

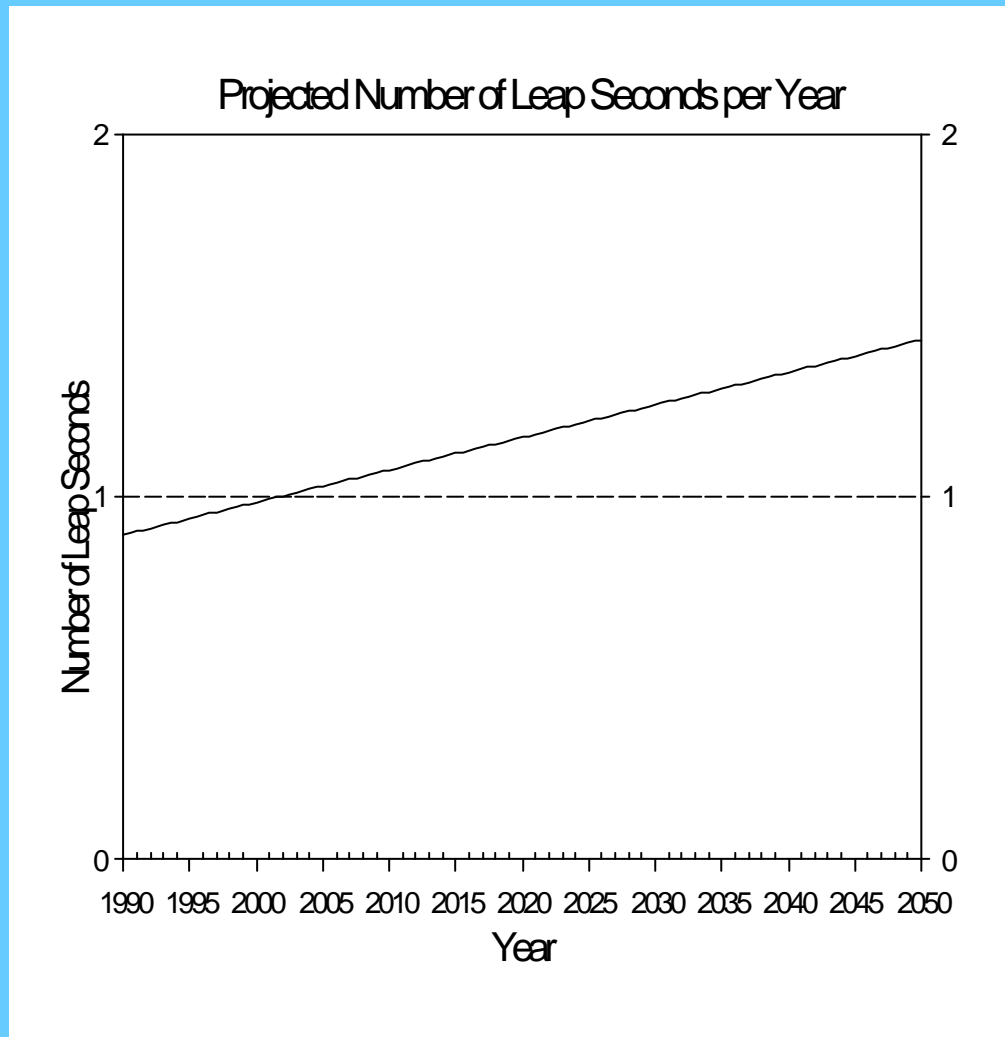
Some Options for the Future Definition of UTC

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Options

- Status quo
- Increase tolerance for $|\text{UTC}-\text{UT1}|$
- Smooth over the leap second step
- Conventional adjustment of UTC
 - Conventional date (every leap year, every ten years,...), unknown number
 - Conventional date and number based on deceleration model
- Discontinue leap seconds
- Use TAI
- Re-define second
- Low-accuracy conventional UT1 time scale (UT1C?)

