What Time is IT, but What Does "IT" Mean?

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The goal of the clock maker has always been to be "accurate." It has been said: "A man with one clock knows what time it is; a man with two clocks is never sure." And, Lewis Carroll noted that a stopped clock is accurate at least twice a day.

Early Times

For most people living prior to the Industrial Age, a device for measuring the precise time was unnecessary. "What time is it?" was not a question posed, since one just took a look at the sky to "see" the correct time. Or, "I will meet you when the sun is there" (pointing to the sky) set the time with sufficient accuracy for appointments. While daylight time was fixed by a glance at the sun, the position of the stars marked the lonely watches of the night to anyone familiar with the night sky. But did anyone notice? The night-time was a non-time; there was no "lights out!" The difference between 11:00 PM and 3:00 AM was meaningless to 99% of the peoples who lived before the advent of electricity.[1] Even today, many of the world's peoples do not have an interest in nor need to know the precise time. They still view "time" as broad demarcations of daylight with little reference to a night-time. The circadian body-clock was sufficient to get people to bed at night and up in the morning!

The First Clocks

As societies changed, the need for a better accountability of time was being realized in time-telling devices, i.e., sundial. A number of cultures divided the day into segments. The Chinese divided a sun-cycle into 12 sections as did the Egyptians. The Babylonians added 12 segments to the night and came up with 24 segments (hours) in a whole day/night. This "24-hour" day became our modern method of reckoning time. One problem with the early definition of an "hour" was that the length of an hour varied with the position of the sun at different latitudes at different periods of the year. An "hour" could vary between 45 minutes to 75 minutes in length. Finally, Hipparchos, 2100 BCE, suggested that hours be determined at the equator. All hours would become 60 minutes at all times of the year. However, it wasn't until the invention of mechanical clocks that 60-minute hours became the norm.[2] Water clocks were more accurate than sundials, but time "leakage" and evaporation were surely problematic.

Mechanical Clocks

Clocks powered by mechanical means advanced the accuracy of time keeping. The first mechanical weight-driven clocks were developed in the 14th Century and consisted of falling weights. Because of their sheer size the clocks were housed in churches. These clocks did not display the time, as on a clock face; they chimed the time with bells. Mechanical clocks made a substantial improvement in accuracy and brought relatively precise 60-minute hours to the breakdown of a cyclical day. A hundred years later, coiled springs became the power source for mechanical clocks.[3] Spring-driven clocks not only were smaller, but they produced a greater accuracy down to the parts of hours or minutes.

In 1582, Galileo Galilei watched a lamp swing from a long rope in the Pisa Cathedral. He must have thought: I'll bet this will serve to power a clock. And so, in 1637 Galileo drew up the plans for using a swinging weight to control the speed of a clock mechanism. Although Galileo invented the first pendulum clock, he did not build one. It was not until 20 years later that, Christian Huygens built the first pendulum clock and thereby increased time-accuracy to an error rate of less than a minute per day. Pendulum clocks underwent a number of significant refinements, and by the 1920s they had achieved accuracy to a hundredth of a second a day.[4]

Quartz Clocks

About the time the pendulum clock reached its potential in accurate time keeping, a replacement, the quartz clock, was invented. Enhanced time-keeping accuracy was provided by passing electricity through a quartz crystal. Accuracy improved in a major way, this time to a plus or minus error rate of a second per month.[5] Quartz-clocks still are a somewhat popular mechanism of today's clocks and serve the needs of most people for an accurate method of determining the "correct time."

Atomic Clocks

Accuracy-in-time-keeping was closer to the meaning of the word "accurate" with the development of the atomic clock (oscillations occur in an electromagnetic field). The first generation (1960s) of atomic clocks were accurate to one second in 6 million years (Figure 1), but that was yesteryear; the cesium atomic clock---the Fountain F-1 (Figure 2), developed by the National Institute of Standards and Technology (NIST)—is accurate to plus or minus one second in 80 million years. But the real question is: Why do we need hyper-accuracy for time keeping, anyway? For those of us who show up 2 minutes late for a 12:00 o'clock lunch-date, what difference does it make? It turns out that our lives depend on super-accurate clocks!

