=frontcover#v=onepage&q&f=false

The Nautical Almanac and Astronomical Ephemeris for the year 1922 For the Meridian of the Royal Observatory at Greenwich published by order of The Lords Commissioners of the Admiralty pp596 Standard Times
http://books.google.com/books?id=DMpVAAAAYAAJ&pg=PA596&lpg=PA596&dq#v=onepage&q&f=false

Traceability in Time and Frequency Metrology, Michael A. Lombardi
http://tf.nist.gov/general/pdf/1305.pdf

Why is a minute divided into 60 seconds, an hour into 60 minutes, yet there are only 24 hours in a day? Michael A. Lombardi
http://www.scientificamerican.com/article/experts-time-division-days-hours-minutes/

Measurements of Newton's gravitational constant and the length of day
http://iopscience.iop.org/0295-5075/110/1/10002/article