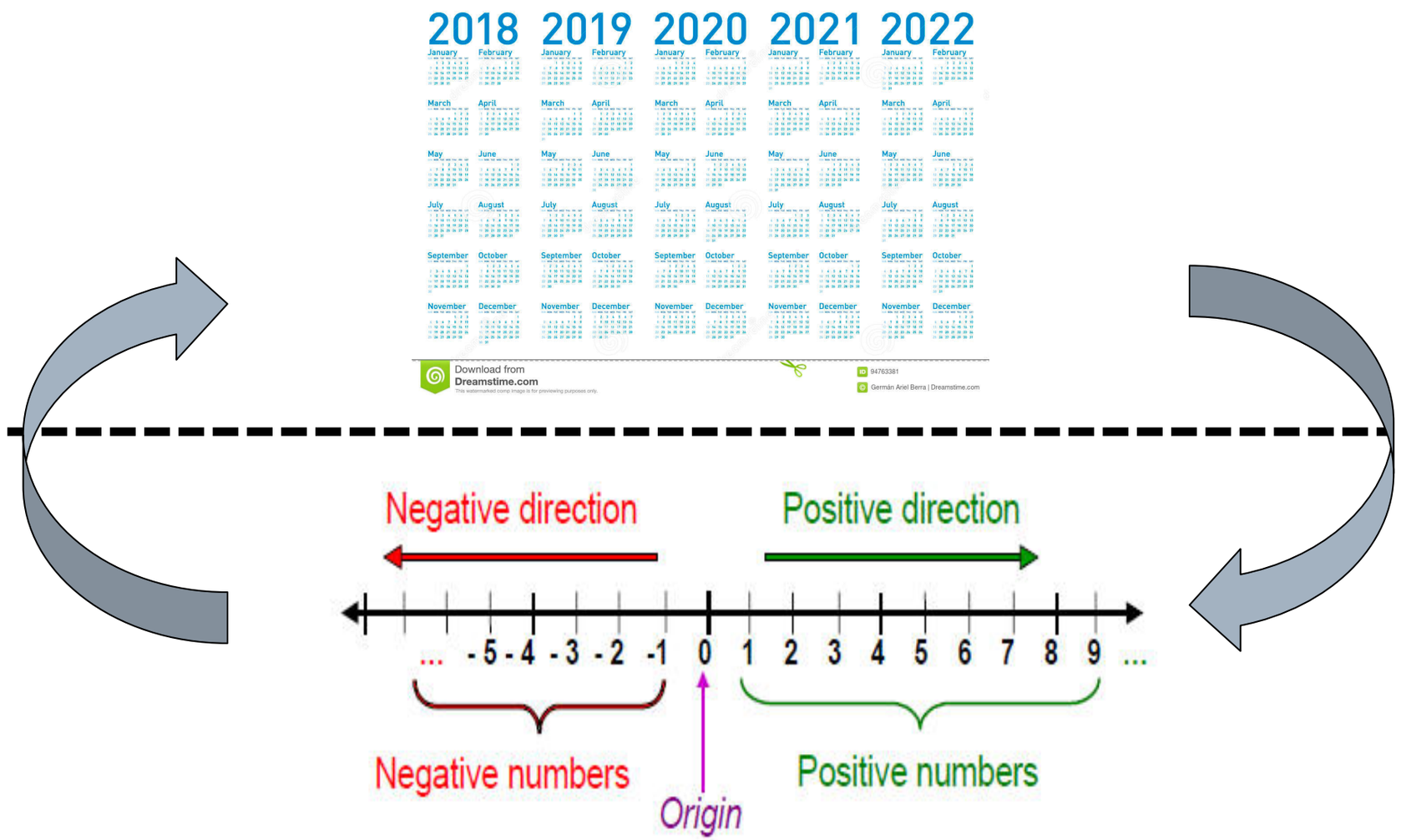
Time

Lecture 40

Big Picture


2018
2019
2020
2021
2022
January
February
March
April
May
June
July
August
September
October
November
December
Download from
Dreamstime.com
94763381
Germán Ariel Berra | Dreamstime.com
Negative direction
Positive direction
... -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 ...
Negative numbers
Origin
Positive numbers

Interval vs Point

- Two different kinds of question:
  - "How long did it take to run 5k?"
  - "When is our final exam?"
- Answering "how long?" is easy
  - Count the number of elapsed seconds
  - Easy to code
- Answering "when?" is tricky
  - 10 am (Dec 10, 2024) is *not* sufficient
  - Meaning depends on geolocation!
  - Dates (Nov 25, 2024) have same problem

Solving Time/Place Problem

- Fix one place on earth, and use *that* location's time
  - We agreed (in 1884): Greenwich, England
  - Same location as used for longitude
  - *Prime Meridian* of longitude (ie 0°)
    - Aside: What are the co-ordinates of the oval?

FYI: Where Are We?

