Project Services Pty Ltd

# The origins of the Coordinated Universal Time (UTC) calendar


**Volume III, Issue 7 – July 2014**

(Augmented with additional materials received since publication)

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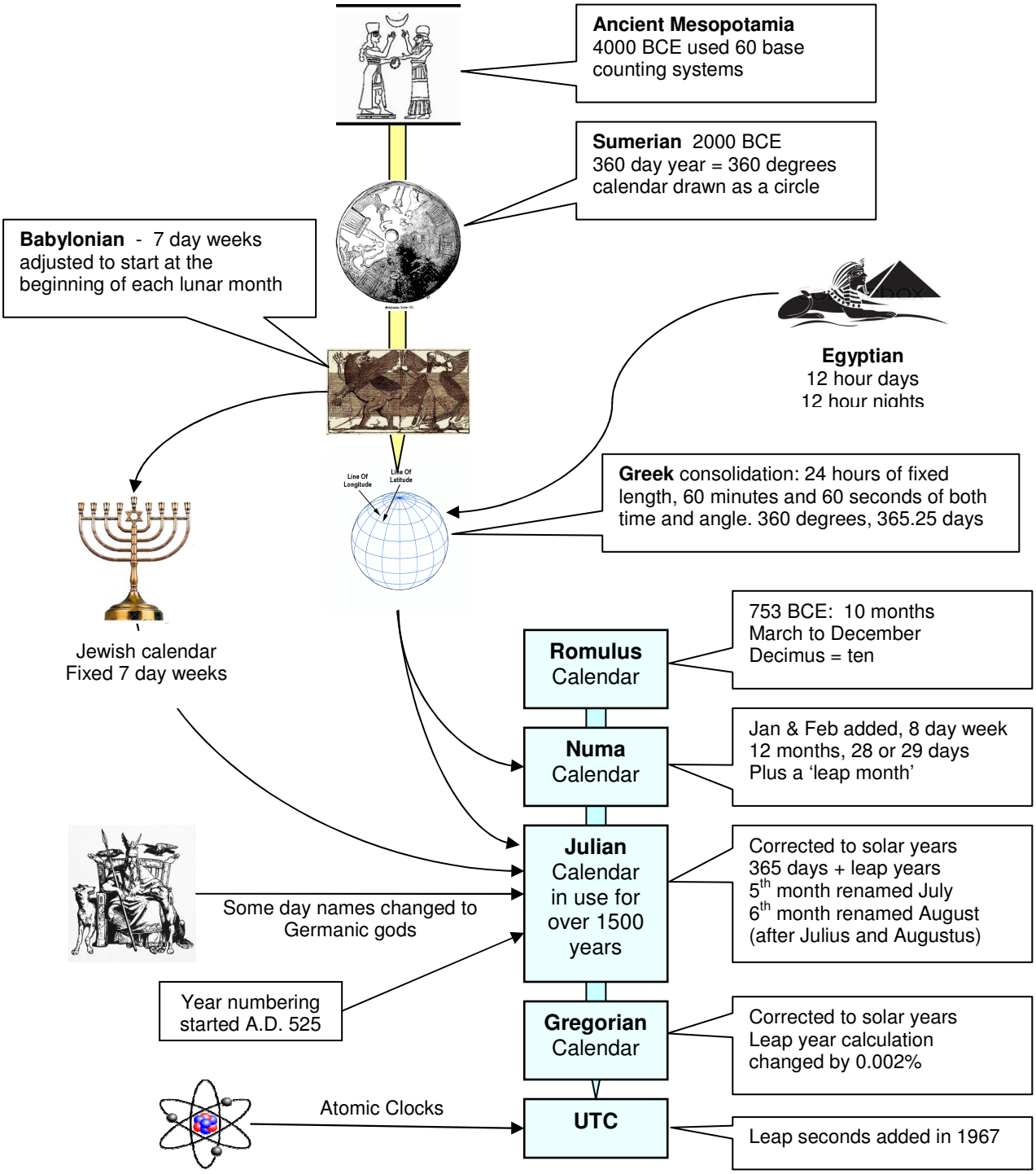
## Introduction