Status Quo

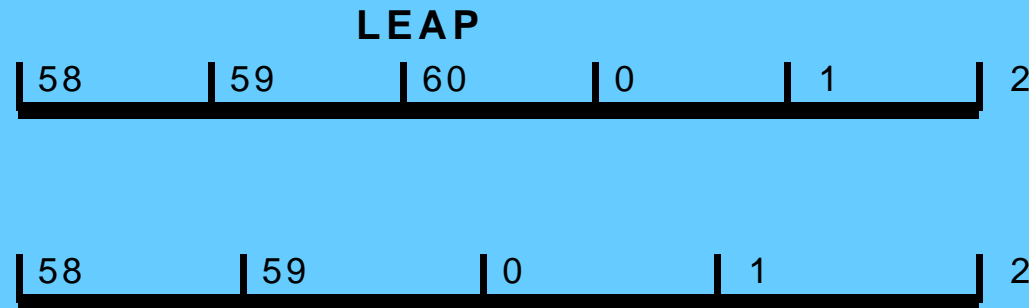


- **Pro:**
 - No changes required
 - Minimize concerns of software engineers
- **Con:**
 - Frequency of leap seconds increasing
 - Possible communications, software problems
 - Possible growth of systems based on independent time scales

Increase Tolerance for |UTC-UT1|

- **Pro**
 - Easy to accomplish
- **Con**
 - Larger discontinuities
 - DUT1 code limitations
 - Date of adjustment unpredictable
 - What is an acceptable limit?

Smooth Over Leap Second Step



- **Pro**
 - Eliminates the “extra” second
- **Con**
 - Requires seconds of different lengths
 - Date of adjustment unpredictable
 - Implementation?

Conventional Adjustment of UTC

- Unknown number of leap seconds at predictable intervals

- **Pro**

- » Date of adjustment is predictable

- **Con**

- » Number of leap seconds remains unpredictable
 - » Large discontinuities possible
 - » $|\text{UTC}-\text{UT1}| \gg 1$