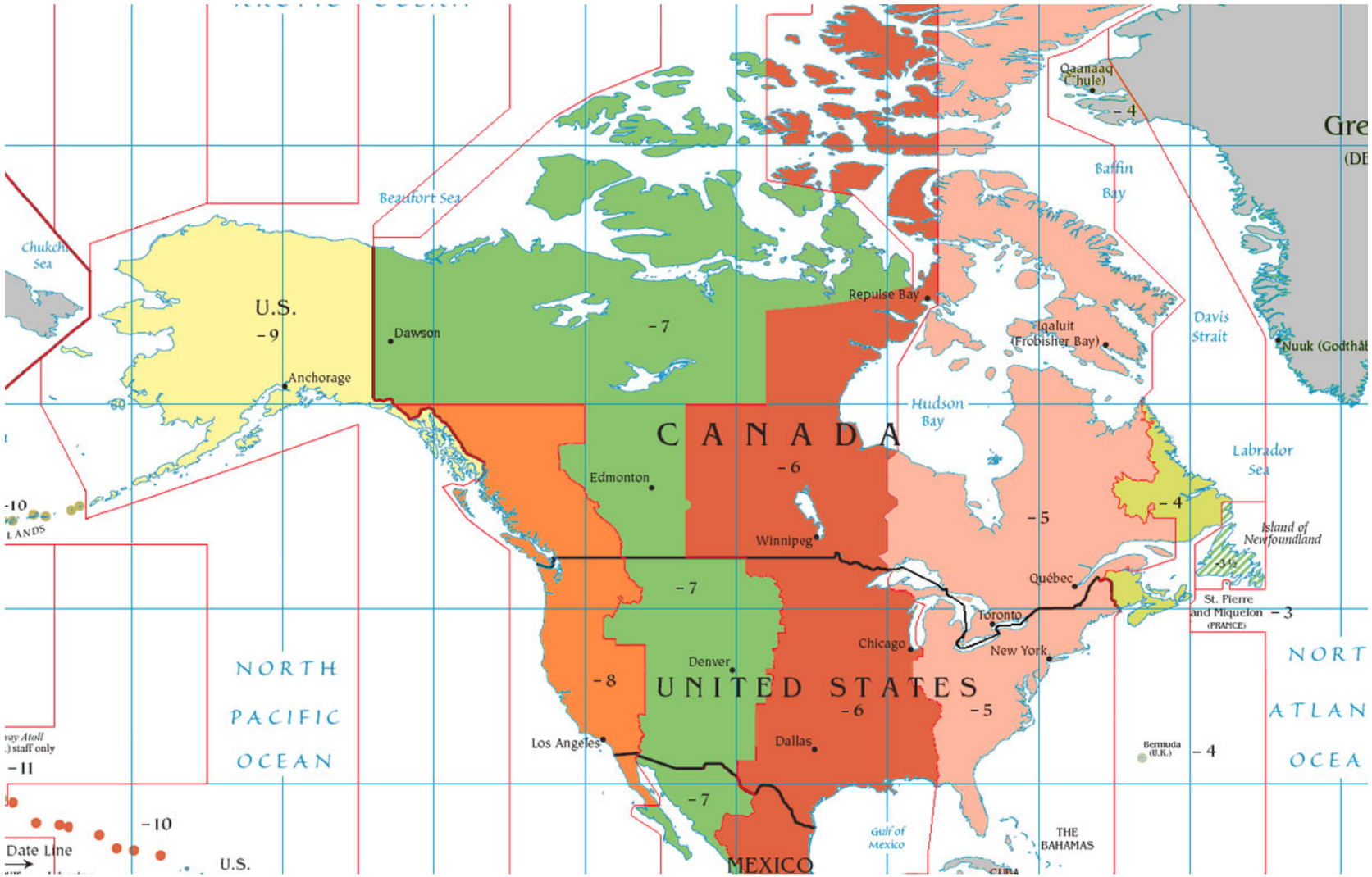
Solving Time/Place Problem: Example

- Fix one place on earth, and use *that* location's time
  - We agreed (in 1884): Greenwich, England
  - Same location as used for longitude
  - *Prime Meridian* of longitude (ie 0°)
    - Aside: What are the co-ordinates of the oval?
  - Once called "Greenwich Mean Time" (GMT)
    - Now called "Coordinated Universal Time" (UTC)
- Example
  - CSE 3901 final exam is at *3 pm* (on Dec 10, 2024)
  - So why does it say 10 am on SIS?

Time Zones

- People want their clocks to show 12:00 when the sun is high in the sky
- Solution: Time zones
  - Geographic region that uses the same offset from Greenwich
  - Politically defined
- Abbreviations
  - EST = UTC-5:00 ("**S**tandard", *i.e.* winter)
  - EDT = UTC-4:00 ("**D**aylight savings" summer)
- To report a time, append time zone
  - 2024-12-10 10:00:00 EST
  - 2024-12-10 10:00:00 UTC-5:00
  - 2024-12-10 15:00:00 UTC

North American Time Zones



Notation: Encoding Date/Time

- Computer scientists understand the importance of *representation/encoding*
- Big Endian
  - **`year-month-day hour:minute:second`**

    `2024-12-10 15:00:00`
  - Benefit: lexicographic = chronological
- Start at 0, not 1
  - Non-CS folks call this a 24-hour clock!
  - CS folks call this… normal
  - 00:00 is midnight, 12:00 is noon
  - Benefit: Avoids am/pm ambiguities

Mixing Intervals and Points

- Mapping between these is tricky
- *E.g.* run a task every day at 9 am
  - Naïve solution: java.util.Timer's schedule

```
schedule (TimerTask t, Date first,
                long period)
```

  - Period is an interval (number of milliseconds)

```
schedule(job, noonToday, 86400000);
```

- Problem?

