

Click to prove
you're human



Strontium optical lattice clock at the National Physical Laboratory. In today's interconnected world, accurate timekeeping is essential for everything from global communications to financial markets and navigation systems. At the core of this precision are atomic clocks and GPS timing, two critical technologies that form the backbone of modern time synchronization. In this blog, we'll explore the workings of atomic clocks, how they play a vital role in the Global Positioning System (GPS), and why both are essential to accurate timekeeping in our everyday lives.

An atomic clock is a highly accurate timekeeping device that measures time based on the vibrations or oscillations of atoms. Unlike traditional clocks that rely on mechanical movements (like pendulums or gears), atomic clocks use the natural frequency of atoms, most commonly cesium or rubidium, to keep time with extraordinary precision. Atomic clocks operate by exploiting the stable, resonant frequency of specific atoms. For example, in a cesium atomic clock, the clock uses the natural resonance frequency of cesium-133 atoms, which oscillate exactly 9,192,631,770 times per second. This frequency is used to measure the passage of time extremely accurately. Every second, these oscillations are counted, and this number is used to define one second. This precision makes atomic clocks the most accurate timekeeping devices in the world, with the ability to maintain time to within a few nanoseconds (billions of a second) over long periods.

There are several types of atomic clocks, each with varying levels of accuracy:

- Cesium Atomic Clocks:** These are the most widely used atomic clocks, defining the international standard for time (1 second).
- Rubidium Atomic Clocks:** Often used in smaller applications, such as portable GPS receivers, rubidium clocks are less accurate than cesium clocks but are still incredibly precise.
- Hydrogen Maser Clocks:** These provide even higher short-term stability than cesium clocks and are used in specific applications like deep-space tracking and astronomical observations.

The Global Positioning System (GPS) is an essential technology for navigation, mapping, and timing applications. GPS relies on atomic clocks to provide the precise timing data necessary for accurate location information. GPS satellites orbit the Earth, constantly broadcasting signals that contain time and location data. Each satellite is equipped with its own atomic clock, synchronized to a universal time standard. These signals are picked up by GPS receivers on Earth, which calculate their exact location by measuring the time delay between the satellite signals. Since GPS relies heavily on time, any inaccuracies in timekeeping would lead to errors in positioning. For example, a timing error of just one microsecond (one-millionth of a second) would cause a GPS location to be off by 300 meters (984 feet). Therefore, the extreme accuracy of atomic clocks ensures that GPS systems can pinpoint locations with high precision.

The atomic clocks on GPS satellites are constantly synchronized with ground-based atomic clocks at monitoring stations around the world. These stations track the satellites' positions and adjust their clocks to account for time dilation caused by the satellites' high speeds (a phenomenon predicted by Einstein's theory of relativity). By continually correcting any time discrepancies, GPS systems maintain an accuracy of better than 10 nanoseconds, which is essential for everything from personal navigation devices to the coordination of global financial transactions.

In modern technology, timing accuracy goes far beyond just knowing the correct time. Here are some industries and applications where precise time synchronization is essential:

- Telecommunications:** Networks rely on synchronized clocks to ensure that data is transmitted in the correct order and without errors. Mobile phone towers, internet exchanges, and data centers use GPS timing signals to ensure seamless communication.
- Financial Institutions:** Transactions happen in milliseconds. Financial institutions use GPS time signals to timestamp trades accurately, which is essential for tracking the exact order of transactions, especially when trading across different markets.
- Electric Power Grids:** Rely on synchronized clocks to ensure the proper flow and distribution of electricity. GPS timing is used to synchronize the operations of different power plants and manage load balancing across the grid.
- Scientific Experiments:** That require ultra-precise timing, such as gravitational wave detection or space exploration, depend on the accuracy of atomic clocks and GPS signals. While atomic clocks are fundamental to GPS timing, their role extends into other time synchronization systems: NTP is a widely used protocol for synchronizing clocks over a computer network. Atomic clocks act as the primary time source (stratum 0), and their time data is distributed across the internet via NTP servers, ensuring that computer systems around the world maintain accurate time.
- Navigation:** For systems that require even greater accuracy than NTP, PTP (Precision Time Protocol) offers sub-microsecond synchronization. PTP is used in industries like telecommunications and broadcasting, where precise timing is crucial for transmitting high-bandwidth data streams. Atomic clocks are at the top of the hierarchical time server system, feeding ultra-accurate time data into PTP and NTP networks. Devices using these protocols adjust their internal clocks to match the atomic clock source, ensuring that they remain synchronized with the global time standard.