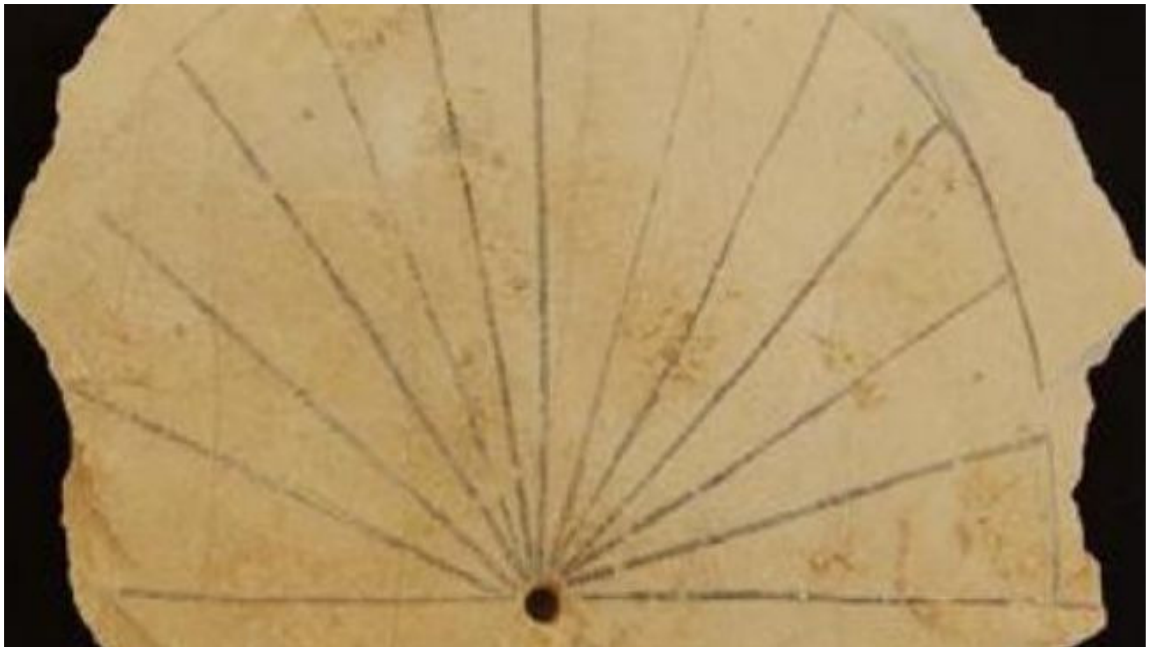
Next time you are setting up your calendars in favorite scheduling tool, stop for a minute and consider the odd collection of numbers that make up the standard UTC calendar, 60 seconds in a minute, 60 minutes in an hour, 24 hours in a day and varying numbers of days in the months and years. The origins of these numbers and the basis of the modern calendar go back a very long way.



## Origins of the 24 Hour day

It appears that the Ancient Egyptians were responsible for the 24 hour day. They were fond of counting in base twelve (instead of base 10 which is commonly used today). This is thought to be because they counted finger joints instead of fingers. Each of your fingers has three joints, so if you count by pointing to finger joints with your thumb you can count to twelve on each hand[1].

The Egyptians divided their day into 10 hours of daytime with 1 hour of twilight at each end of the day (making 12 hours in total) and 12 hours of night-time. This is known from various sundials dating from the period and various tables defining the stars visible during the 12 hours of night[2].



One of the world's earliest sundials excavated from the Kings' Valley, Upper Egypt

In the Egyptian system, the lengths of the day-time and night-time hours were unequal and varied with the seasons. Ordinary people continued to use these seasonally varying hours until the advent of mechanical clocks in Europe in the 14th Century, made the more precise system we use today common place.