Mixing Intervals and Points: A Problem

- Mapping between these is tricky
- *E.g.* run a task every day at 9 am
  - Naïve solution: java.util.Timer's schedule

```
schedule (TimerTask t, Date first,
                long period)
```

  - Period is an interval (number of milliseconds)

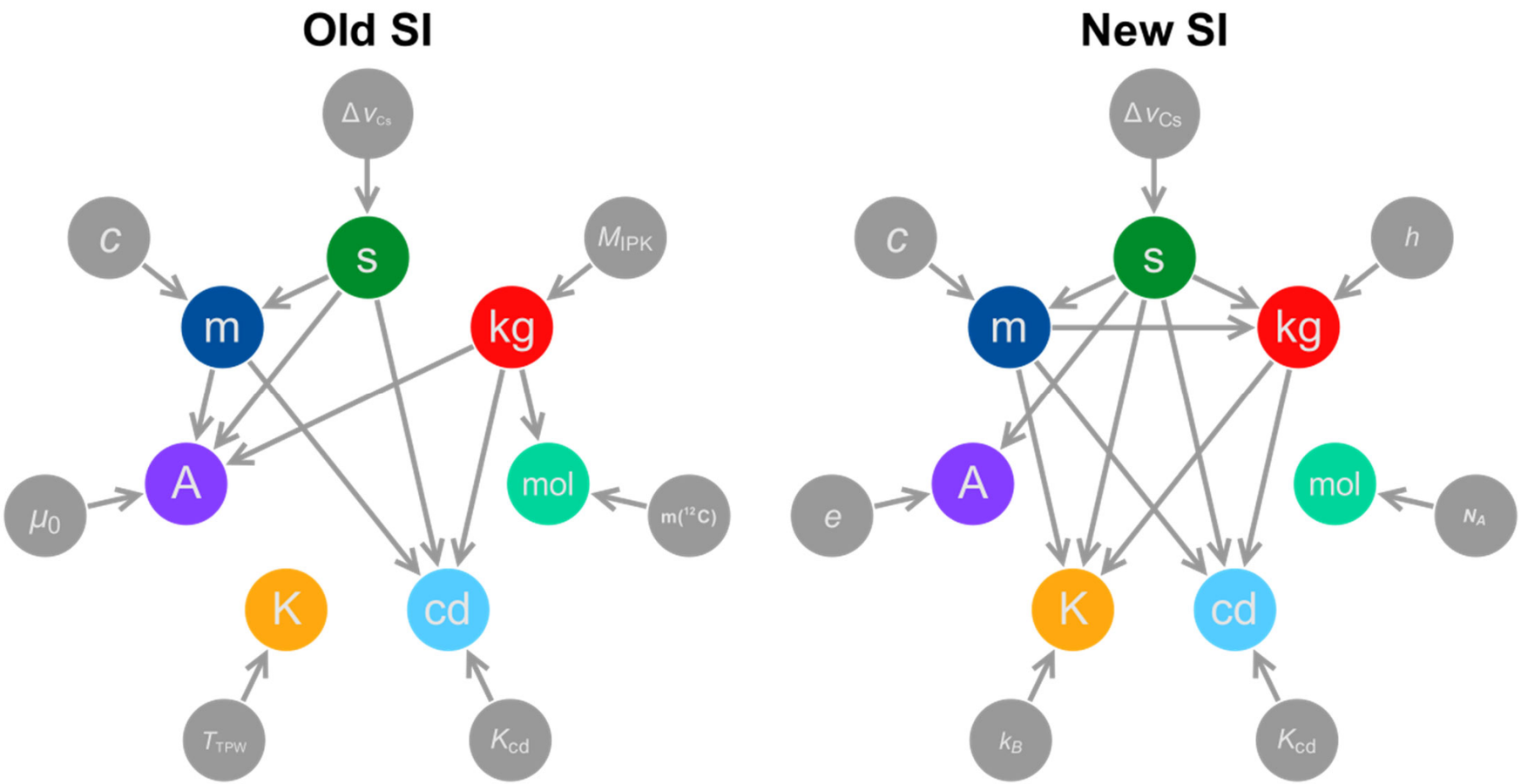
```
schedule(job, noonToday, 86400000);
```

- Problem?
  - Not every day has 24 hrs!
  - Daylight savings ==> a day can be 24, 23, or 25 hours long

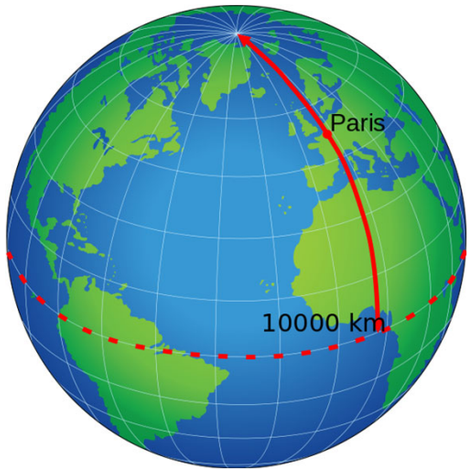
From Intervals to Points: Limitation

- Measure interval from a fixed point
  - Choice of origin defines an *epoch*
  - Needed for both date (BC/AD) and time
- Unix: chose Jan 1, 1970
  - `long time_t`, count of elapsed seconds
  - What time is it? Answer: 1,732,566,946
    - See http://www.unixtimestamp.com
  - Stored as a (signed!) 32-bit integer
    - max time = ½ (2^{32}-1) = 2.1 billion = 68 years!
- Will overflow on Jan 19, 2038
- Solution: use 64 bit!
  - Postpones the problem for 290 billion years…