While today's atomic clocks are already incredibly precise, scientists are working on developing even more advanced versions. Optical lattice clocks, for instance, are a new type of atomic clock that could be 100 times more accurate than current cesium-based clocks. These optical clocks use the frequency of visible light to measure time, allowing for far greater precision than microwave-based atomic clocks. Although still in the experimental phase, optical lattice clocks could one day redefine the international time standard and further enhance the accuracy of GPS and global time synchronization systems.

Atomic clocks and GPS timing systems are the foundation of modern timekeeping. Without the extreme accuracy provided by atomic clocks, many of the technologies we rely on today like GPS navigation, financial trading, telecommunications, and scientific research would simply not function as efficiently or accurately. As technology continues to evolve and demand for precision increases, atomic clocks will remain at the forefront of time synchronization, ensuring that our digital world runs seamlessly, from satellite navigation to high-speed data transmission.

For applications where accurate timekeeping is critical, understanding the relationship between atomic clocks and GPS timing is essential. With ongoing advancements in both technologies, we can expect even greater precision in the future, making atomic clocks and GPS even more indispensable in our modern world.

by Chris Woodford. Last updated: October 7, 2022.

You might have the most expensive watch in the world, but if it's set to the wrong time to begin with, it's no use to you at all. Even really good quartz clocks struggle to keep time to better than a second a day; if they wander out by just a couple of seconds in 24 hours (an amazing accuracy of 99.998 percent), and the errors don't cancel out, that could add up to a minute a month or almost a quarter of an hour a year. That's why most people regularly check their watches against a reliable time signal like the ones you hear before news broadcasts on radio stations. Now wouldn't it be neat if your watch could listen to those broadcasts and set itself to the right time automatically without you ever needing to worry? That's the basic idea behind radio-controlled clocks and watches, which set their time by super-accurate atomic clocks.

Let's take a closer look at what these things are and how they work!

Artwork: Watches and clocks synchronized using radio signals mean anyone can own a watch as accurate as an atomic clock. Radio-controlled clocks and watches were popularized by such companies as Junghans in the late 1980s and early 1990s. Today, many different manufacturers make them and there are millions in use all over the world.

Photo by Stefan Khn courtesy of Wikimedia Commons.

Listen instead... or scroll to keep reading. Your browser does not support the audio element.

Contents: An ordinary clock or watch is a time-keeping device that adds up the number of seconds, minutes, hours, and days that have passed. But it doesn't actually know what time it is until you tell it: it's not a time-keeping device unless you set it to the right time to start with. A radio-controlled clock (RCC) is different. It's similar to an ordinary electronic clock or watch but it has two extra components: a antenna that picks up radio signals and a circuit that decodes them. The circuit uses the radio signals to figure out the correct time and adjusts the time displayed by the clock or watch accordingly. Unlike an ordinary clock or watch, an RCC always knows what time it is; you never have to tell it! The radio signals come from a unique radio "station" that doesn't broadcast any words or music. There's no DJ and no irritating advertisements for car insurance. All the station broadcasts is the time over and over again in the form of a special code that only radio-controlled clocks can understand. In the United States, these time signals are broadcast by a station called WWVB operated by the National Institute of Standards and Technology (NIST) from a base near Fort Collins, Colorado. (Other countries have equivalent radio stations. In the UK, for example, the station is called MSF and operated by the National Physical Laboratory, while China's station is called BPC and broadcast by the National Time Service Center.) The NIST time code contains the basic time and date, whether it's a leap year, whether it's daylight-saving time, and so on and takes about a minute to broadcast in its entirety.

