# Summary of elements for consideration

# Coordinated Universal Time (UTC)

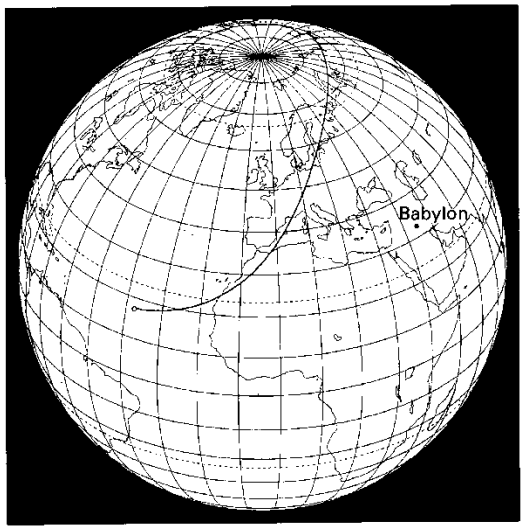
Robert A. Nelson

19th meeting of the CCTF

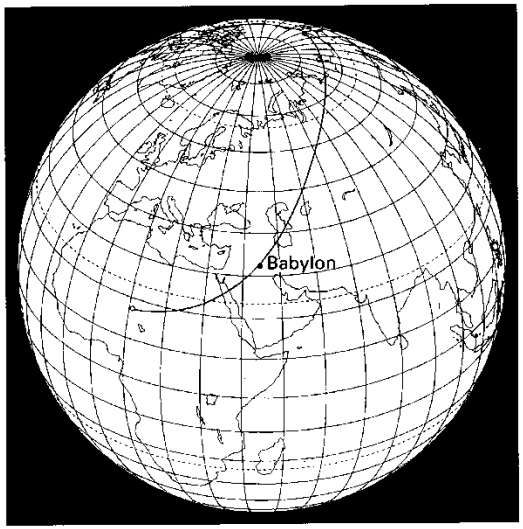
14 September 2012

# Earth's Rotation is Slowing Down

(a)




(b)



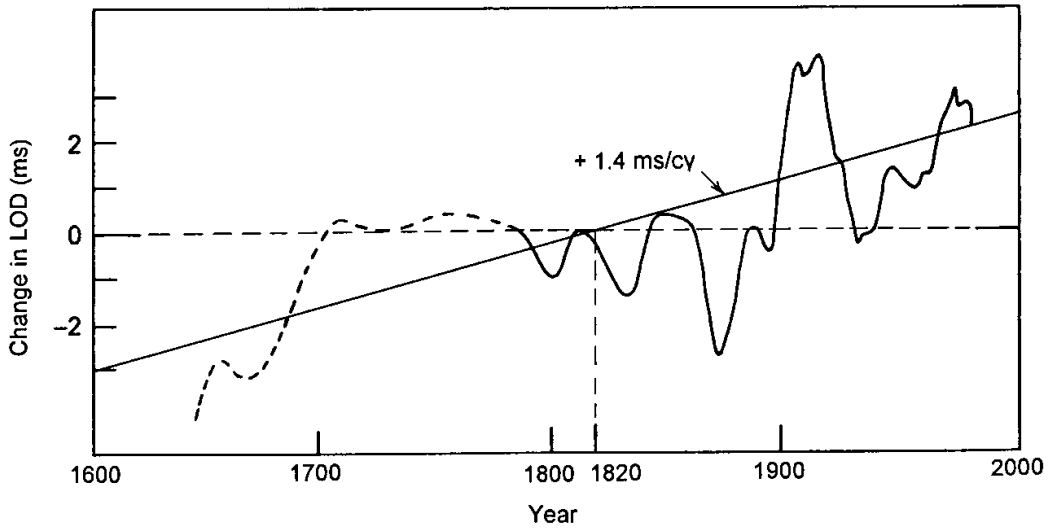

The figures on the left depict the effect of the slowing of the Earth's rotation over the past two thousand years on the path of the eclipse of 136 BC. The observed eclipse was total in Babylon.

(a) path of totality assuming uniform rotation of the Earth.

(b) path of totality taking into account the slowing of the Earth's rotation (difference of 48° or 3.2 h in 2,000 years).

Eclipse observations provide data on changes in Earth's rotation.

