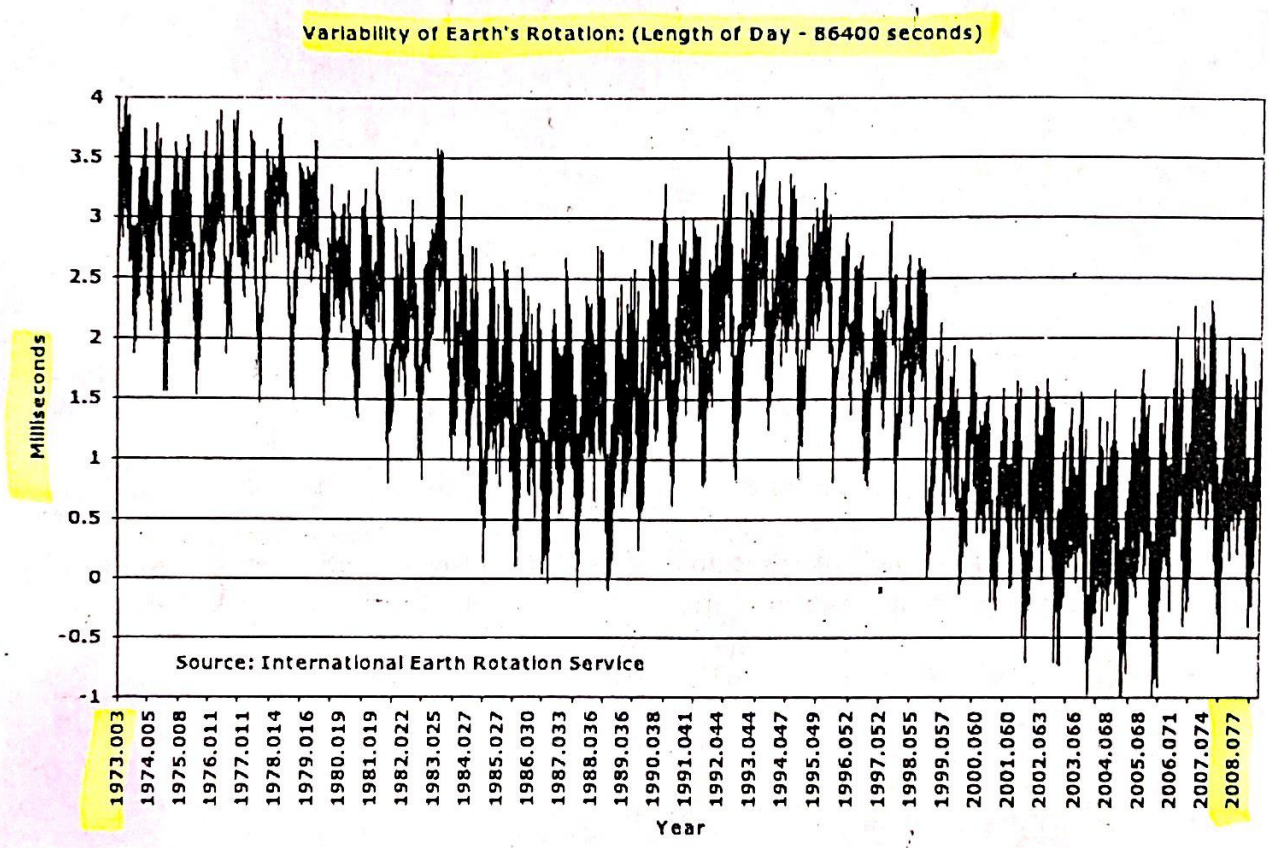
Systems of Time

"Now let me see," the Golux said. "If you can touch the clocks and never start them, then you can start the clocks and never touch them. That's logic, as I know and use it...."
-- James Thurber, "The 13 Clocks"