Artwork: The basic concept of RCC radio-controlled clocks: a radio transmitter hundreds or thousands of km/miles from your home beams regular signals to your quartz clock or watch to keep it in time. Most RCCs synchronize themselves with a time broadcast signal once a day, at night, although some check themselves every few hours. Generally, that gives them an accuracy of better than plus or minus a half second (0.5s) a day. Another advantage is that they automatically correct themselves for daylight-saving time, leap years, months with different numbers of days, and so on. It's pretty cool that an RCC is only going to be as accurate as the time signals it uses to regulate itself. How can you be sure those are accurate? The time-signal radio stations operated in different countries broadcast UTC (Coordinated Universal Time), the officially agreed time used worldwide that's officially known as GMT (Greenwich Mean Time). UTC is maintained by hundreds of atomic clocks (the world's most accurate timekeeping devices) around the world, all of which are synchronized with one another. It's because RCC radio signals are based on time kept by atomic clocks that you'll sometimes see RCC manufacturers describing their products as "atomic" clocks and watches (even though they're really no such thing).

What are atomic clocks? Atomic clocks are actually quartz clocks just like the ones you have at home. The difference is that an ordinary quartz clock relies purely on the oscillations of its quartz crystal to count seconds. As we've already seen, the rate at which quartz vibrates is affected by things like ambient temperature, so although a quartz clock is generally very accurate, it doesn't necessarily keep time as well as you might think. By contrast, an atomic clock has an extra mechanism pulsating atoms that it uses to keep an ordinary quartz clock to time. Photo: Before atomic clocks were developed, highly accurate quartz clocks like this one were used as "time standards" to which other clocks could be synchronized. This is the 1941 Quartz Crystal Time Standard, used in the United States until 1949, including during World War II, when it helped to synchronize military forces all around the world.

Photo courtesy of National Institute of Standards and Technology Digital Collections, Gaithersburg, MD 20899.

Cesium Atomic Clocks: This atomic mechanism is based on the idea that atoms have electrons in particular energy states. When an atom absorbs energy, electrons leap to higher energy states and become unstable. They then give out the same energy as photons of light (or some other kind of electromagnetic radiation such as X-rays or radio waves), returning to their original or ground state. The cesium atoms used in many atomic clocks have 55 electrons arranged in orbitals. The very outermost electron can oscillate between two different energy states by spinning in two slightly different ways. When it shifts from the higher to the lower of these states, it gives out a photon that corresponds to microwave waves with a frequency of exactly 9,192,631,770 Hz (roughly 9.2 billion hertz or 9.2 gigahertz). That means it can be stimulated from its lower to its higher state by exactly the same microwaves. We can use this neat fact to keep a quartz clock to very precise time.

Photo: The NIST-F1 Cesium fountain atomic clock: the amazingly accurate clock by which pretty much every other clock and watch in the United States is set! Photo by courtesy of National Institute of Standards and Technology (NIST) Physics Laboratory. In a cesium atomic clock, there's a quartz oscillator tuned to exactly the same frequency, 9,192,631,770 Hz, which makes microwaves and fires them at a bunch of cesium atoms. If its frequency is incorrect, and hasn't drifted at all, these microwaves will have exactly the right amount of energy to shift the electrons in the atoms to their higher energy state. A magnetic detector in the clock measures how many atoms are in the higher state. If most are in the higher state, it means most have been excited by the waves from the quartz oscillator. And that means those waves are exactly the right frequency, so the quartz oscillator must be telling time correctly. However, if the atoms are mostly in the lower state, it means the oscillator has drifted away from its correct frequency and isn't giving out the right amount of energy to promote electrons in the cesium atoms. A feedback mechanism in the clock detects this and adjusts the frequency of the oscillator so it's correct again. In this way, the quartz oscillator is constantly regulated so it's always exactly set to 9,192,631,770 Hz. An electronic circuit converts this exact frequency into one-per-second pulses that can be used to drive a relatively ordinary quartz clock mechanism.

"Amazing" in this case means just that: the best atomic clocks are accurate to within 2 nanoseconds per day, or one second in 1.4 million years!

Photo: Not all atomic clocks are as huge as NIST-F1. Here you can see a miniaturized, chip-scale atomic clock (CSAC) designed for use in missiles and other weapons. Photo by Ed Thompson courtesy of US Army and DVIDS.