## Origins of the 60 minute Hour and other odd numbers

The counting systems that would later become the classical standard for the Babylonian empire were developed during the 'Uruk Period' in Mesopotamia, (the Early Bronze Age c 4000 BCE – c3500 BCE[3]). Studies of protocuneiform clay tablets indicate counting systems based on 60 were used. It is believed the sexagesimal (60) base was used because it is convenient for both counting large numbers

[1] 12 also has a larger number of integers (than 10) allowing precise divisions into quarters, thirds, etc.

[2] The Egyptians had a system of 36 star groups called 'decans'; chosen so that on any night one decan rose 40 minutes after the previous one.

[3] Whilst 4000 BCE is incredibly ancient, Neolithic settlements in nearby Southern Turkey date back 10,000 years; the settlement of Çatalhöyük is dated to about 7500 BCE; Aşıklı Höyük to about 8000 BCE. These settlements (small towns) relied on agriculture and there is some evidence of them trading with communities in Cyprus and Syria. Agriculture and trade need an understanding of calendars and numbers, and 4000 years of development provides ample opportunity for a society to start developing the sophisticated religious and counting systems that were used in Mesopotamia - what's missing is written records.

and expressing the fractions which were essential for trade, business and astronomical calculations; the subdivision of hours and minutes into 60 comes from this source (but only after a few thousand years). The Sumerians inherited the Mesopotamian sexagesimal (base 60) numbering system and used place-value numbering in the same way we do[4].

The recorded history of astronomy in Mesopotamia, and the world[5], also begins with the Sumerians around 3500–3200 BCE. Astronomy, astrology, religion and the development of calendars were closely intertwined in Sumerian culture. They used a 360 day year and began the modern practice of dividing a circle into 360 degrees to represent the cycle of the seasons through the year and the movements of the stars and planets, their calendar!



The sexagesimal (base 60) system and astronomy were in turn inherited by the Babylonians from the Sumerians. The Babylonians were the first to recognize that astronomical phenomena are periodic and apply mathematics to their predictions. The earliest Babylonian star catalogues dating from about 1200 BCE contain many star names in Sumerian suggesting this continuity reaching back to the Early Bronze Age and forward into the Persian Empire.

## Consolidation by the Greeks

The conquests of Egypt and the Persian Empire by Alexander the Great brought these two strands of knowledge together and combined their systems into the modern form.

[4] The Sumerians also created one of the first standards of measurement in 2150 BCE during the Akkadian Empire under the reign of Naram-Sin when competing systems were unified by a single official standard, the royal gur-cube. This standard continued to be used through the Babylonian, Assyrian, and Persian Empires.

[5] Aboriginal Australians may be the world's oldest known astronomers (but their 30,000 year old culture is based on oral storytelling). In indigenous culture everything that happened on earth is recorded in the sky; they studied the movement of, and named celestial objects, understood the moon governs the tides and worked out the causes of eclipses. This information informed the people about navigation, seasonal changes and food economics including hunter-gathering, fishing and even agriculture in some locations.

In the last couple of centuries of the BC era, Greek astronomers normalised the lines of latitude and longitude to encompass the full 360 degrees of the globe and divided the day into 24 hours of equal length[6].

In his treatise *Almagest* (circa A.D. 150), Claudius Ptolemy explained and expanded on this work by subdividing each of the 360 degrees of latitude and longitude into smaller segments. Each degree was divided into 60 parts, each of which was again subdivided into 60 smaller parts. The first division, *partes minutae primae*, or first minute, became known simply as the *minute*[7]. The second segmentation, *partes minutae secundae*, or "second minute," became known as the *second*.

So although it is no longer used for general computation, thanks to the Greeks, the sexagesimal system is still used to measure angles, geographic coordinates and time[8]. But as we all know a year is not 360 days……..

## The Roman Calendars

The basis of the UTC calendar with 12 months of varying duration is Roman. The original Roman calendar is believed to have been a lunar calendar, which may have been based on one of the Greek lunar calendars.

