A LEAP OF FAITH

STORY
David Rooney
ILLUSTRATIONS
Ūla Šveikauskaitė

When dinosaurs roamed the planet, a day was 23 hours long. Since modern times, it has taken approximately 24 hours for the earth to make one full revolution. The planet's rotation has never entirely matched our counting of time, but it was only as clocks became more accurate that this variance inspired a bold idea

It was hot and muggy in New York City on Tuesday June 30, 2015. The heady humidity hung over the East River and the busy streets of Lower Manhattan. As evening approached, some workers in the Financial District began to trickle out of their offices. Others remained at their desks as the after-hours markets were still trading and the Asian markets would soon be opening. It seemed like just another day on Wall Street.

But there was an unusual atmosphere that evening. Financial traders, always driven by a sense of urgency and the split-second tempo of the markets, were glancing more often than usual at the wall clocks and their fine wristwatches. They were waiting for the strike of midnight by Coordinated Universal Time (or UTC, the primary time standard by which the world's clocks are regulated), which would fall at eight o'clock in the evening in New York, USA, when one leap second would be inserted. Nobody knew what would happen to the complex IT networks of the global financial market when the sixty-first second struck across the world.

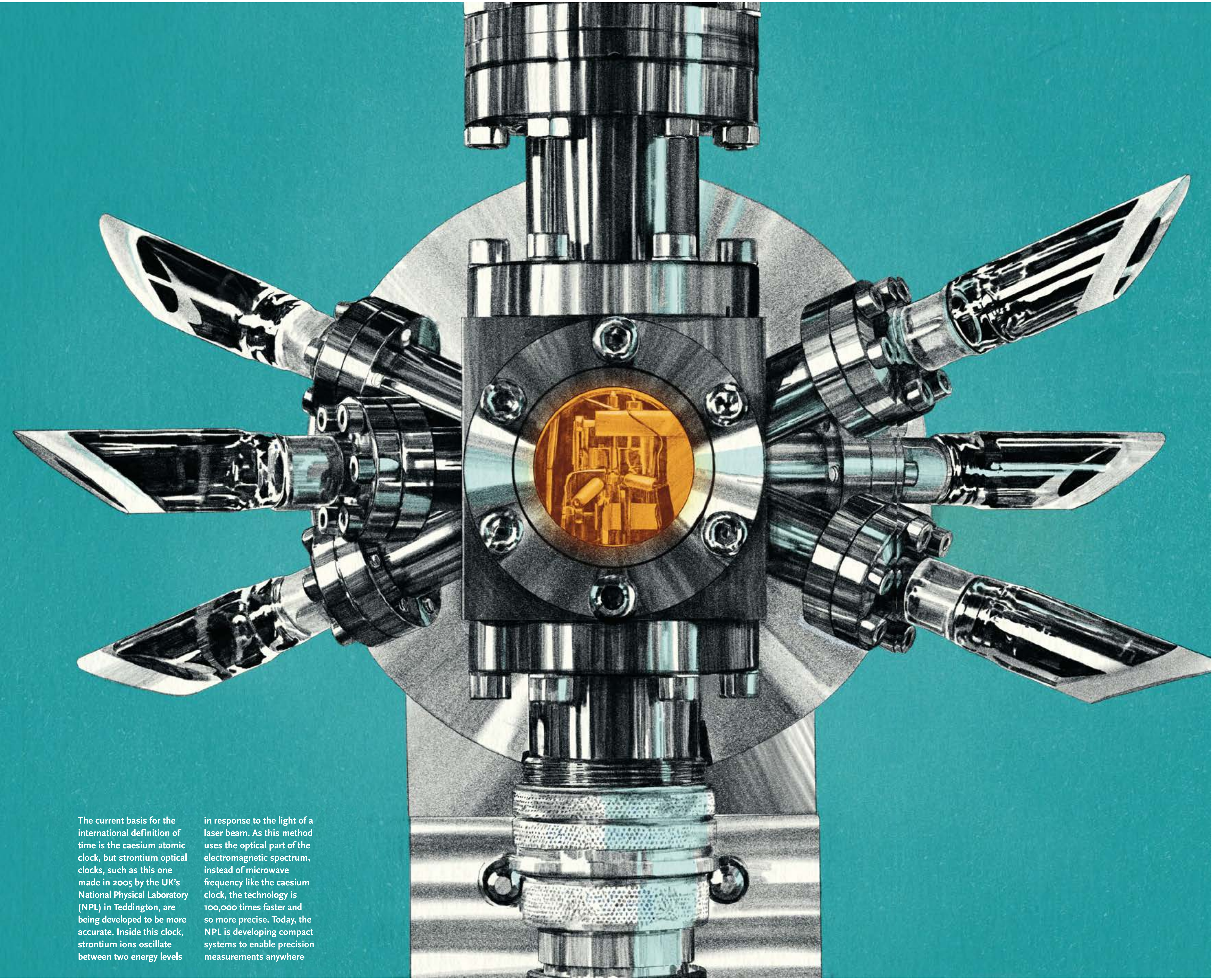
"A sixty-one-second minute is not something that our computer systems know how to deal with," explained Victor Yodaiken, whose company, FSMLabs, provides time-synchronization services to the financial industry. "It's like Y2K," he said, "but it's a little bit more weird, because at least with Y2K the calendars made sense, it was just that the programs didn't deal with it. In this case, the official idea that you have a minute of sixty-one seconds is strange."