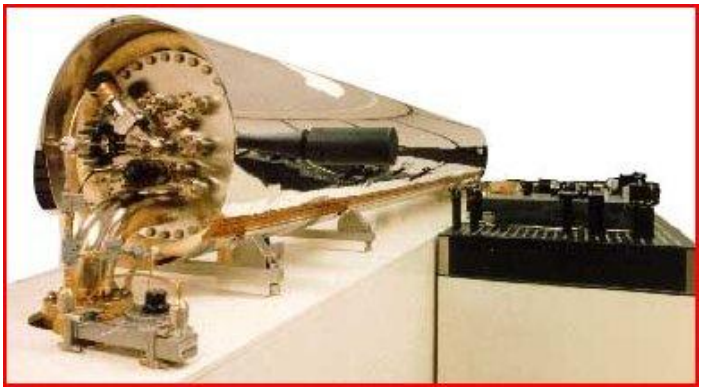

Figure 1
NIST-7 Accurate to 1 second in 6 million years
Photo: Courtesy of NIST

Figure 2
NIST Fountain-1 Accurate to 1 second in 20 million years.
Photo: Courtesy of NIST.

Such super accurate time is critical for the Internet, law enforcement, golfers, television broadcasts, financial markets, computers, cell phones, and automobiles—each dependant on global positioning satellites. In astronomy, fractional-second errors could sabotage radio telescopes and the associated activities of space exploration and national defense. With atomic-time, the Air-Force operated GPS system can determine---to several feet in accuracy---the three-dimensional position of a receiver anywhere on or off earth. The receiver performs this trick by timing the arrival of signals from four GPS satellites, then doing a quick calculation to triangulate its position.[6] Stephen Dick, the United States Naval Observatory's historian, points out that each nanosecond---billionth of a second--- of error translates into a GPS error of one foot. A few nanoseconds of error, he points out, "may not seem like much, unless you are landing on an aircraft carrier, or targeting a missile."

The quest for "absolutely accurate time" does not stop with a 80 million year projected accuracy as noted above. It may be found in the strontium clock with an accuracy of plus or minus 1 second in 200 million years![7] But wait! The next atomic clocks will be accurate to within 1 second in 400 million years. Now wait again. Already scientists have begun working on a clock with an anticipated accuracy of 1 second in 10 billion years![8]

Personal Atomic Clocks

Someone once said: "Clocks were like philosophers; you could never find two that agreed. Clearly, that was then. Now most new consumer clocks, whether for travel, wearing/carrying, or home use, can display or announce not the approximate time, but the precise time courtesy of radio-controlled "atomic" clocks. How civilian-atomic-time works is that a radio signal, known as the WWVB signal, transmits at 60 kHz to wherever the clock/watch-receiver is located. An atomic watch/clock has a built-in receiver that automatically tunes in to the WWVB signal that emanates from NIST in Boulder, Colorado. Atomic clocks/watches automatically adjust to Daylight Savings Time and leap-year, can forecast the weather, and set the calendar (Figure 3)!

Figure 3
Talking Wireless Clock/Weather Station. Features: Crescendo alarm with snooze function, remote sensor, illuminated with electro-luminescent backlight, 3 levels of pressure, temperature and humidity, 12-24 hour weather forecast, language (French, German, Spanish) selectable auto-announcement of time, temperature, humidity, and weather forecast data, radio controlled time setting for 4 time zones. 3.33" x 1.5" x 8.10" Oregon Scientific 2004 (istcc)

Atomic time is also available in Windows XP/Vista (a very difficult effort for Windows 2000). Windows XP/Vista has an Internet time synchronization clock feature included as part of the operating system. To set the atomic-time on one's computer, double click or right click on the "time" in bottom right of the task bar. On the first tab, set the date and time, on the second tab, set the time zone, and on the third tab (if present); check the box for "Automatically synchronize with an Internet time server," and select a time server from the list at http://www.time.nist.gov. Atomic time synchronization will occur automatically after a set interval.