### Calendar of Romulus

Roman writers attributed the original Roman calendar to Romulus, the founder of Rome around 753 BC. The Romulus calendar had ten months with the regular calendar year consisted of 304 days, and the winter days after the end of December and before the beginning of the following March not being assigned to any month.

The names of the first four months were named in honour of Roman gods: *Martius* in honour of Mars; *Aprilis* in honour of Fortuna Virilis *Maius* in honour of Maia[9]; and *Iunius* in honour of Juno; The names of the months from the fifth month on were based on their position in the calendar: *Quintilis* comes from Latin quinque meaning five; *Sextilis* from sex meaning six; *September* from septem meaning seven; *October* from octo meaning eight; *November* from novem meaning nine; and *December* from decem meaning ten.

Numa Pompilius, the second of the seven traditional kings of Rome, reformed the calendar of Romulus around 713 BC. He added January and February and created a standard year of 355 days. To

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[6] The Greek astronomer Eratosthenes (who lived circa 276 to 194 B.C.) used a sexagesimal system to divide a circle into 60 parts in order to devise an early geographic system of latitude, with the horizontal lines running through well-known places on the earth at the time.

A century later, Hipparchus normalised the lines of latitude, making them parallel and obedient to the earth's geometry. He also devised a system of longitude lines that encompassed 360 degrees and that ran North to South, from pole to pole. He also proposed dividing the day into 24 hours of equal length (which came to be known as equinoctial hours because they are based on 12 hours of daylight and 12 hours of darkness on the days of the Equinoxes) to facilitate astronomical calculations.

[7] It appears having the same word for very small (minute) and 60 seconds of time or angle (minute) is no accident.

[8] The Antikythera Mechanism, the world's oldest analogue computer, was created by the Ancient Greeks around 250 BCE to provide a 'ready reckoner' showing the Greek zodiac and an Egyptian calendar, information about lunar cycles and eclipses, and the movement of the five known planets. The device appears to combine Babylonian mathematics with Greek geometry: https://en.wikipedia.org/wiki/Antikythera_mechanism

[9] In ancient Roman religion and myth, Maia embodied the concept of growth and may have been associated with the Greek goddess Maia, the daughter of Atlas, mother of Hermes, and is the eldest of the seven Pleiades.

keep the calendar year roughly aligned with the solar year, a leap month was added in the middle of February every couple of years[10] but this process lacked predictability.

## Julian calendar

Julius Caesar, as *Pontifex Maximus*, reformed the calendar in 46 BC by increasing the number of days in most months to 30 or 31 to create a year of 365 days. The Julian months have the modern form and an extra day is added to February every fourth year to keep the calendar aligned with the earths rotation around the sun. The Julian year is, therefore, on average 365.25 days long. His new calendar took effect in 45 BC after a year of 445 days (in 46 BC) needed to realign the calendar with the seasons.

The reforms to the Julian calendar were completed during the reign of his successors; Augustus renamed Quintilis as Iulius (July) in honour of Julius Caesar in 44 BC and Sextilis was renamed Augustus (August) in honour of Augustus in 8 BC.

This calendar became the predominant calendar in most of Europe, and in European settlements in the Americas and elsewhere, until it was refined and superseded by the Gregorian calendar more than 1500 year later.

## Gregorian calendar

Greek astronomers had known, for at least a century before the Julian reform that the tropical year was a few minutes shorter than 365.25 days, and the Julian calendar did not compensate for this difference. As a result, the calendar year gained about three days every four centuries compared to observed equinox times and the seasons. This discrepancy was corrected by the Gregorian reform of 1582.