Other types of atomic clocks work in broadly the same way but using atoms of different gases to regulate the quartz oscillator. In a hydrogen clock, atoms of hydrogen gas are stimulated with a microwave-frequency laser (maser), but they're less practical because hydrogen is a fairly hard

Rubidium clocks are simpler, and therefore more compact and portable; they use microwaves to excite the atoms in rubidium glass. The world's most advanced atomic clocks, such as NIST-7 at the National Institute of Standards and Technology in Boulder, Colorado, use what are called atomic fountains. They use six laser beams to contain cesium atoms, cool them almost to absolute zero, bounce them upward, and let them fall back down through gravity (hence the name "atomic fountain"). This process makes them oscillate between two precise energy states that can be measured, in a broadly similar way to how we explore above, and used to keep a quartz clock to time. According to Michael Lombardi of the NIST, one of the world's authorities on radio-controlled clocks: "There is no true consensus on who invented the first RCC that could synchronize to a wireless signal." He suggests the first such device may have been the Horophone invented by Frank Hopkinson (1871-1950) and sold from 1913 by his Synchronome Company of London, England. I looked through numerous patents covering RCCs on the US Patent and Trademark Office database and the earliest one I found was filed on March 24, 1921 (granted February 5, 1925) by Thaddeus Casner for the Radio Electric Clock Corporation of New York City. Casner explains that his invention covers "... mechanism by means of which a clock may be periodically corrected by electrical impulses transmitted through space... [by] Hertzian waves [what we now call radio waves]..." You can read a full description and browse numerous detailed drawings (including the one shown here) in US Patent #1,755,096: Mechanism for Synchronizing Clocks (via Google Patents). Artwork: One of the drawings of Thaddeus Casner's early radio-controlled clock. It keeps time using a traditional gear mechanism (which I've roughly indicated in blue), but also uses electromagnets (red) controlled by radio signals to keep the time correct. Artwork courtesy of US Patent and Trademark Office. Can clocks really be this accurate? We can now tell time with an incredible degree of accuracy, a nanosecond or two each day. While you might think that's wonderful, it really just swaps one problem for another. In past times, the problem was that we couldn't tell time well enough to keep up with the "natural accuracy" of the real world. So while the heavens turn and the planets whizzed round the Sun, our clocks struggled to keep time as effectively as the natural clock high in the sky. Today, ironically, it's just the opposite. We now define time not in terms of moving planets but using oscillating atoms. Since 1967, the second has been defined as 9,192,631,770 oscillations of the cesium-133 atom. The second is now defined as "the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom." For the first time in human history, the measurement of time is no longer based on the movement of the stars and planets. 1993: NIST builds NIST-7, a cesium beam atomic clock used for official timekeeping in the United States until 1999. 1999: NIST builds NIST-F1, a replacement for NIST-7 that is 10 times more accurate. Based on cesium fountain technology, it is accurate to about one second in 100 million years. Chris Woodford is the author and editor of dozens of science and technology books for adults and children, including DK's worldwide bestselling Cool Stuff series and Atoms Under the Floorboards, which won the American Institute of Physics Science Writing Award in 2016. You can hire him to write books, articles, scripts, corporate copy, and more via his website chriswoodford.com. If you'd rather listen to our articles than read them, please subscribe to our new podcast on Apple Podcasts, Spotify, Audible, Amazon, Podchaser, or your favorite podcast app, or listen below: Find out more on this website. On other sites: Books News article: The Most Important Radio Station You've Never Heard of Marks 50 Years On The Air by Joe Hanson, Wired, 2 July 2013. Marking the first half-century of WWVB, the time-signal radio station run by the NIST. Time change marks end of an era: BBC News, 25 March 2007. How radio-controlled clocks use the WWVB signal to keep time: BBC News, 25 March 2007. How radio-controlled clocks using MSF time signals keep Britain synchronized. Technology Review: The Clock by Joe Hanson, Wired, 2 July 2013. Marking the