The latest developments involving computer-time have evolved to include software add-ons that speak the correct (atomic) time in preset intervals of 5, 10, 15, 30 and 60 minutes in as many as 50 languages. Google "talking clock software" and 206,000 plus speaking clock resources were available in .29 seconds. The time-keeping utilities include a host of speaking features and graphics that go way beyond the single function of monitoring time. Almost all the clock-packages include features along the following lines: An alarm alert function that speaks the time and/or plays self selected miscellaneous sounds, multiple time zones, timers to launch programs or customized message announcements, stop watches, pop up avatars that do the talking, a speaking calculator, spoken e-mail, news headlines, appointment calendars, and voice time displays in either a graphical digital or analogue interface, which can serve in the system tray, or as a desktop background, or as a screen saver (Figure 4). Time marches on.

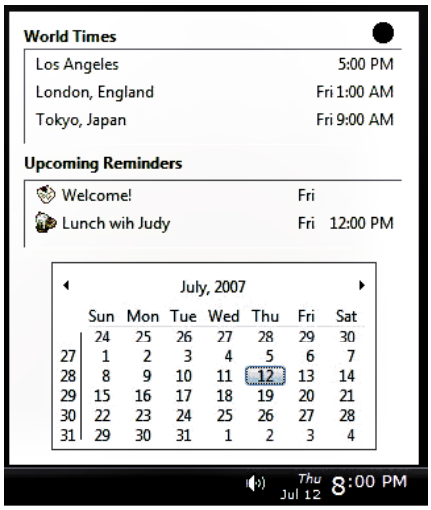

Figure 4
Features: "Atomic Time" with spoken date and time announcements in a female or male voice. Choose a preferred time interval, anywhere from every five minutes to every hour. Specify a time period for which to suspend time announcements - especially useful if computer is on all night. Schedule reminders one time, or have them recur hourly, daily, weekly, monthly, or yearly. Reminders to occur at either a specific time or choose to have a reminder occur when Windows/Say the Time starts. Customize reminder messages. Choose fonts and colors. Automatically launch any Windows program at a pre-determined time. Spoken reminder messages via a text-to-speech translation engine. © Say the Time, 2007 (istcc)

A Quest

The pursuit of accuracy in time keeping is an evolutionary occurrence. As society changes, along with concomitant advancements in science, the quest for the "correct time" will not cease. As was noted above, the next generation of atomic clocks will be accurate to within 1 second in 30 billion years. The clock is based on the strontium atom which resonates at 444,779,044,095,484.6 cycles per second.[8] But I wonder, who on earth is going to be around to check if this target is really realized?

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[3] K. Higgins, D. Miner, C.N. Smith, D.B. Sullivan (2004), *A Walk Through Time* (version 1.2.1). [Online] http://physics.nist.gov/time (December 22, 2006). National Institute of Standards and Technology, Gaithersburg, MD. (December 23, 2006).
[4] Science Museum, [Online] http://www.sciencemuseum.org.uk/on-line/huygens/page3.asp (December 23, 2006).
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[6] National Institute of Standards and Technology, " A Brief History of Atomic Clocks at NIST," no. 1 http://www.boulder.nist.gov/timefreq/cesium/atomichistory.htm (March 6, 2003)
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About the Author

Mark B. McKinley is a professor of psychology at Lorain County Community College in Elyria, Ohio, where he has taught a variety of psychology courses for the past 40 years. Dr. McKinley, for the past 16 years has been involved with both the study of the psychology of time (perception) and as a timepiece collector (over 800 talking clocks). They range from the "primitive" Hiller, through radio-controlled atomic talking clocks. He had an article published in the June 2004 issue of the NAWCC Bulletin, which has become the impetus for a book on Talking Clocks entitled: TIC, TOCK TALK: The Collected History and Significance of Talking Clocks. McKinley has established the International Society of Talking Clock Collectors (ISTCC). The ISTCC website may be accessed at: http://www.istcc.org. A small part of the ISTCC collection is located at: http://www.talkingclocks.net