The Gregorian calendar has the same months and month lengths as the Julian calendar, but inserts leap days according to a slightly different rule. The Gregorian reform modified the Julian calendar's scheme of a leap year every fourth year as follows:

> ***Every year that is exactly divisible by four is a leap year, except for years that are exactly divisible by 100, but these centurial years are leap years if they are exactly divisible by 400. For example, the years 1700, 1800, and 1900 were not leap years, but the year 2000 was.***

This alteration changed in the mean length of the calendar year from 365.25 days (365 days 6 hours) to 365.2425 days (365 days 5 hours 49 minutes 12 seconds), a reduction of 10 minutes 48 seconds per year; a difference of 0.002%; resulting in a remarkably accurate tracking of the summer solstice over centuries[11].

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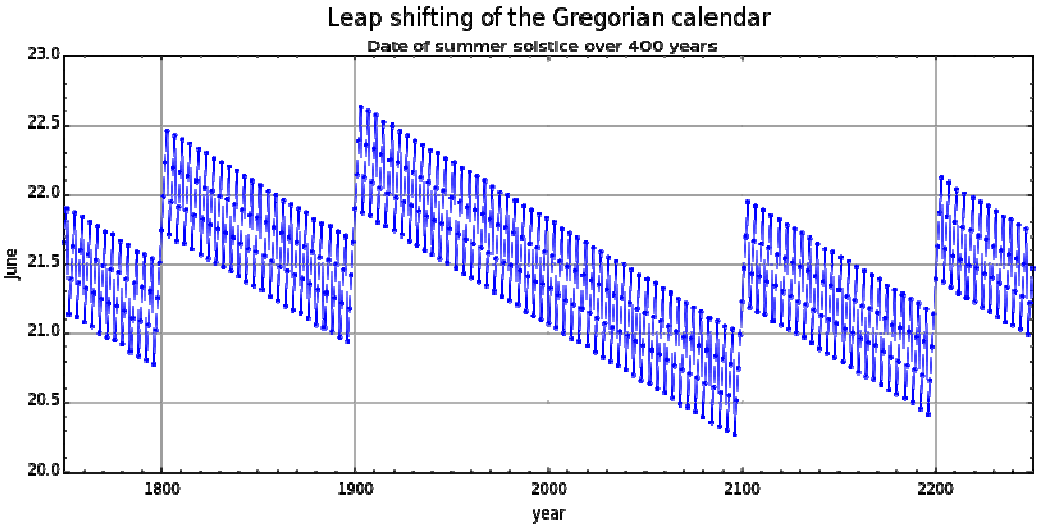
[10] To keep the Numa calendar year roughly aligned with the solar year, a leap month, called the *Mensis Intercalaris*, was added in the middle of February every couple of years. The *Pontifex Maximus* determined when this intercalary month was to be inserted. On average, it should have happened every two to three years but was subject to political interference.

[11] As accurate as it is, on a time scale of thousands of years, the Gregorian calendar will still fall behind the astronomical seasons due to the slowing of the Earth's rotation. By the year 4000, the Gregorian calendar will be between 0.8 and 1.1 days behind solar time, but this is unlikely to affect any current projects……...




The Gregorian calendar reforms also dealt with the accumulated difference between the Julian calendar and the solar year. To correct the difference, the Gregorian calendar began by skipping 10 calendar days, to restore the 21st March as the date of the vernal equinox.


The Gregorian calendar was initially adopted by the Catholic countries of Europe. Protestant and Eastern Orthodox countries continued to use the traditional Julian calendar and only adopted the Gregorian reform after many years, usually for the convenience of international trade. The last European country to adopt the Gregorian calendar was Greece, in 1923.

## Numbering the Years

As well as retaining the Julian months, the Gregorian calendar also continued the previous year-numbering system (*Anno Domini*), which counts years from the traditional date of the Nativity. This year-numbering system is the predominant international standard today (although there are other year numbering systems).

Up to the 6th century, each year in the Julian calendar was identified by naming the two *consuls* who took office in Rome on the 1st January of that year[12].