first half-century of WWVB, the time-signal radio station run by the NIST. How it Works: Clocks That Won't Miss a Second in 20 Million Years by Catherine Greenman, The New York Times, January 17, 2002. La Crosse Technology atomic clocks set their time automatically by synchronizing to a radio signal called WWVB that the National Institute of Standards and Technology (NIST) broadcasts continuously from Fort Collins, Colorado. THE ADVANTAGE? TIMELY: Sticklers for punctuality from an atomic level, our atomic clocks stay accurate because time is at the essence of each one. TIMELESS: Our atomic clocks don't just keep time; they transcend it. Crafted with quality materials and an eye for design, they're a timeless addition to any mantle (or desk, or wall... or? Only time will tell). CONVENIENCE: Our atomic clocks automatically adjust for Daylight Saving Time or the drift that other clocks eventually succumb to. When you put time in your hands, it frees up yours. Power up your clock using a new set of regular alkaline batteries for best results. Follow the instructions in your setup guide to ensure your settings are adjusted correctly; this will vary by product. Place the clock near a window with the front or back facing Fort Collins, Colorado; this will help it pick up the WWVB signal faster. Once the signal is received and the clock shows the correct time, you can move it to its permanent location. The clock will continue to search for the signal and adjust as needed. La Crosse Technology atomic clocks set their time automatically by synchronizing to a radio signal called WWVB that the National Institute of Standards and Technology (NIST) broadcasts continuously from Fort Collins, Colorado. TIMELY: Sticklers for punctuality from an atomic level, our atomic clocks stay accurate because time is at the essence of each one. TIMELESS: Our atomic clocks don't just keep time; they transcend it. Crafted with quality materials and an eye for design, they're a timeless addition to any mantle (or desk, or wall... or? Only time will tell). CONVENIENCE: Our atomic clocks automatically adjust for Daylight Saving Time or the drift that other clocks eventually succumb to. When you put time in our hands, it frees up yours. Power up your clock using a new set of regular alkaline batteries for best results. Follow the instructions in your setup guide to ensure your settings are adjusted correctly; this will vary by product. Place the clock near a window with the front or back facing Fort Collins, Colorado; this will help it pick up the WWVB signal faster. Once the signal is received and the clock shows the correct time, you can move it to its permanent location. The clock will continue to search for the signal and adjust as needed. La Crosse Technology atomic clocks set their time automatically by synchronizing to a radio signal called WWVB that the National Institute of Standards and Technology (NIST) broadcasts continuously from Fort Collins, Colorado. TIMELY: Sticklers for punctuality from an atomic level, our atomic clocks stay accurate because time is at the essence of each one. TIMELESS: Our atomic clocks don't just keep time; they transcend it. Crafted with quality materials and an eye for design, they're a timeless addition to any mantle (or desk, or wall... or? Only time will tell). CONVENIENCE: Our atomic clocks automatically adjust for Daylight Saving Time or the drift that other clocks eventually succumb to. When you put time in our hands, it frees up yours. Power up your clock using a new set of regular alkaline batteries for best results. Follow the instructions in your setup guide to ensure your settings are adjusted correctly; this will vary by product. Place the clock near a window with the front or back facing Fort Collins, Colorado; this will help it pick up the WWVB signal faster. Once the signal is received and the clock shows the correct time, move it to its permanent location. The clock will continue to adjust as needed. Custom-designed to receive an enhanced phase-modulated WWVB broadcast, these premium analog clocks offer unparalleled reception throughout all North American time zones. Custom-designed to receive an enhanced phase-modulated WWVB broadcast, these premium analog clocks offer unparalleled reception in nearly any area. Custom-designed to receive an enhanced phase-modulated WWVB broadcast, these premium analog clocks offer unparalleled reception throughout all North American time zones. Custom-designed to receive an enhanced phase-modulated WWVB broadcast, these premium analog clocks offer unparalleled reception in nearly any area. Custom-designed to receive an