SI Units: Changed Nov 16, 2018



Definition of a Meter

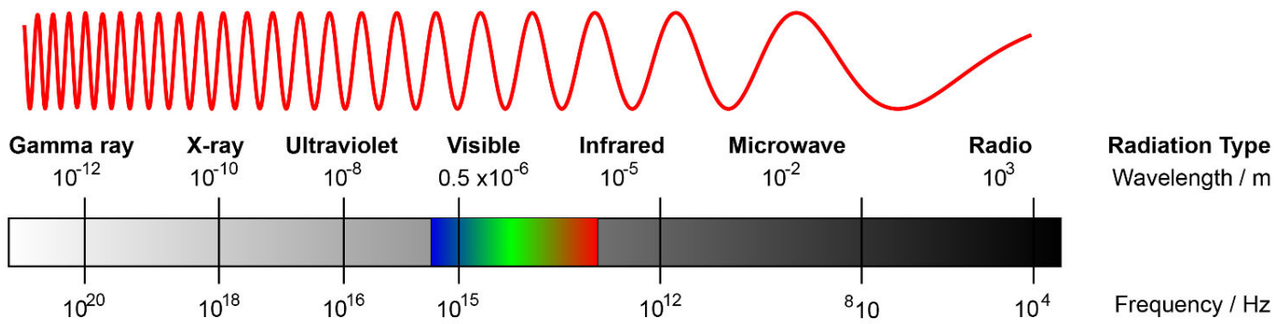


1793

1799

1960

1983



$c = 299\ 792\ 458\ m\ s^{-1}$

Definition of a Kilogram

1795

1889

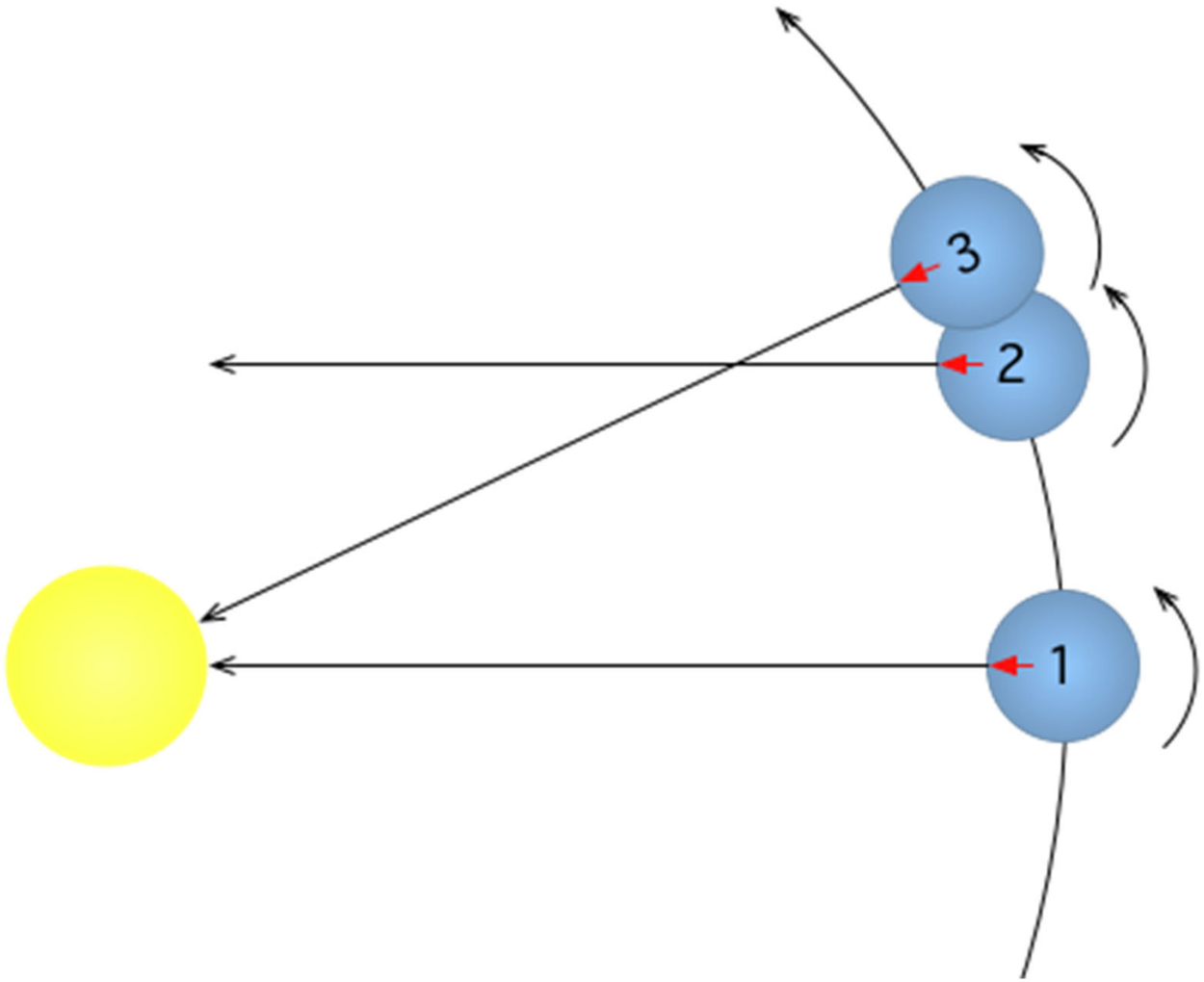
2019

h = 6.626 070 040(81) x10^{-34} kg m^2/s
h = 6.626 070 040 x10^{-34} kg m^2/s

Seconds, Minutes, Hours, Days

- Days *do not* divide years evenly
  - About 365.242199 days/year
- But seconds *do* divide days evenly!
  - Exactly 24 * 60 * 60 = 86,400 s/day
- Why?
  - Days & years are set independently by nature
  - Seconds are our invention
- How long is a second?
  - Defined to be 1/86,400th of a day
  - SI second = 9,192,631,770 oscillations of a caesium-133 atom (at rest, sea level, 0 Kelvin)
  - Just one problem… how long is a day?