- **Atomic Time**, with the unit of duration the *Systeme International (SI) second* defined as the duration of 9,192,631,770 cycles of radiation corresponding to the transition between two hyperfine levels of the ground state of cesium 133. **TAI** is the International Atomic Time scale, a statistical timescale based on a large number of atomic clocks.
- **Universal Time (UT)** is counted from 0 hours at midnight, with unit of duration the *mean solar day*, defined to be as uniform as possible despite variations in the rotation of the Earth.
  - **UT0** is the rotational time of a particular place of observation. It is observed as the diurnal motion of stars or extraterrestrial radio sources.
  - **UT1** is computed by correcting UT0 for the effect of polar motion on the longitude of the observing site. It varies from uniformity because of the irregularities in the Earth's rotation.
- **Coordinated Universal Time (UTC)** differs from TAI by an integral number of seconds. UTC is kept within 0.9 seconds of UT1 by the introduction of one-second steps to UTC, the **"leap second."** To date these steps have always been positive. UTC has replaced Greenwich Mean Time (GMT) as an international standard.
- **Dynamical Time** replaced *ephemeris time* as the independent argument in dynamical theories and ephemerides. Its unit of duration is based on the orbital motions of the Earth, Moon, and planets.
  - **Terrestrial Time (TT)**, (or Terrestrial Dynamical Time, **TDT**), with unit of duration 86400 SI seconds on the geoid, is the independent argument of apparent *geocentric* ephemerides. TDT = TAI + 32.184 seconds.
  - **Barycentric Dynamical Time (TDB)**, is the independent argument of ephemerides and dynamical theories that are referred to the *solar system barycenter*. TDB varies from TT only by periodic variations.
- **Geocentric Coordinate Time (TCG)** is a *coordinate time* having its spatial origin at the center of mass of the Earth. TCG differs from TT as: TCG - TT = Lg x (JD -2443144.5) x 86400 seconds, with Lg = 6.969291e-10.
- **Barycentric Coordinate Time (TCB)** is a *coordinate time* having its spatial origin at the solar system barycenter. TCB differs from TDB in rate. The two are related by: TCB - TDB = iLb x (JD -2443144.5) x 86400 seconds, with Lb = 1.550505e-08.
- **Sidereal Time**, with unit of duration the period of the Earth's rotation with respect to a point nearly fixed with respect to the stars, is the *hour angle of the vernal equinox*.

Delta T is the difference between Earth rotational time (UT1) and dynamical time (TDT). Predicted values of **UT1 - UTC** are provided as an **Earth Orientation Product**. An example showing the variation of the length of the day to late 2008 is shown below. Units are milliseconds.

