

The U.S. Naval Observatory

Master Clock

Dr. Demetrios Matsakis

1. **What** is time?
2. **What instruments** do we use?
3. What instruments are we preparing?
4. How do we compute time **from raw data**?
5. What improvements are we considering?



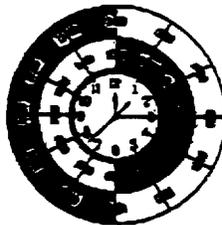
WHAT IS TIME?

“That coordinate which can be most simply related to the evolution of closed systems”

According to Webster's New Collegiate Dictionary:

“The measure or measurable period during which an action, process, or condition exists”

time /tīm/ n [OE; fr. OE *timē* akin to ON *tíma*; cf. OE *tíma* — more at TIDE] 1 a: the measured or measurable period during which an action, process, or condition exists or continues; DURATION b: a continuous which lacks spatial dimensions and in which events succeed one another from past through present to future c: MEASURING (~ for reading) 2: the point or period when something occurs; OCCASION 3: an appointed, fixed, or customary moment or hour for something to happen, begin, or end (arrived about 4 ~) 4 a: an historical period; AGE b: a division of geologic chronology c: conditions at present or at some specified period (~s are hard) (compare with the ~) d: the present time (Games of the ~) 5 a: LEPTON b: a period of apprenticeship c: a term of military service d: a prime minister 6: MASON (very lax for this ~ of year) 7 a: rate of speed; TEMPO b: the grouping of the beats of music; METRE 8 a: a moment, hour, day, or year as indicated by a clock or calendar (what ~ is it) b: any of various systems (as sidereal or solar) of reckoning time 9 a: one of a series of recurring instances or repeated actions (you've been told many ~s) b pl (1): multiple instances (the ~s are greater) (2): equal fractional parts of which an indicated number equal a whole (paralytic greater capacity (two ~s smaller) (three ~s slower) c: TUNE (three ~s at the C) 10: time as concerned with infinite duration 11: a person's experience during a specified period or on a particular occasion (a good ~) 12 a: the hours or days occupied by one's work (make up ~) b: an hourly pay rate (rough ~) c: wages paid at discharge or resignation (pick up your ~ and get out) 13 a: the playing time of a game b: TIME-OUT — at the same time; HOWEVER, NEVERTHELESS (glorify the equilibrium ideal and at the same time keep women in the subordinate role — Vance Packard) — at intervals; OCCASIONALLY — for the time being; for the present — from time to time; once in a while; OCCASIONALLY — in no time; in the shortest possible time — in time 1: sufficiently early 2: in the course of time; EVENTUALLY 3: at certain intervals (lets to ~ day in ~) — on time 1 a: at the appointed time b: on schedule 2: on the immediate plan — time and again; FREQUENTLY, REPEATEDLY