enhanced phase-modulated WWVB broadcast, these premium analog clocks offer unparalleled reception throughout all North American time zones. Custom-designed to receive an enhanced phase-modulated WWVB broadcast, these premium analog clocks offer unparalleled reception throughout all North American time zones. The only atomic clock capable of receiving the new NIST signal for vastly improved reception in nearly any area. Custom-designed to receive an enhanced phase-modulated WWVB broadcast, these premium analog clocks offer unparalleled reception throughout all North American time zones. The only atomic clock capable of receiving the new NIST signal for vastly improved reception in nearly any area. Shop Digital Atomic Clocks. This can vary greatly depending on your geographical location as well as the location of the clock within your home. Moving the clock near a window with the front or back facing Fort Collins, Colorado, should help speed this up, but it is not unusual for this to take a few nights. This can vary greatly depending on your geographical location as well as the location of the clock within your home. Moving the clock near a window with the front or back facing Fort Collins, Colorado, should help speed this up, but it is not unusual for this to take a few nights. The WWVB signal should reach most U.S. locations. However, we cannot guarantee the signal will extend everywhere. For instance, if you live in a valley, are surrounded by buildings, or have other strong radio signals nearby, these can all cause interference, delaying or even entirely blocking this radio signal from reaching your clock. We apologize for any inconvenience. The WWVB signal should reach most U.S. locations. However, we cannot guarantee the signal will extend everywhere. For instance, if you live in a valley, are surrounded by buildings, or have other strong radio signals nearby, these can all cause interference, delaying or even entirely blocking this radio signal from reaching your clock. We apologize for any inconvenience. Once the WWVB radio signal is received, the clock will automatically adjust according to the device's specific time zone and daylight saving time settings. You'll want to tweak those as needed, but yes, our atomic devices will search daily for this signal, keeping your time and date accurate. Once the WWVB radio signal is received, the clock will automatically adjust according to the device's specific time zone and daylight saving time settings. You'll want to tweak those as needed, but yes, our atomic devices will search daily for this signal, keeping your time and date accurate. Of course! This convenience is one of their main advantages. If your time hasn't been updated after a recent DST change, check out our support page [HERE](#) for further assistance. Of course! This convenience is one of their main advantages. If your time hasn't been updated after a recent DST change, check out our support page [HERE](#) for further assistance. Yes. All of our clocks offer a manual set option. However, we should note that outside of our UltrAtomic options, our analog atomic clocks will automatically adjust according to your settings when they receive the WWVB radio signal. For instructions on how to manually set your analog clock, watch our video [HERE](#). Yes. All of our clocks offer a manual set option. However, we should note that outside of our UltrAtomic options, our analog atomic clocks will automatically adjust according to your settings when they receive the WWVB radio signal. For instructions on how to manually set your analog clock, watch our video [HERE](#). This will vary by product, but batteries should generally keep your clock running for years at a time. In fact, our analog clocks with multiple battery slots boast an impressive 5-year life! Talk about convenience. This will vary by product, but batteries should generally keep your clock running for years at a time. In fact, our analog clocks with multiple battery slots boast an impressive 5-year life! Talk about convenience. Our owner, Allan McCormick, brought atomic time technology to the United States in 1992, and we've been selling radio-controlled clocks ever since. As the world leader in this field, we offer our expertise to you and are committed to providing high-quality products and superior customer service. Our owner, Allan McCormick, brought atomic time technology to the United States in 1992, and we've been selling radio-controlled clocks ever since. As the world leader in this field, we offer our expertise to you and are committed to providing high-quality products and superior customer service.