- Known number of leap seconds at predictable intervals

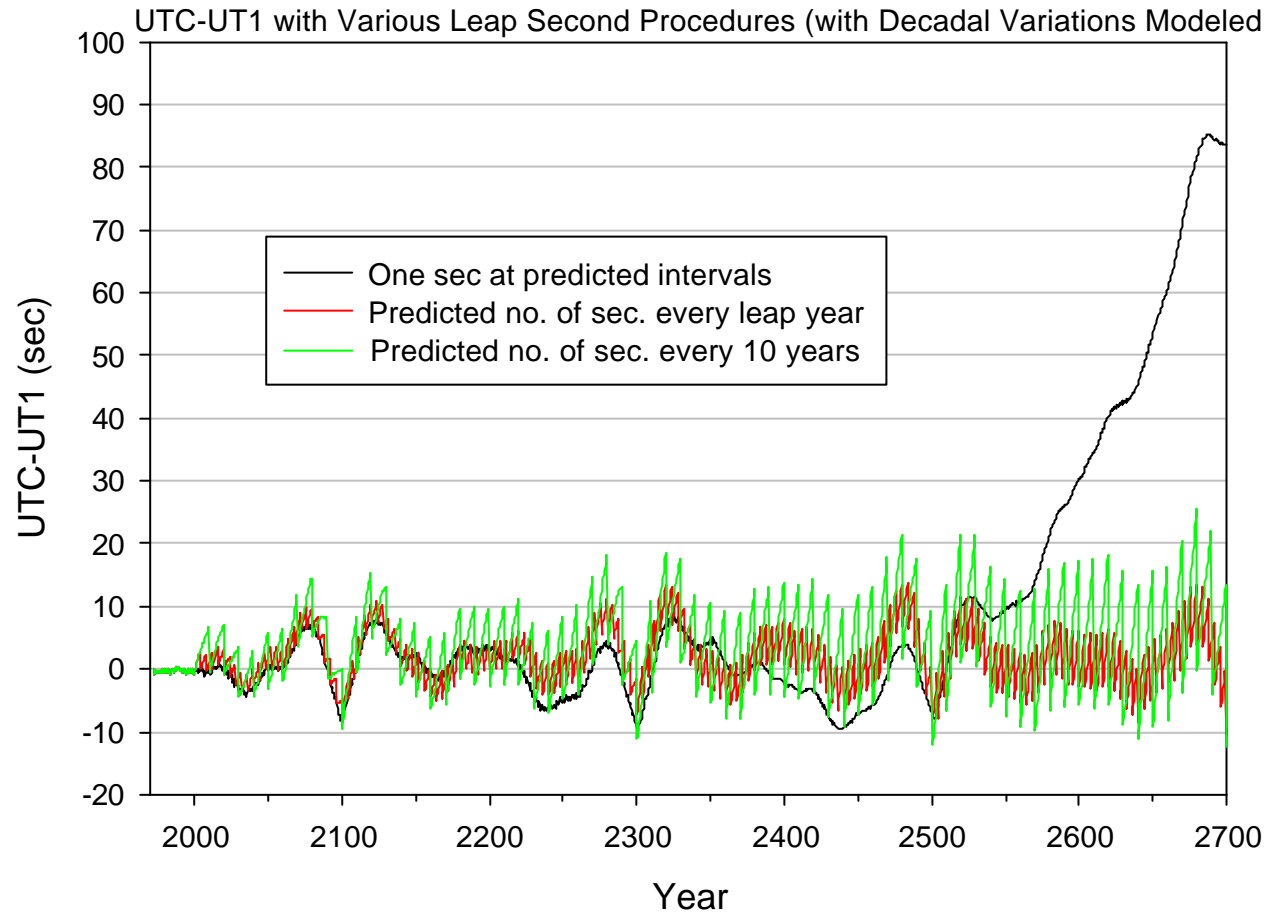
- **Pro**

- » Date of adjustment and number of leap seconds predictable
 - » Available for ephemerides