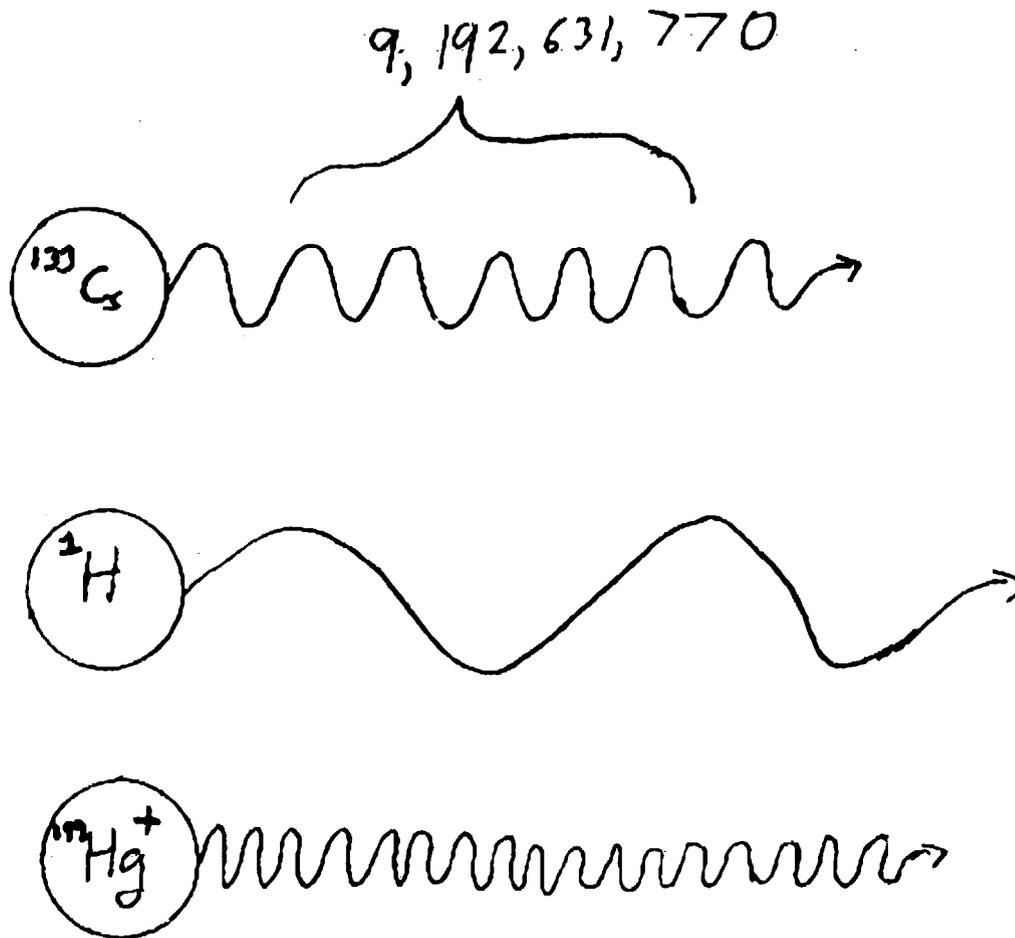


time 8b: a standard 12-hour dial surrounded by hands to show equivalent 24-hour time



Time as Defined by Measurement

“The second is the duration of 9,192,631,770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom, located on the geoid and in the absence of a magnetic field”



Multi-Cultural Time

I. Atomic Time

1. Free-running time scales: USNO(A. 1), **BIPM(EAL)**, NIST
2. **International Atomic Time (TAI)**
EAL steered towards primary frequency standards of the PTB and SU, **NIST-7**, and the **LPTF/OP/ENS** atomic fountain)
Computed every month in **5-day** points, and distributed about 2 weeks after the latest computed point.
3. Coordinated Universal Time (UTC)
UTC= TAI with leap seconds for variable Earth rotation
4. Real-time realizations of UTC
Steered time scales such as **UTC(USNO)**, **UTC(NIST)**
GPS time **steered** towards **UTC(USNO)**
5. **TT** (Terrestrial Time), TAT recomputed long after-the-fact, but offset by **32.184 seconds** for historical continuity with Ephemeris Time.

II. Relativistic Corrections

1. Terrestrial Dynamical Time (**TDT**), referenced to the geoid:
TDT = TT+32.184 seconds
2. Geocentric Coordinate Time (TCG), referenced to the Earth's center
3. **Barycentric** Coordinate Time (TCB), referenced to the solar system barycenter
4. The: **BAD GUY**: TDB, Barycentric Dynamical Time
Relativistic transformation to the solar system barycenter, but then the time coordinate is scaled so as to track TT. The result changes many physical constants, and the mass of the **solar** system bodies!



U. S . Naval Observatory

- * Defense timekeepers since 1830**
- * Serves GPS, LORAN, and more**
- * Largest contributor to international atomic time (TAI and UTC)**



STEERING OF USNO MASTER CLOCK TO UTC

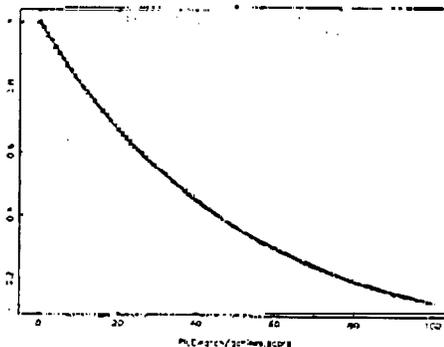
- * UTC is international standard
- * USNO Master Clock outputs **UTC(USNO)**
- * Enhances USNO Master Clock stability over **long** periods.
- * “Gentle” steering algorithms, so that time-transfer noise will
not degrade **USNO** Master Clock stability over short periods.



Master Clock Steering Algorithms

I. Historical

1. Generate a steered time scale by paper-steering of the unsteered time scale (A.1) so that it closely approximates UTC. Steered time scale has phase and frequency discontinuities with each monthly adjustment.
2. Steer a maser to that steered time scale once daily so that the steered maser output is **identical** differs from the steered mean in frequency by an amount **that** would **each** day reduce the difference between the steered maser's time and the steered mean by 1 part in 50.



II. Under consideration

1. Variations in the numerical values of the steering parameters.
2. Steered time scales based on only maser or cesium clocks
3. Gentler **parameterization** techniques, involving accelerating steers or steering a maser to an intermediate mean which itself is steered to the predictions of UK-A.1
4. Better ways to predict UTC vs A. 1