The *Anno Domini* dating system that replaced this naming convention with year numbers was devised in 525 by Dionysius Exiguus, originally to enumerate the years in his Easter table[13]. The term *Anno Domini* (*AD*) is Medieval Latin, translated as *In the year of the Lord*. The start of the year numbering used by Dionysius was based on his estimate of the year of the birth of Jesus of Nazareth. Despite an error of several years in Dionysius' counting[14], his year numbering convention remains unchanged though to modern times.

The Anglo-Saxon historian the Venerable Bede used *Anno Domini* dating in his *Ecclesiastical History of the English People*, finished in 731. Bede also added the Latin term, *"ante vero incarnationis dominicae tempus"* ("the time before the Lord's true incarnation"), equivalent to the English "before Christ", to identify years before the first year of the current era, starting at 1 BC and counting backwards. This AD / BC convention was generally adopted and as a consequence, there is no year zero in scheme we use for numbering the years, the year AD 1 immediately follows the year 1 BC.

## The origins of the 7 day week

The earliest record of a seven-day week comes from ancient Babylon prior to 600 BCE. Babylonians celebrated a holy day every seven days, starting from the new moon, and adjusted the number of days of the final "week" in each month so that months would continue to commence on the new moon.

The Jewish calendar followed the Babylonian's; however, the Jewish tradition broke from the lunar cycle and celebrated every seventh day as a holy day of rest, within a continuous cycle of seven-day weeks[15].

## The origins of the names associated with the seven day week

Between the 1st and 3rd centuries the Roman Empire gradually replaced the eight-day Roman nundinal cycle with the Jewish / Christian seven-day week with the days named after Roman deities[16].

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[12] The *consuls* were the highest elected office in the Roman Republic and whilst they lost most of their powers and responsibilities under the Roman Empire, the tradition of appointing consuls each year continued through to AD 541.

[13] The calculation of Easter depends on both lunar and solar cycles. The First Council of Nicaea (325) established the date of Easter as the first Sunday after the full moon (the Paschal Full Moon) following the March equinox. Calculating the date each year depends on the calendar used (Julian or Gregorian) and astronomical predictions of the sun and moon; thereby creating the need for enumerated tables.

[14] Modern scholars and the Roman Catholic Church acknowledge that the birth of Jesus was a few years earlier than AD 1. Whilst Dionysius stated that the *"present year"* was *"the consulship of Probus Junior"*, which was 525 years *"since the incarnation of our Lord Jesus Christ"*; thereby implying that Jesus' *Incarnation* (birth or conception) occurred 525 years earlier, this assessment was made without Dionysius stating the specific year during which the *Incarnation* occurred.

Nowhere in the exposition of his table does Dionysius relate his system of year numbering to any other dating system or relate the Nativity to any defined year in the Julian calendar.

[15] The seven-day week is strongly identified with Judaism: it appears in the Hebrew Bible (Tanakh) in the Creation account in the Book of Genesis (first of the five books of the Torah), where *Elohim* (God) creates the heavens and the earth in six days and rests on the seventh (Genesis 1:1-2:3). And in the Book of Exodus, the fourth of the Ten Commandments is to rest on the seventh day (Shabbat), which can be seen as implying a socially instituted seven-day week. The Tanakh was probably formalised around 450 BCE but the Torah is much older. The Old Testament in the Christian Bible is based on the Hebrew Bible.

The Germanic peoples adopted the system introduced by the Romans, but used a naming convention based on their own gods in preference to the Roman deities. The date of the introduction of this system is not known exactly, but it must have happened during the final phase or soon after the collapse of the Western Roman Empire but before the Christianity took hold in the region in the 6th and 7th centuries.

The Germanic names were used across most of Northern Europe and came into English usage as a consequence of the Anglo Saxon invasions that followed the collapse of the Roman rule during the 5th century.

Within this Germanic tradition, Saturday is the only day of the week to retain its Roman origin, named after the Roman god Saturn. Sunday and Monday retain their pagan connections to the sun and moon respectively. The other days of the week are named after Norse or Germanic gods: Tuesday = Tiw (Norse Týr), Wednesday = Wodan, Thursday = Thor, Friday = Norse goddess Fríge.