atomic time technology to the United States in 1952, and we've been selling radio-controlled clocks ever since. As the world leader in this field, we offer our expertise to you and are committed to providing high-quality products and superior customer service. Radio-controlled clocks can receive signals from a radio system set up and operated by NIST. RUNSTUDIO / Getty Images Many gadget catalogs and high-tech stores sell "radio-controlled" clocks and wrist watches that are able to receive these radio signals. These clocks and watches truly are synchronizing themselves with the atomic clock in Colorado. This feature is made possible by a radio system set up and operated by NIST--the National Institute of Standards and Technology, located in Boulder, Colorado. NIST operates radio station WWVB, which is the station that transmits the time codes. WWVB is a very interesting radio station. It has high transmitter power (50,000 watts), a very efficient antenna and an extremely low frequency (60,000 Hz). For comparison, a typical AM radio station broadcasts at a frequency of 1,000,000 Hz. The combination of high power and low frequency gives the radio waves from WWVB a lot of bounce, and this single station can therefore cover all of the continental United States plus much of Canada and Central America as well (scroll about three-quarters of the way down the page for a nice coverage map). The time codes are sent from WWVB using one of the simplest systems possible, and at a very low data rate of one bit per second (for comparison, a typical modem transmits over the phone lines at tens of thousands of bits per second -- imagine receiving a web page at one bit per second!). The 60,000 Hz signal is always transmitted, but every second it is significantly reduced in power for a period of 0.2, 0.5 or 0.8 seconds: 0.2 seconds of reduced power is a binary zero. 0.5 seconds of reduced power is a binary one. 0.8 seconds of reduced power is a separator. The time code is sent in BCD (Binary Code Decimal) and indicates minutes, hours, day of the year and year, along with information about daylight savings time and leap years. The time is transmitted using 53 bits and 7 separators, and therefore takes 60 seconds to transmit. A clock or watch can contain an extremely small and relatively simple antenna and receiver to decode the information in the signal and set the clock's time accurately. All that you have to do is set the time zone, and the clock can display a very accurate time. The only thing more accurate than you can carry around easily is a GPS receiver, which derives atomic clock accuracy in real time from the atomic clocks in orbiting GPS satellites. See How GPS Receivers Work for details. Here are several interesting links: ShareAlike You are free to copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt, remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions. You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation. No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. NIST-F1, the nation's primary time and frequency standard, is among the most accurate clocks in the world. (Image credit: NIST) Timekeeping can be as simple as counting "one Mississippi, two Mississippi, . . ." prior to lining up backyard football, or tracking the back-and-forth swings of a pendulum in a grandfather clock. In both cases, the trick is counting the intervals of something that occurs repeatedly with as little variation as possible. A pendulum swing, say, or a 'Mississippi' just about equates to a second, the unit of timekeeping that we know comprises minutes and hours. But even the best mechanical pendulums and quartz crystal-based clocks develop discrepancies. Far better for timekeeping is the natural and exact "vibration" in an energized atom. You may like When exposed to certain frequencies of radiation, such as radio waves, the subatomic particles called electrons that orbit an atom's nucleus will "jump" back and forth between energy states. Clocks based on this jumping within atoms can therefore provide an extremely precise way to count seconds. It is no surprise then that the international standard for the length of one second is based on atoms. Since 1967, the official definition of a second is 9,192,631,770 cycles of the radiation that gets an atom of the element called cesium to vibrate between two energy states. Inside a cesium atomic clock, cesium atoms are funneled down a tube where they pass through radio waves. If this frequency is just right, 9,192,631,770 cycles per second, then the cesium atoms "resonate" and change their energy state. A detector at the end of the tube keeps track of the number of cesium atoms reaching it that have changed their energy states. The more finely tuned the radio wave frequency is to 9,192,631,770 cycles per second, the more cesium atoms reach the detector. Get the world's most fascinating discoveries delivered straight to your inbox. The detector feeds information back to the radio wave generator. It synchronizes the frequency of the radio waves with the peak number of cesium atoms striking it. Other electronics in the atomic clock count this frequency. As with a single swing of the pendulum, a second is ticked off when the frequency count is met. The first quality atomic clocks made in the 1950s were based on cesium, and such clocks hold to greater precisions over the decades remain the basis used to keep official time throughout the world. In the United States, the top clocks are maintained by the National Institute of Standards and Technology (NIST) in Boulder, Colo., and the United States Naval Observatory (USNO) in Washington, D.C. The NIST-F1 cesium atomic clock can produce a frequency so precise that its time error per day is about 0.03 nanoseconds, which means that the clock would lose one second in 100 million years. Super-accurate timekeeping is integral to many elements of modern life, such as high-speed electronic communications, electrical grids and the Global Positioning System (GPS) and of course knowing when your favorite television show comes on. Got a question? Email it to Life's Little Mysteries and we'll try to answer it. Due to the volume of questions, we unfortunately can't reply individually, but we will publish answers to the most intriguing questions, so check back soon. Atomic timekeeping sounds like a phrase from a Sci-Fi movie, isn't it? However, this technology is not fiction and is being used since 1948 after the invention of the first atomic clock. The notable use of this technology is in the operation of GPS (Global Positioning System). However, its use is not just limited to laboratories and GPS as it also has day-to-day practical use which is updating the atomic watches to the most