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News & Highlights

Global Timekeepers Push Pause on the Leap Second

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Half a century—plus 37 seconds—after it was first introduced to the world, the leap second has been scheduled for retirement. On 18 November 2022 at the General Conference on Weights and Measures (CGPM) outside of Paris, France, representatives of governments around the globe decided that astronomical time (known as UT1), which is determined by Earth's rotation, will be allowed to diverge by more than one second from Coordinated Universal Time (UTC), which is based on the steady ticking of atomic clocks [1]. While the change—not to be implemented until 2035—will go unnoticed by most people, it promises to simplify the timekeeping vital to services provided by a wide range of global industries, including transportation, defense, and finance.

"Nobody wants to abolish leap seconds entirely, but they want to increase the tolerance in the deviation between astronomical and atomic time," said Marina Gertsvolf, team leader for the Frequency and Time Group of Canada's National Research Council (NRC).

For more than 2000 years, an extra day has been tacked onto the end of February every four years to realign the 365-day calendar year with the approximately 365.25 days it takes Earth to circumnavigate the sun. Each leap year's added day ensures that the seasons stay put rather than migrating as the incongruity grows.

More recently, a similar adjustment has also been needed on the scale of the second. Traditionally, the unit was defined in astronomical terms as $1 \times 86\,400^{-1}$ of the mean solar day, or the time it takes Earth to complete a full rotation on its axis. However, the Earth's rotation is not constant. Everything from atmospheric movements [2] to the pull of the moon's gravity [3] to natural disasters such as earthquakes [4,5] can affect it, adding or subtracting a few milliseconds every day. Over time, those differences add up. So, in 1967 the world's metrologists decided to tie the second to a fixed phenomenon and declared the official length of the second to be 9 192 631 770 vibrations of an atom of cesium 133.

"All the systems we use to measure time are just conventions," said Georgette Macdonald, director general of the Metrology Research Centre at the Canadian NRC (Ottawa, ON, Canada). "We choose how we define a second, and making that choice allows us better precision and knowledge. But that sets up a discrepancy between the natural world and the engineering world, so we make an adjustment to line them up."

Starting in 1972, to compensate for the growing difference between astronomical time and atomic time, metrologists began to occasionally insert an extra second—a leap second—to an atomic day. Whenever an organization called the International Earth Rotation and Space Systems Service (Washington, DC, USA) determines that atomic time is a full second ahead, a second is added to the final minute of June 30 or December 31—whichever comes next—to allow Earth time to catch up. Ten leap seconds were added to atomic time in 1972, with 27 more added at irregular intervals since, the last one in 2016 [6].

The slight inconsistency of the Earth's rotation makes the need for a leap second unpredictable. Fifty years ago, this made the process of adding a leap second difficult. Because precise timing is now so integral to our digitally interconnected world (Fig. 1), doing so today augurs a technical nightmare. Telecommunications, computer networks, and navigation systems are synchronized to tiny fractions of a second. Financial transactions are often executed in thousandths and even billionths of a second. By international law, data packages related to these transactions must be time-stamped with that level of precision, recorded, and made traceable back to UTC [6], the universally agreed-upon standard. UTC, in turn, is determined by averaging readings from about 400 atomic clocks kept at national laboratories around the world [7] and managed by the timekeepers at the International Bureau of Weights and Measures (BIPM) in Sèvres, France. Every leap second added to UTC introduces the possibility that some digital networks will incorrectly implement the change and fail to synchronize properly.

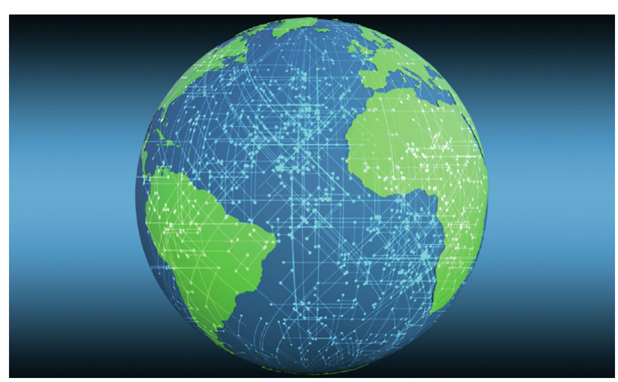

Fig. 1. To remove any discontinuity—even a momentary one—in how digitally interconnected systems across the planet keep time, the world's timekeepers have decided to abandon the leap second. Credit: Pixabay (public domain).