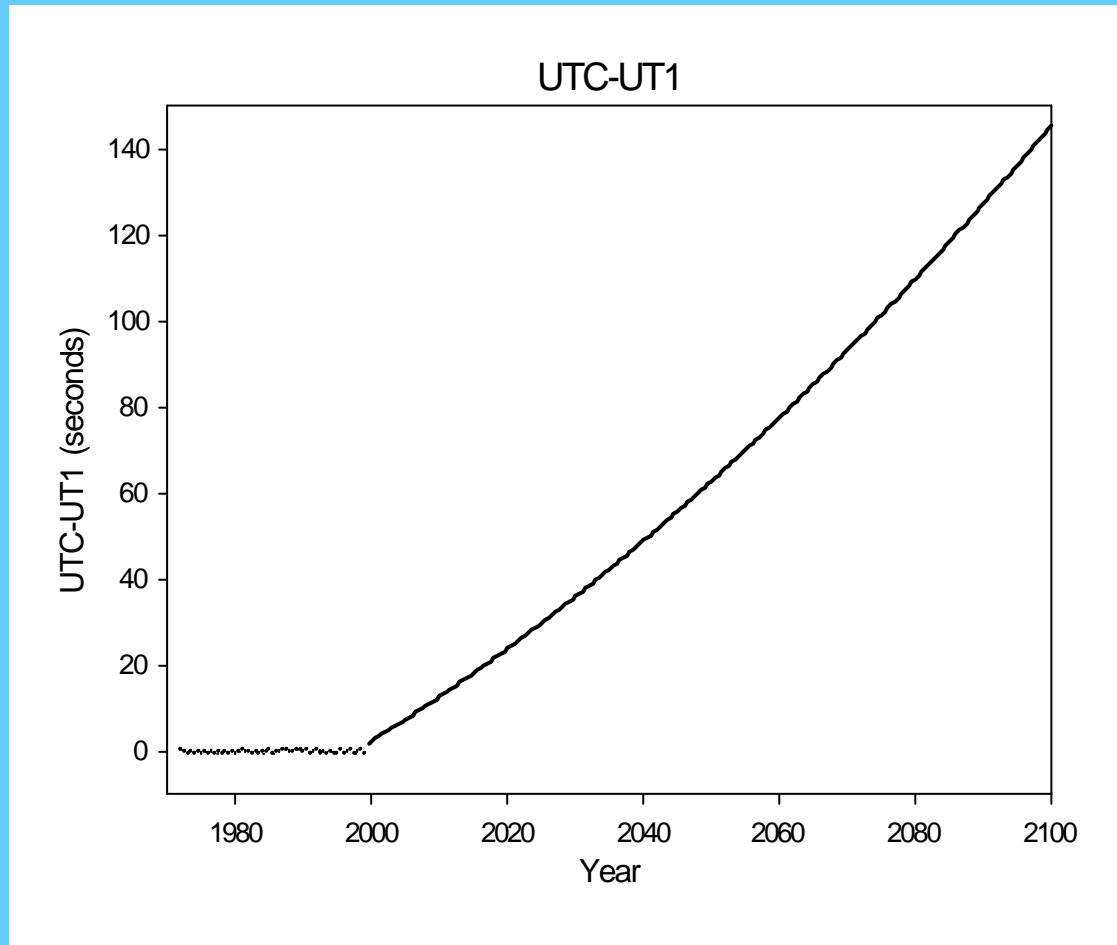
- **Con**

- » Large discontinuities possible
 - » $|\text{UTC}-\text{UT1}| \gg 1$

Conventional Adjustment of UTC



Discontinue Leap Seconds



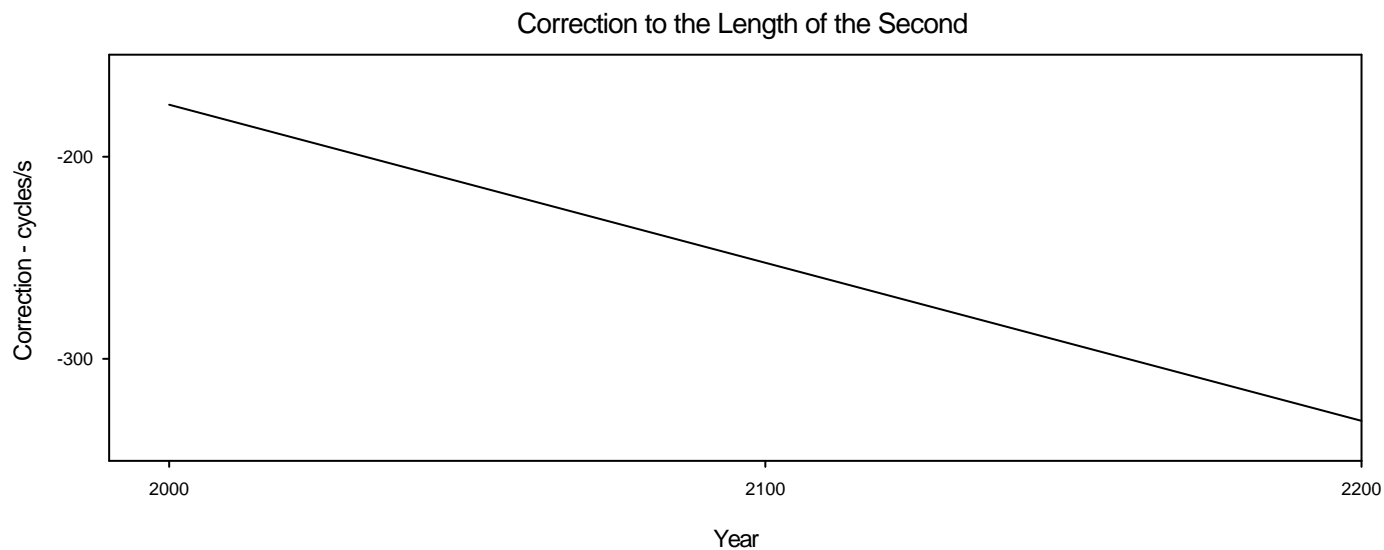
- **Pro:**
 - Eliminate causes for concern
- **Con:**
 - Unlimited growth of $|\text{UTC-UT1}|$
 - Two time scales separated by constant bias?