Problem: Solar / Sidereal Day

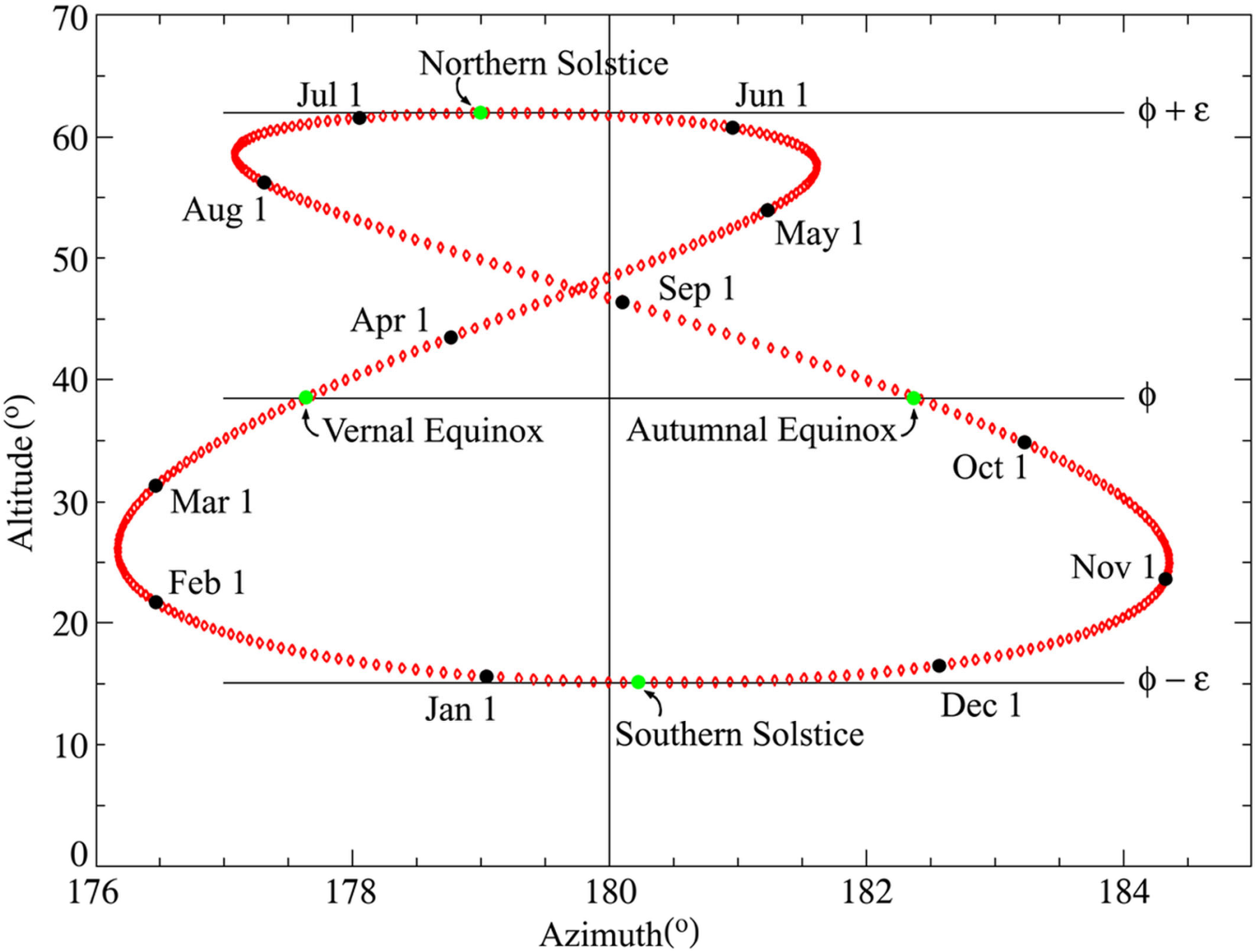


Problem: Apparent / Mean Solar

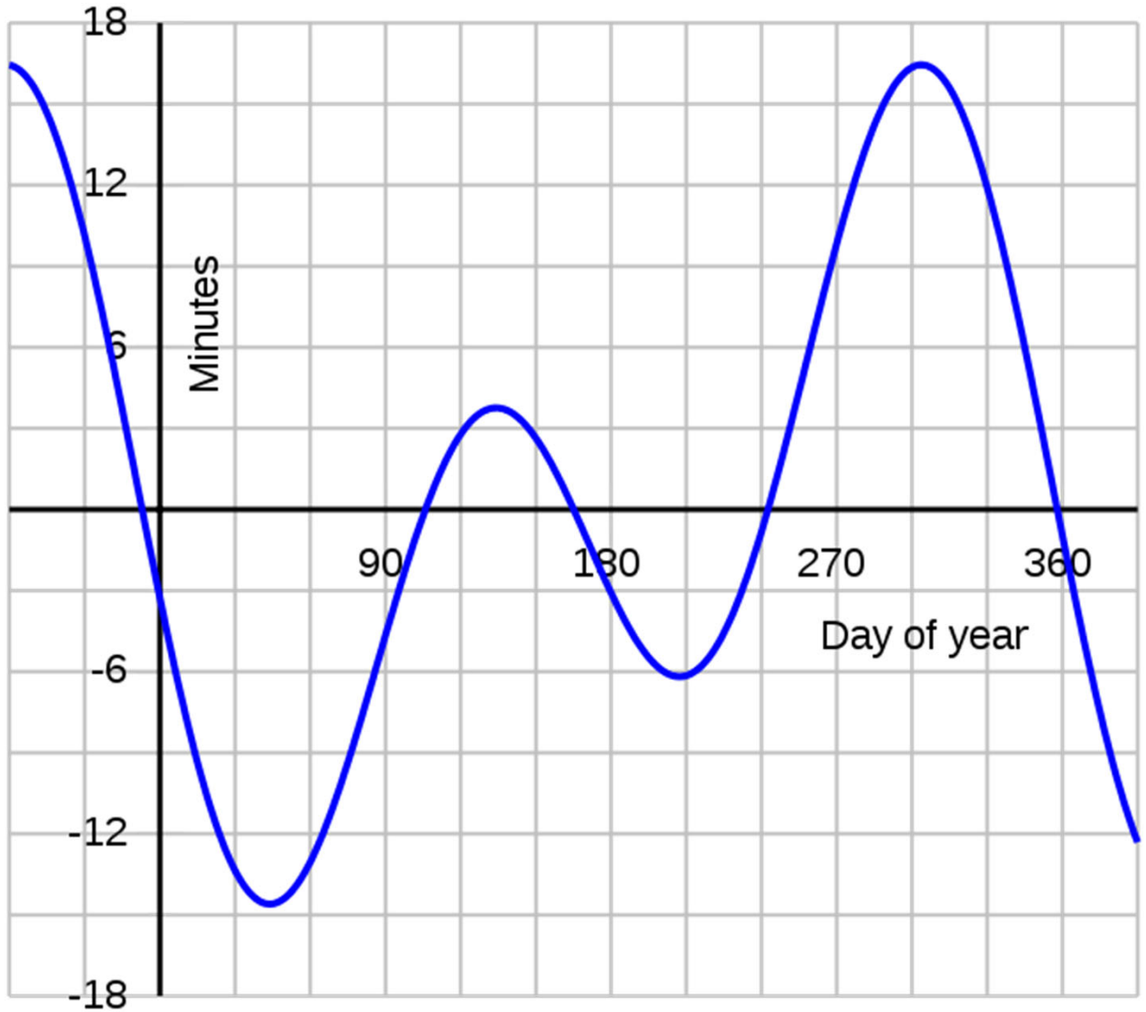
- We are closest to the sun in winter
  - Speed of orbit ∝ distance to sun
- Also, Earth's axis is tilted
  - Sun (appears to) move along ecliptic
  - But Earth rotates along celestial equator
- Result: Each apparent solar day (24 hrs?) varies in length!
  - Can be +/- 30 *seconds* of average length
- Even worse: Variation is correlated!
  - Long days are consecutive during the year
  - Difference (local noon vs watch) accumulates
- Result: Net difference of +/- 15 *minutes*

Analemma: Murray Hill, NJ

https://en.wikipedia.org/wiki/Analemma


Northern Solstice
Jul 1
Jun 1
ϕ + ε
Aug 1
May 1
Sep 1
Apr 1
ϕ
Vernal Equinox
Autumnal Equinox
Oct 1
Mar 1
Nov 1
Feb 1
Jan 1
Dec 1
ϕ − ε
Southern Solstice
Altitude (°)
Azimuth(°)
70
60
50
40
30
20
10
0
176
178
180
182
184