# The Length of the Day is Increasing

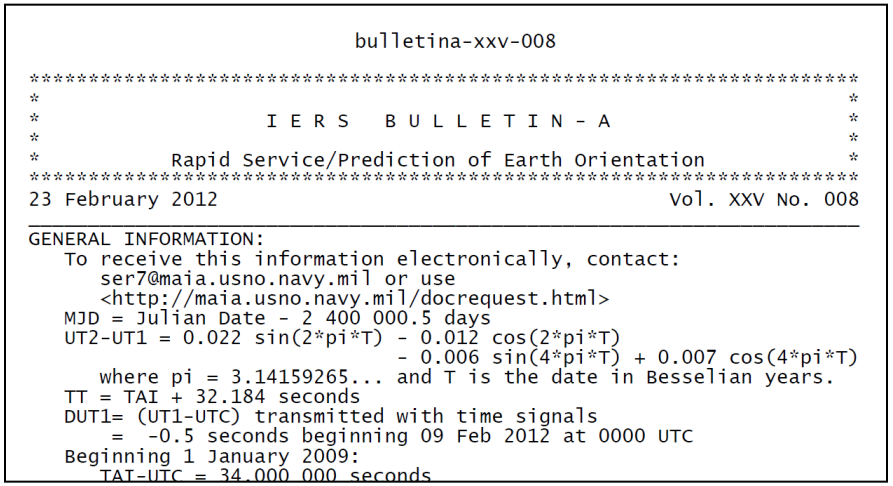



- The Length of Day has been increasing by an average rate of 0.0014 second per day per century.
- The SI second is equal to a mean solar second of about 1820 (average mean solar second of eighteenth and nineteenth centuries).

Since 1820 the Length of Day has increased by about 0.0025 second. In one year this increment accumulates to nearly one second.

# IERS Bulletins A and C

- International Earth Rotation and Reference System Service (IERS) bulletins
  - Bulletin A: reports the latest determinations for Earth Orientation, including UT1 – UTC
  - Bulletin C: 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.
- Available on the IERS website www.iers.org



bulletina-xxv-008

I E R S  B U L L E T I N - A

Rapid Service/Prediction of Earth Orientation

23 February 2012 Vol. XXV No. 008

GENERAL INFORMATION:

To receive this information electronically, contact:
ser7@maia.usno.navy.mil or use
<http://maia.usno.navy.mil/docrequest.html>

MJD = Julian Date - 2 400 000.5 days

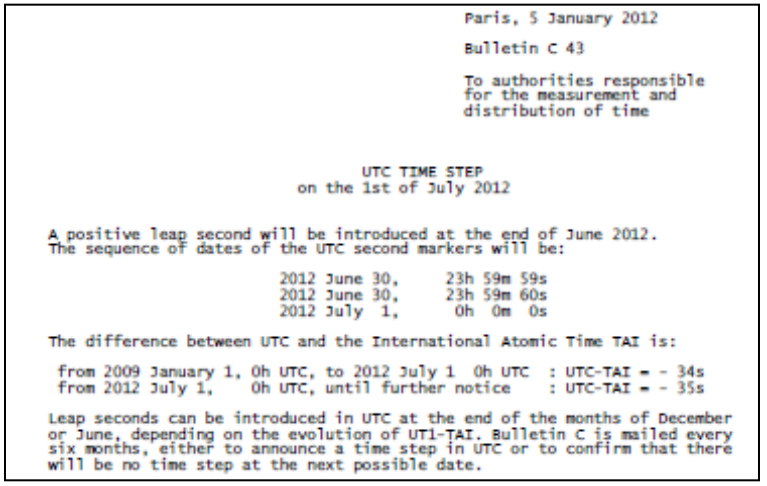
UT2-UT1 = 0.022 sin(2*pi*T) - 0.012 cos(2*pi*T)
- 0.006 sin(4*pi*T) + 0.007 cos(4*pi*T)

where pi = 3.14159265... and T is the date in Besselian years.

TT = TAI + 32.184 seconds

DUT1= (UT1-UTC) transmitted with time signals
= -0.5 seconds beginning 09 Feb 2012 at 0000 UTC

Beginning 1 January 2009:
TAI-UTC = 34.000 000 seconds



Paris, 5 January 2012

Bulletin C 43

To authorities responsible
for the measurement and
distribution of time

UTC TIME STEP
on the 1st of July 2012

A positive leap second will be introduced at the end of June 2012.
The sequence of dates of the UTC second markers will be:

2012 June 30, 23h 59m 59s
2012 June 30, 23h 59m 60s
2012 July 1, 0h 0m 0s

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

from 2009 January 1, 0h UTC, to 2012 July 1 0h UTC : UTC-TAI = - 34s
from 2012 July 1, 0h UTC, until further notice : UTC-TAI = - 35s

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.

IERS Bulletins A and C provide: (a) the UT1 – UTC Earth rotation parameter; and (b) leap-second announcements.

# Precision of IERS Data

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I E R S  B U L L E T I N – A

Rapid Service/Prediction of Earth Orientation

**********

19 April 2012 Vol. XXV No. 016

IERS Rapid Service

| MJD | UT1-UTC s | error s |
|---|---|---|
| 12 4 13 56030 | -0.525837 | 0.000009 |
| 12 4 14 56031 | -0.527050 | 0.000008 |
| 12 4 15 56032 | -0.528289 | 0.000008 |
| 12 4 16 56033 | -0.529569 | 0.000006 |
| 12 4 17 56034 | -0.530877 | 0.000006 |
| 12 4 18 56035 | -0.532200 | 0.000005 |
| 12 4 19 56036 | -0.533490 | 0.000005 |

| MJD | UT1 – UTC (s) |
|---|---|
| 2012 4 27 56044 | -0.54163 |
| 2012 4 28 56045 | -0.54263 |
| 2012 4 29 56046 | -0.54375 |
| 2012 4 30 56047 | -0.54502 |
| 2012 6 29 56107 | -0.57678 |
| 2012 6 30 56108 | -0.57701 |
| 2012 7 1 56109 | 0.42292 |
| 2012 7 2 56110 | 0.42294 |