Use TAI

- Similar to elimination of leap seconds
- TAI must be more accessible
- **Pro:**
 - Eliminate causes for concern
- **Con:**
 - TAI must be more accessible
 - Legal definitions of time?

Redefine the Second

- **Pro**
 - Fundamental Solution
- **Con**
 - Require redefinition of physical units
 - Temporary solution



Low-accuracy UT1

- UT1C
- Approximation to UT1
- Distributed by Network Time Protocol (NTP), coded signal, ...

CONCLUSION

- Status Quo
- Change Current Definition
 - Increase tolerance for $|\text{UTC}-\text{UT1}|$
 - Smooth over the leap second step
 - Conventional adjustment of UTC
 - Every leap year? Every 10 years?
 - Predict leap seconds based on deceleration model
 - Low-accuracy Conventional UT1Time Scale
- Effectively Switch to Strict Atomic Time
 - Discontinue leap seconds
 - Use TAI or redefined UTC
 - Re-define second
 - Low-accuracy Conventional UT1Time Scale

BACKUPS

Definition of Seconds

- Rotational Second
 - 1 / 86,400 of mean solar day
- Ephemeris Second
 - First used in 1956
 - $1/31,556,925.9747$ of tropical year 1900
 - Length of year based on 19th century astronomical observations

Atomic Second

- SI second: 9,192,631,770 periods of the radiation corresponding to the transition between 2 hyperfine levels of the ground state of the Cesium 133 atom (adopted 1964)
- Realizes the Ephemeris Second
- Frequency based on lunar observations from 1954.25 to 1958.25

SI second preserves the rotational second of mid-nineteenth century

Time Scales

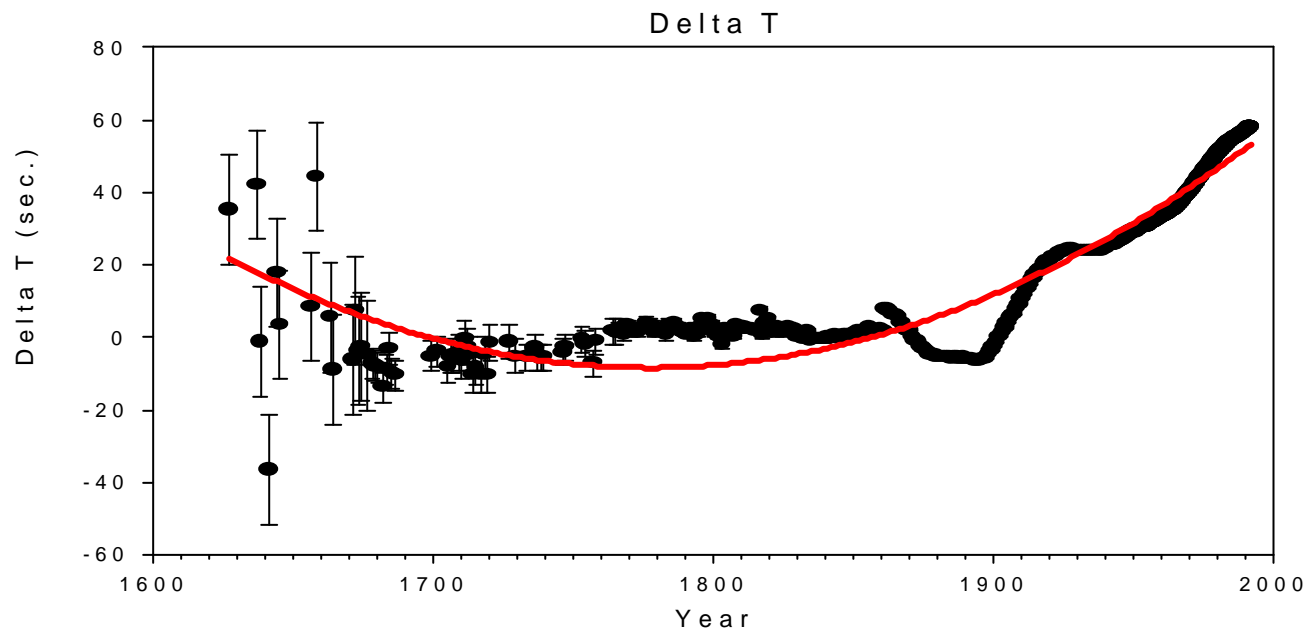
- Rotational
 - UT1 is modern realization of historical astronomical time scales including
 - Mean Solar Time
 - Greenwich Mean Time
 - Greenwich Civil Time
 - Universal Time (without suffixes)
 - Weltzeit