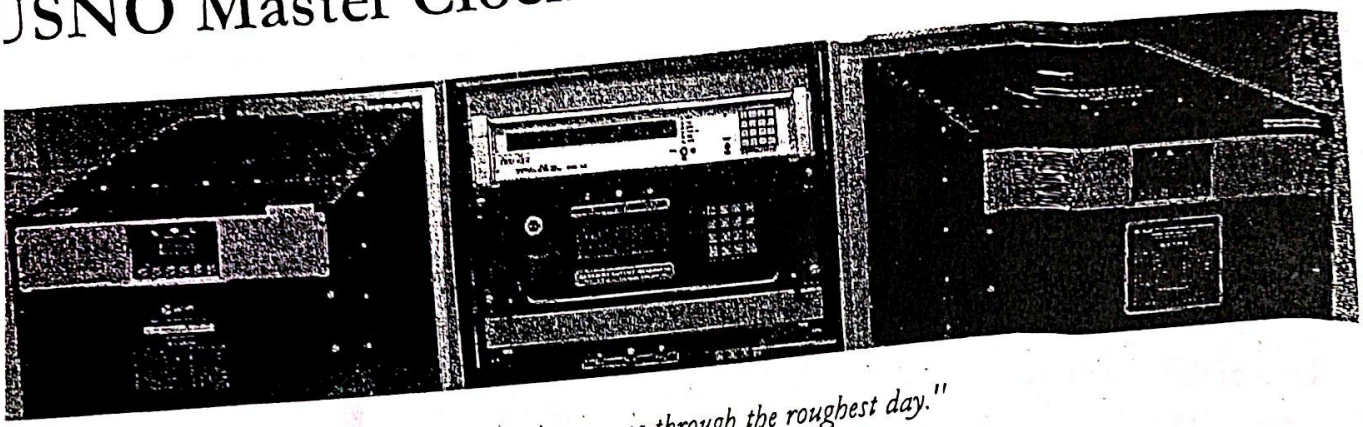


Julian Day Number is a count of days elapsed since Greenwich mean noon on 1 January 4713 B.C., Julian proleptic calendar. The **Julian Date** is the Julian day number followed by the fraction of the day elapsed *since the preceding noon.*

We frequently make use of the **Modified Julian Date (MJD)**, which is defined as MJD = JD - 2400000.5. An MJD day thus begins and ends at midnight. Julian dates can be expressed in UT, TAI, TDT, etc. and so for precise applications the timescale should be specified, *e.g.* MJD 49135.3824 TAI.

To see the current MJD, click this link: MJD

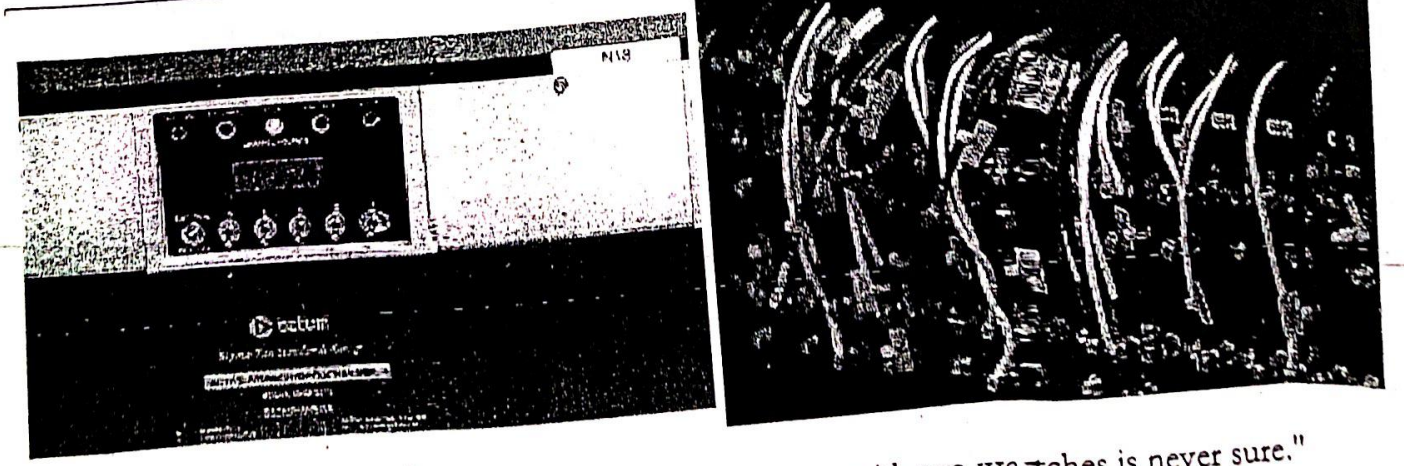
JSNO Master Clock Description



"Time and the hour runs through the roughest day."
-- W. S.

The U.S. Naval Observatory (USNO) is charged with the responsibility for precise time determination and management of **time dissemination**. Modern electronic systems, such as electronic navigation or communications systems, depend increasingly on precise time and time interval (PTTI). Examples would be the ground-based LORAN-C navigation system and the satellite-based Global Positioning System (GPS). These systems are based on the travel time of the electromagnetic signals: an accuracy of 10 nanoseconds (10 one-billionths of a second) corresponds to a position accuracy of 10 feet. In fast communications, time synchronization is equally important. All of these official systems are referenced to the **USNO Master Clock**

The present **USNO Master Clock** is based on a system of dozens of independently operating **cesium atomic clocks** and a dozen **hydrogen maser clocks**.