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"There was hope from the very beginning that this problem would eventually go away, that people would learn how to do it, but that has not been the case," said Judah Levine, leader of the Network Synchronization Project in the Time and Frequency Division at the US National Institute of Standards and Technology (Gaithersburg, MD, USA). "The problems continue, so that every time there is a leap second, there are a bunch of hassles."

Those hassles have included problems at the International Exchange, parent body to 11 global stock exchanges, which had to halt operations for 61 min when a leap second was added on 30 June 2015 [8]. The same leap second caused interruptions for users of Twitter, Instagram, Pinterest, Netflix, and Amazon, among other digital-based businesses [9]. The 2015 leap second also begat Linux software bugs that crashed the Altea reservation system used by Qantas and Virgin Australia airlines [10].

Different computing systems insert leap seconds differently. While Google spreads the extra second across an entire day, Alibaba, Meta, and Microsoft each add the extra second in their own bespoke way [5]. Because precise time stamps are required for commercial and financial transactions, these inconsistencies leave room for system crashes and a lack of traceability when it comes time to add another leap second to the ledger. "These different solutions to how leap seconds are implemented contribute to a proliferation of different reference time scales and complete confusion regarding accurate time around the leap second," Gertsvolf said.

The problems have made tech companies some of the most vocal critics of the leap second [11]. The world's timekeepers themselves have voiced discontent with the leap second since the late 1990s, with different stakeholders each pushing for their own solutions. No side has compromised, and all discussions have resulted in stalemates, as illustrated by deadlocked votes to abolish the leap second in 2012 and 2015 [1]. Indeed, the International Telecommunications Union (Geneva, Switzerland), the institution that oversees UTC, was so conflicted that the organization effectively ceded its decision-making power over the leap second to the CGPM in 2015 [12].

At the 2022 Paris meeting, the CGPM advised against adding a leap second for at least a century, which could put UT1 and UTC out of alignment by about 1 min [1]. After consulting with other international organizations, the CGPM will decide by 2026 by how much it will allow the two systems to diverge [1].

"We are now contemplating whether we really need astronomical time and atomic time to be aligned so tightly," said Macdonald. "And we are saying, 'Yes, the world can probably live with a discrepancy for a longer period of time.'"

Representatives from Canada, France, and the United States were among those at the CGPM who called for scrapping the leap second as early as 2025 or 2030 [1]. Voting against the proposal was Russia, which wanted to push back the date to 2040 or later, citing technical issues in its GLONASS satellite-navigation system. The compromise was to postpone the abolishment of the leap second until 2035 [1].

However, all the disagreement may be made moot by an unprecedented event that could occur well before 2035. While adding leap seconds has been necessary because atomic time runs faster than Earth time, the Earth's rotation rate has recently slowed. On 29 June 2022, the Earth experienced its shortest day on record, shaving 1.59 milliseconds off the previous record [13]. This means that, sometime in 2023, Earth time could catch up to atomic time. If the slowing persists, by about 2030 Earth time could overtake atomic time by about a second, meaning that metrologists could be obligated to insert a negative leap second to keep the two-timing systems in sync. Such an exercise has never been performed across the world's digital systems. "There is great interest in the implications of a negative leap second, but it is not going to be a bug that stops the world," Macdonald said.

Whatever becomes of the leap second, most metrologists agree that time should maintain a connection to the solar system. The differences between UT1 and UTC will continue to be calculated and made available, just not actively implemented. "Broadcasting the differences is important for astronomers," said Levine, citing their need to precisely time celestial events relative the motion of the earth.

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