Time Scales (continued)

- Atomic
 - TAI (International Atomic Time)
 - Follow-on from
 - A.1 (maintained at USNO with input from 9 other laboratories originally. - now only USNO)
 - AM (at BIH with input from many laboratories)
 - A3
 - at BIH with input from 3 best laboratories
 - became AT (or TA) in 1969, TAI in 1971
 - others
 - All atomic time scales were made equal to UT1 corrected for seasonal effects on 1 Jan 1958 0h 0m 0s
 - may be considered modern realization of Ephemeris Time (offset in epoch)

Earth Rotation

- Well documented deceleration
 - Tidal
 - Change in figure

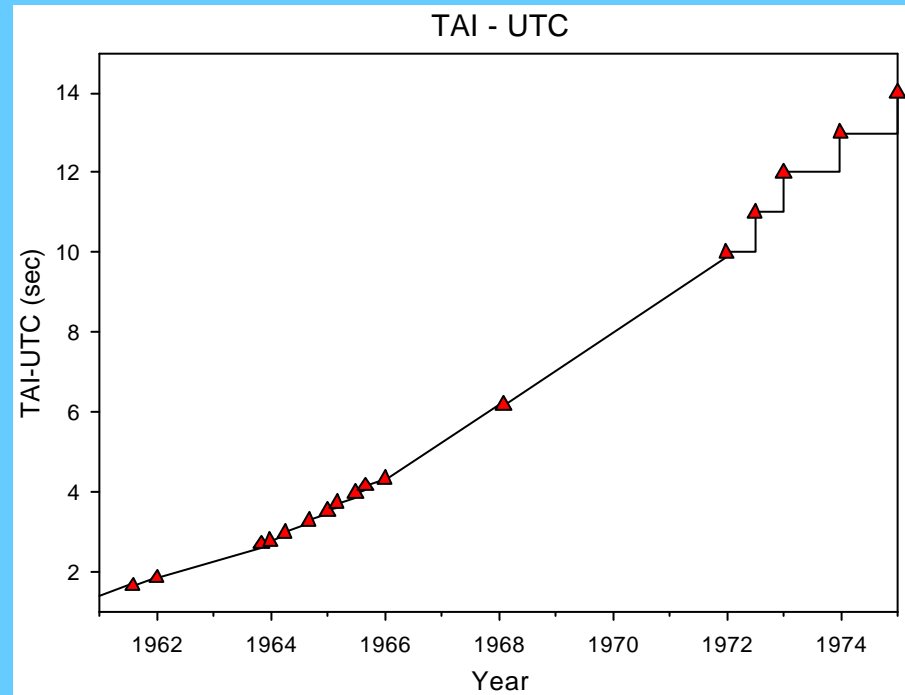
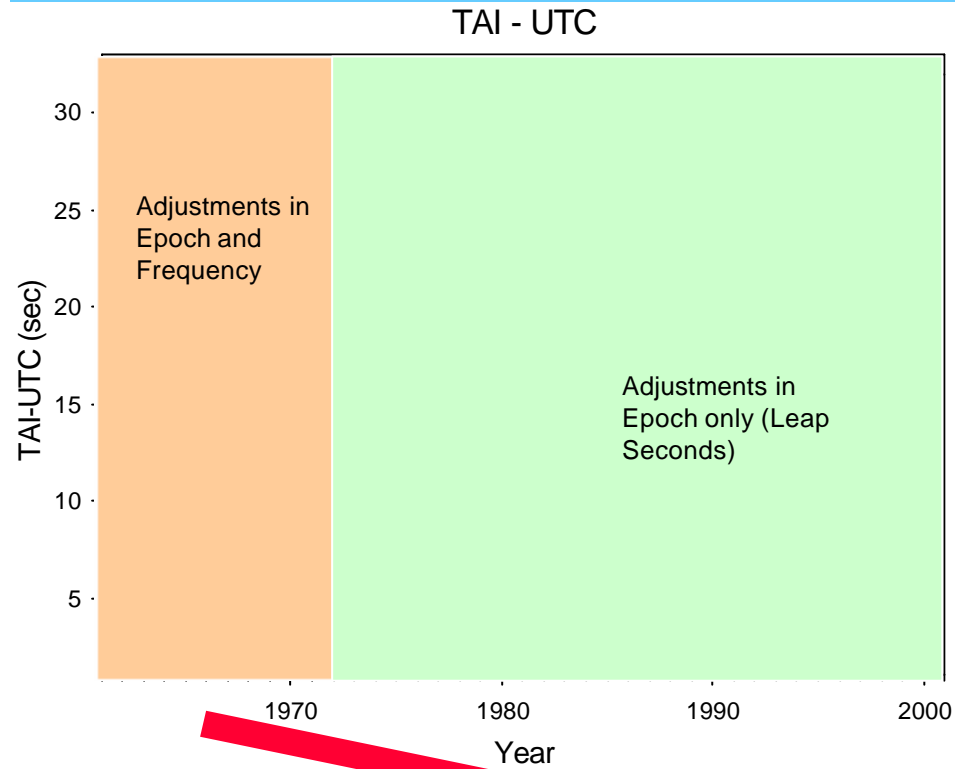


Historical Answers

- UTC (Coordinated Universal Time)
 - Begun in 1960 as cooperative effort of U.S. Naval Observatory and Royal Greenwich Observatory to make coordinated changes to clocks
 - in 1965 BIH defined UTC with respect to atomic time
 - Epoch and frequency adjusted to match UT1 corrected for seasonal variations
- Current UTC adopted beginning in 1972
 - no changes in frequency
 - leap seconds so that $|\text{UTC}-\text{UT1}| < 0.9 \text{ s}$

UTC consistent with previous definitions of legal time

TAI-UTC



Causes for Concern

- Frequency of leap seconds increasing
 - Increasing public annoyance
- Software issues
 - Unpredictable
 - Continuous second counts: days with 86,401 seconds
 - Time stamping 23h 59m 60s
- Communications problems
 - coordination of events during a leap second
- Growth of systems based on independent time scales

Things to Consider

- Navigation
 - 1 second = 1/4 mile at the equator
- Computer software
 - Continuous second counts? 61-second minute?
- Communications
 - Maintain synchronization over the leap second?
- Legal definitions
 - Mean solar time?
- Religious observances
 - Sunrise, noon, sunset?

What to do?

- Question needs study
 - URSI
 - IAU
 - ITU-R