Estimated accuracy of UT1 - UTC (s)

| 10 d | 20 d | 30 d | 40 d |
|---|---|---|---|
| 0.0014 | 0.0024 | 0.0032 | 0.0040 |

Currently TAI - UTC = 34.0 s

IERS provides UT1 – UTC with a precision of 1 to 10 *micro*seconds

# Proposal to Discontinue Leap Seconds in UTC

- UTC with leap seconds as an approximation to UT1 was introduced in 1972 to permit navigation at sea via radio time signals
- GPS and other components of the GNSS have rendered this motivation obsolete
- Modern timekeeping systems suffer loss in reliability because they may not perform as planned during a one-second timing discontinuity
- Leap seconds interrupt normal operation of timekeeping infrastructures and are costly in staff time to implement

**On June 30, 2012, every clock in the world had to stop for one second.**

It would be advantageous to modern timekeeping systems to eliminate leap seconds and produce a uniform, continuous timescale.

# Applications of UTC

- Communications systems
- Electrical power grids
- Air traffic control
- Financial transactions
- Spacecraft navigation

Discontinuities reduce the reliability of systems that depend on time and introduce the possibility of catastrophic failure

# Legal Time

PUBLIC LAW 110–69—AUG. 9, 2007
AMERICA COMPETES ACT

"(b) COORDINATED UNIVERSAL TIME DEFINED.—In this section, the term 'Coordinated Universal Time' means the time scale maintained through the General Conference of Weights and Measures and interpreted or modified for the United States by the Secretary of Commerce in coordination with the Secretary of the Navy."

If UTC is redefined no change in U.S. law would be required.

# Suitability of Other Time Scales

- Issues to be considered when determining the suitability of a time scale:
  - How it is determined
  - Epoch (time origin)
  - Method of dissemination and acquisition
  - Precision
- Coordinated Universal Time (UTC)
  - Atomic timescale formed by the BIPM with contributions from timing laboratories around the world that is disseminated for civil, government, and scientific use
- International Atomic Time (TAI):
  - TAI is a background laboratory atomic timescale that is uniform (without leap seconds). However, it is not an alternative to UTC because it is not disseminated.

UTC is the only disseminated timescale that can provide the necessary precision for many timekeeping applications.

# Conceptual Difference Between UTC and UT1

- UTC
  - The universal scale of atomic time
  - Used by everybody to order events and meet precise schedules
  - Disseminated by radio signals and similar methods
- UT1
  - Is called a time but conceptually it is really an angle – the angle of rotation of the Earth in space
  - Used by engineers for tracking satellites and pointing telescopes
  - Dissemination:
    - By IERS in Bulletin A in the form UT1 – UTC
    - By UTC by applying leap seconds
  - Precision:
    - From Bulletin A: 1 to 10 microseconds
    - From UT1 = UTC with leap seconds: up to 0.9 second

There is a need to disseminate UTC via signals. There is no need to disseminate UT1 via a separate signal because it is already available from IERS Bulletin A.

# Name of UTC

- UTC means "Coordinated Universal Time"
  - "Coordinated" means that national laboratories coordinate their time via the BIPM. "Coordinated" does not mean coordinated with the Sun.
  - "Universal" means the same time for the entire Earth. It does not imply solar time.*
- The name was not changed in 1972 when leap seconds replaced small steps and frequency offsets.

*International Meridian Conference, 1884

"The scheme set forth in the recommendations has in view three principal objects, *viz*:
1. To define and establish a universal day for securing chronological accuracy in dates common to the whole world.
2. To obtain a system of universal time on a basis acceptable to all nations, by which, everywhere, at the same time, the same instant may be observed.
3. To establish a sound and rational system of reckoning time which may eventually be adopted for civil purposes everywhere, and thus secure uniformity and accuracy throughout the globe."

If leap seconds are eliminated, the name of UTC should be retained to avoid confusion and legal issues.

# Summary

- UTC is a *time*.
- UT1 is *not* a time, it is an *angle* describing Earth rotation.
- UTC is the most precise and most widely disseminated timescale available.
- There is no need to disseminate UT1 via a signal, as the information is available through IERS independently with a precision that is 100,000 times greater than the coarse approximation UT1 = UTC.
- The original motivation for leap seconds for navigation at sea is obsolete due to the evolution of the GNSS including the GPS.
- The name UTC implies universal (global, the same everywhere), not solar.
- If leap seconds are eliminated from UTC, there will be no perceptible impact on social activities and conventions but there will be significant reduction in the risk to national and international infrastructure and significant cost reduction in their implementation.