"A man with a watch knows what time it is. A man with two watches is never sure."
-- Segal's Law

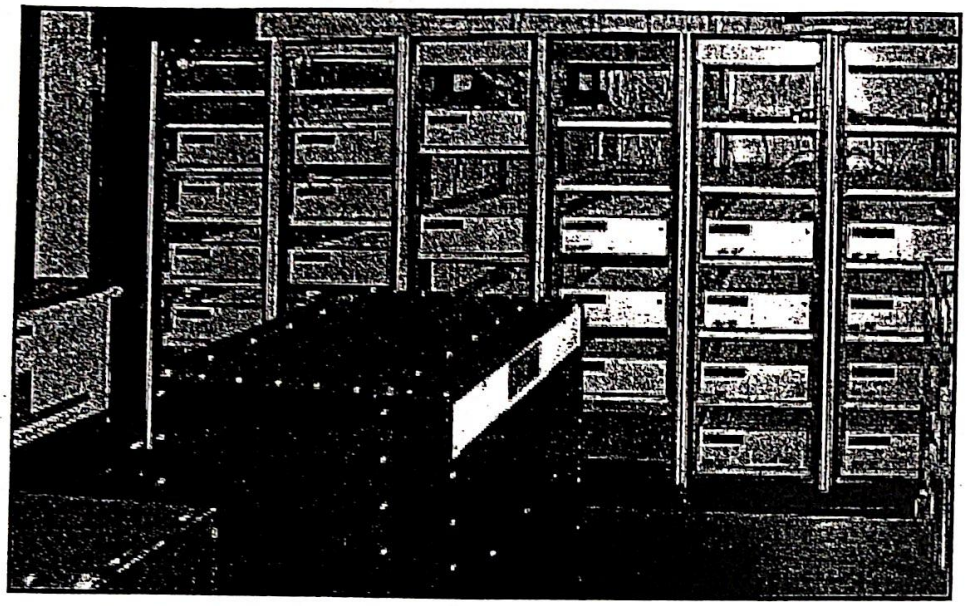
To find out how many cesiums and H-masers are currently in the USNO mean timescale, click:

How Many Clocks?

These clocks are distributed over 20 environmentally controlled clock vaults, to ensure their stability. By automatic intercomparison of all clocks *every 100 seconds*, the **USNO time scale** can be computed which is not only reliable but also extremely stable. Its rate does not change by more than about 100 *picoseconds* (0.000 000 000 1 seconds) per day from day to day.

On the basis of this computed time a clock reference system can be steered to produce clock signals which serve as the USNO Master Clock. The clock reference system is driven by a hydrogen maser atomic clock. Hydrogen masers are extremely stable clocks over short time periods (less than one week). They provide the stability, reliability and accessibility needed to maintain the accuracy of the Master Clock system.

USNO Master Clock



A USNO clock vault. Masers in the foreground, cesium beam clocks in the background.

The USNO Master Clock is the underlying product for all of our precise time and time interval products. The timing reference produced by this timing ensemble is called UTC(USNO). This timing reference is mandated to be the precise time reference for all of the DoD.

- **USNO Master Clock Description**

  Technical information about the physical components that make up our timing ensemble.

- **USNO Time Scales**

  Descriptions of the time scales determined at USNO and their relationships.

- **International Time Scales and the BIPM**

  Information about the relationship between international time scales and the USNO products. This section includes data files and plots of these time scales.

- **Definitions of Systems of Time**

Definitions of systems for determining and referencing times. These range from atomic time scales to the rotation of the earth.