## Agreeing the Modern UTC Calendar

None of the foundations outlined above had universal acceptance world-wide. But as global trade expanded in the 19th century, the need for a consistent means of calculating dates and time became increasingly important.

The first step towards a standardised global calendar and time system was achieved at the 1884 International Meridian Conference held in Washington, D.C., when the local mean solar time at the Royal Observatory, Greenwich in England was chosen to define the Universal day[17]. This allowed the development of 'time zones' and the creation of the international date line in the middle of the Pacific ocean.

Coordinated Universal Time (UTC), the primary time standard by which the world now regulates time was initiated in 1960 by the International Radio Consultative Committee, and is based on the Greenwich Meridian[18] and the Gregorian calendar.

The main difference between UTC, as it is now applied, and the Gregorian calendar is the way seconds are defined. Seconds were originally defined as a fraction of the mean tropical year. This changed in 1967, when the second was redefined as the duration of 9,192,631,770 energy transitions of the cesium atom and ushered in the era of atomic timekeeping.

Despite the precision of UTC, it is desirable that the civil time scale should not be very different from the Earth's time. The current definitions state that UTC cannot differ from UT1 (the earth's actual rotation) by more than 0.9 seconds. A one-second change called a "leap second" is introduced into UTC if it appears that the difference between these two kinds of time is approaching this limit. The

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[16] The order of the days was Sun, Moon, Ares, Hermes, Zeus, Aphrodite, and Cronos (Saturn), named after the heavenly bodies that presided over the first daylight hour of each day, according to Hellenistic astrology.

[17] Virtually instantaneous communication between Europe and the USA started in 1858 with the completion of the first Trans-Atlantic telegraph cable. Before this the 10 day shipping time for a message between the two continents made the coordination of time unnecessary.

[18] Greenwich Mean Time (GMT), had been used in the UK since 1847 to standardise time across the country and facilitate railway timekeeping. Prior to 1847 local time was based on observations of the sun with a difference of several minutes from East to West.

last leap second was added to the minute before midnight on the 30th June 2015[19] (which is 10:00AM on the 1st July in my part of Australia).

The other modern innovation (not related to UTC) has been to change the naming convention from AD to Common Era (CE) and BC to Before the Common Era (BCE) to emphasise the secularism of the standard calendar. Unlike UTC, this change in naming convention is by no means universally accepted.

## Conclusions

The need for a common understanding of time and dates has been driven by the demands of trade over several thousand years. And whilst there are still many different calendars in use for ceremonial, religious and local needs (including the Julian calendar), the effect of an interconnected world has been the steady move towards everyone using UTC for business purposes, including project scheduling.

But despite the 'universality' of UTC, few people realise the circular face of a clock and the sphere of a globe owe their divisions to the 6,000-year-old numeric system of the Mesopotamians and the knuckles on an Egyptian's hand. And it is thanks to these ancient civilizations and the Greek astronomers who defined and preserved their divisions of time, modern society still conceives of a day of 24 hours, an hour of 60 minutes and a minute of 60 seconds; and a circle of 360 degrees with each degree divided into 60 minutes and a minute of angle into 60 seconds.

The two thoughts I would like to leave you with is firstly the incredible accuracy of the calculations made by the astronomers who set the basis for both the Julian and Gregorian calendars; working in a time before computers, using quills and parchment their calculations were accurate to a day in every 2000 years. Second the amazing durability of the ancient Mesopotamian and Egyptian systems that still affect our lives and the project schedules we create some 6000 years or more years after they were initially developed.

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**Note:** This article is a compilation and summarisation of many different entries in Wikipedia (http://en.wikipedia.org/) validated from other reference materials where anomalies were noted. It is not intended as a scholarly article.

Mosaic's complete PM History resource is available from:
**http://www.mosaicprojects.com.au/PM-History.html**

[19] A table of the years in which leap seconds have been added to the calendar can be found at https://en.wikipedia.org/wiki/Leap_second