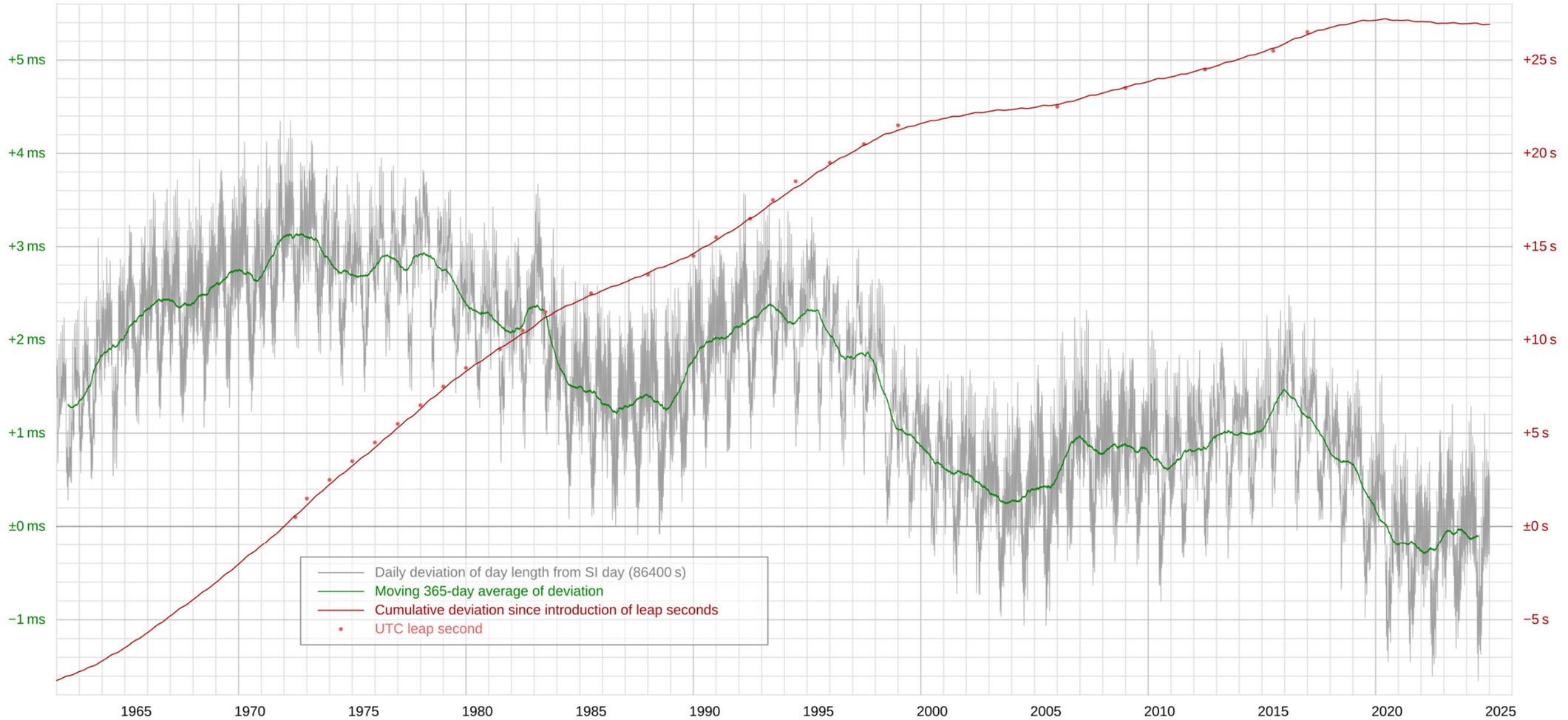
Equation of Time



Do We Care?

- The equation of time lets you correctly convert time to/from position of sun
  - At what time will be “local noon” today?
  - See: www.timeanddate.com/sun
- This only matters if you care about the *exact* position of the sun any given day!
  - Eg sundials and sextants
  - So (mostly) no one cares
- All we need is *average* length of full day
  - A *mean solar day*
  - Horizontal axis in graph of equation of time
  - Measure it, super accurately, then divide by 86,400

Now For the *Really* Bad News



The Earth has Slowed Down

- Planet has been slowing down (and will continue to slow down)
- Today's mean solar day is *longer* than it was 200 years ago!
  - We use the mean solar day of 1750-1892 (averaged)
- Bad news: There are a bit more than 86,400 SI seconds / mean solar day
- *Really* bad news: We can't predict the size of this effect very far into future

Leap Seconds

- Mean solar day is longer than 86,400 SI seconds
  - Tidal forces have slowed the rotation of the earth
  - Must correct clock time to stay synched with solar days
- Leap second: 1 second insertion/deletion
  - Irregular occurrence, UTC decides
  - Based on observation, impossible to predict
  - Since 1972, there have been 27 additions, no deletions
  - Most recent: Dec 31, 2016 (an addition)

Leap Second Episodes

Year	Jun 30	Dec 31
1972	+1	+1
1973	0	+1
1974	0	+1
1975	0	+1
1976	0	+1
1977	0	+1
1978	0	+1
1979	0	+1
1980	0	0
1981	+1	0
1982	+1	0
1983	+1	0
1984	0	0
1985	+1	0
1986	0	0
1987	0	+1
1988	0	0
1989	0	+1
1990	0	+1
1991	0	0
1992	+1	0
1993	+1	0
1994	+1	0
1995	0	+1
1996	0	0
1997	+1	0
1998	0	+1
1999	0	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
2004	0	0
2005	0	+1
2006	0	0
2007	0	0
2008	0	+1
2009	0	0
2010	0	0
2011	0	0
2012	+1	0
2013	0	0
2014	0	0
2015	+1	0
2016	0	+1
2017	0	0
2018	0	0
2019	0	0
2020	0	0
Year	Jun 30	Dec 31
Total	11	16
	27	
Current TAI − UTC		
37		

1 minute ≠ 60 seconds

- Addition (removal) occurs during the last minute of Dec 31 or Jun 30
- Those minutes have 61 (59) seconds!

  23:59:58, 23:59:59, 23:59:60, 00:00:00…
- Screen capture of the clock at time.gov during a leap second:

GMT vs UT1 vs UTC

- GMT: Greenwich mean time
  - Antiquated: Should not be used today
- UT1: Universal time
  - Time at prime meridian
  - Determined by celestial movements
- TAI: Atomic time
  - Was equal to UT1 in 1958
  - Ticks in SI seconds
- UTC: Universal Coordinated Time
  - Ticks in SI seconds, like TAI
  - Periodically *modified* to match UT1

More Complications

- GPS satellites don’t reset their clocks
  - GPS time was equal to UTC time in 1980
  - Since then, has missed 18 leap seconds
  - http://leapsecond.com/java/gpsclock.htm
- Unix time *decrements* during leap second
  - Monotonic timer provided by NTP protocol
- Not all countries have adopted UTC
- Leap seconds will become more frequent
  - Proposals to abolish, replace with leap *hours*
  - Revisited on Nov 18 2022…

We're Still Figuring This Out

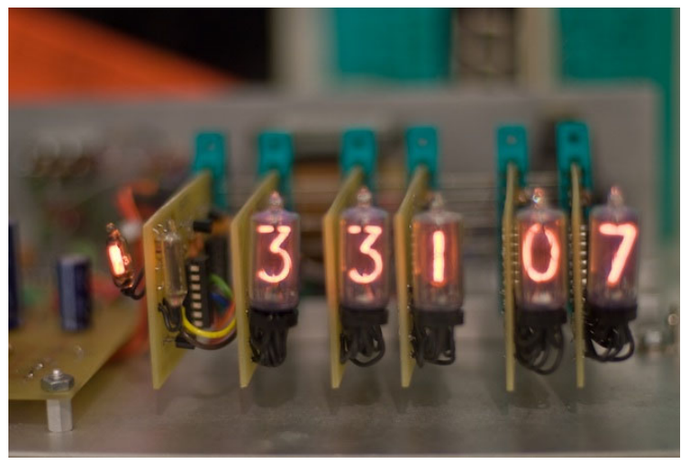
- Nov 2022: Bureau of Weights & Measures
  - Pause leap seconds until 2035
- UT1 and UTC will be allowed to diverge by more than 1 second!
- By 2035, we'll figure out whether/how to do future adjustments
  - Wait millenia, then leap by an hour?
  - Wait centuries, then leap by a minute?
  - Adjust continuously (a time "smear") instead of discrete jump?
  - Don't adjust at all?

And we care because…

WIRED GEAR SCIENCE ENTERTAINMENT BUSINESS SECURITY DESIGN OPINION VIDEO INSIDER MAGAZINE SUBSCRIBE

The Inside Story of the Extra Second That Crashed the Web

BY ROBERT MCMILLAN AND CADE METZ 07.02.12 7:54 PM

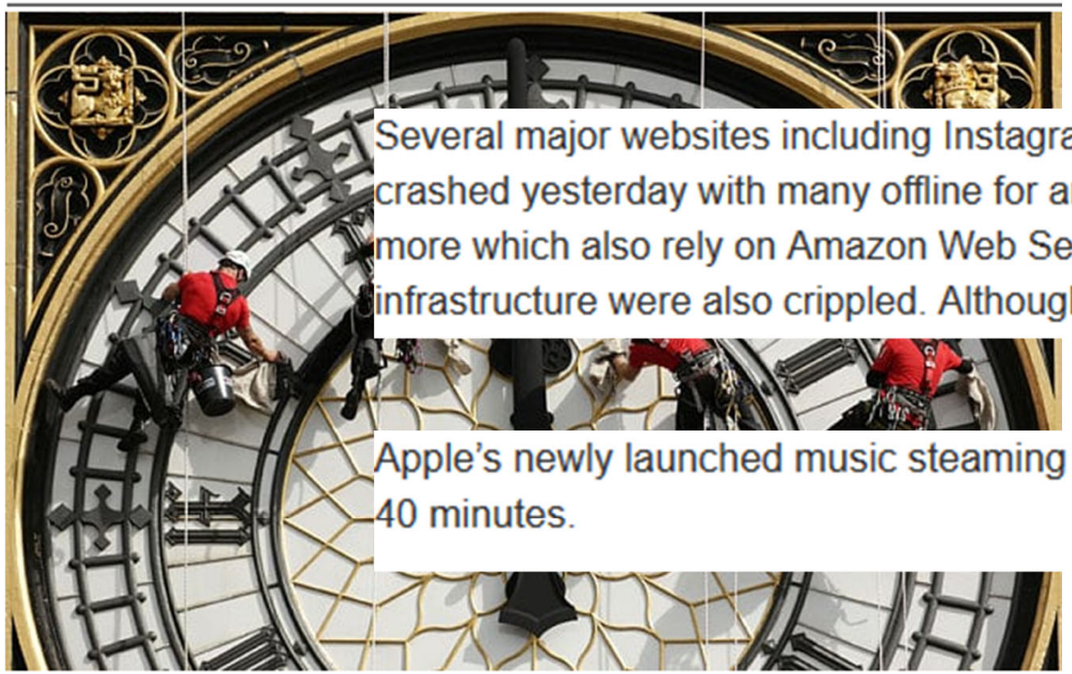


And We Still Care Because…

HOME » NEWS » SCIENCE » SCIENCE NEWS

Leap Second confuses Twitter and Android

Users reported problems with Android and Twitter as the leap second was added to atomic time



Several major websites including Instagram, Pinterest, Netflix and Amazon crashed yesterday with many offline for around 40 minutes. Thousands more which also rely on Amazon Web Services (AWS) software for their infrastructure were also crippled. Although AWS originally told NBC news

Apple's newly launched music steaming services Beats 1 also crashed for 40 minutes.

Twitter users were among those who encountered issues with the leap second Photo: PA

By Sarah Knapton, Science Editor

10:20AM BST 01 Jul 2015

Follow 7,998 followers

Summary

- Intervals vs points
  - Intervals are easy, points are tricky
  - Unix time: Seconds from 01/01/1970
  - Date/time is coupled to geolocation
- Interval between 2 points is hard
  - # days / year can vary
  - # hours / day can vary
  - # seconds / minute can vary
- Standardization
  - Mean solar day, SI seconds
  - They don't match: need leap seconds
- GMT, UT1, UTC, TAI