Strange, perhaps, but on that day in 2015 it would in fact be the twenty-sixth time a leap second had been inserted into UTC as part of a temporal correction system first introduced in 1972, exactly 43 years earlier.

The roots of the problem can be traced back to the 1920s, when engineers at the Bell Telephone Laboratories in Manhattan's West Village, two miles from Wall Street, made the first quartz clock. This form of horological technology evolved quickly and soon took over from pendulum clocks as the preferred instrument for time measurement in the world's national timekeeping centers.

Quartz clocks offered more than just an incremental improvement in timekeeping. In 1945, Harold Spencer Jones, the UK's Astronomer Royal, wrote to his superiors stating, "The time service of the Royal Observatory is now based entirely on quartz crystal clocks; pendulum clocks have been discarded as not being sufficiently accurate." In an article published the same year, he said, "A new era in time measurement has

This astronomical clock on the tower of the Old Town Hall in Prague, Czech Republic, dates from the beginning of the fifteenth century. The dials display: on the outermost ring, the glyphs for ancient Czech time; then, moving closer inward, Roman numerals can be seen, for indicating 24-hour time. The position of the observer on the earth is in the center of the dial, and on top, on the main astrolabe, is the ring of zodiacal symbols that shows the sun's journey through the constellations



The current basis for the international definition of time is the caesium atomic clock, but strontium optical clocks, such as this one made in 2005 by the UK's National Physical Laboratory (NPL) in Teddington, are being developed to be more accurate. Inside this clock, strontium ions oscillate between two energy levels in response to the light of a laser beam. As this method uses the optical part of the electromagnetic spectrum, instead of microwave frequency like the caesium clock, the technology is 100,000 times faster and so more precise. Today, the NPL is developing compact systems to enable precision measurements anywhere

arrived, and clocks made by man now hold out a distinct promise of being able to convict the earth of irregularities in timekeeping."

Spencer Jones's comments marked a turning point in humankind's relationship with time. Since the earliest civilizations, we have kept time based on the earth's rotation, first using sundials, then telescopes at the world's great astronomical observatories, and later with techniques such as lunar laser ranging (in which laser beams are bounced off mirrored reflectors on the moon). The complex medieval astronomical clocks such as in Prague (see page 41) and Strasbourg vividly depict the passage of time as marked by our rotating and orbiting planet. But the earth is not a perfectly uniform timekeeper. Ocean tides, earthquakes, and a host of other factors mean the earth's rate of rotation is neither constant nor wholly predictable.

Through the twentieth century we grew ever more reliant on precision timekeeping. Clocks were setting the beat for all modern infrastructure and the computerized systems that made the world work. But these systems required uniformity in the seconds they marked off. If every earth-rotation day differed in length from the next – even by the tiniest amount – the systems that relied on rigid regularity would start to fail.

Yet, a solution to this problem came only 10 years after Harold Spencer Jones had made his prediction of clocks more accurate than the earth. In 1955, physicists at the National Physical Laboratory in Teddington, southwest London, built the first successful atomic clock. It used caesium atoms to keep time far better than planetary rotation.

The best pendulum clocks could keep time to an accuracy of one second in a year. The best quartz clocks of the 1930s were accurate to one second in 30 years. But the first atomic clock improved on quartz by an order of magnitude: it would neither gain nor lose more than a second over a running time of three hundred years. This was what the system builders of the twentieth century needed. Nonetheless, the rotation of the earth, while not perfectly uniform, is the way humans experience the passage of time. We are hardwired to the patterns of daylight and darkness, so the disparity between astronomical time and atomic time had to be balanced.

In 1972, the leap second system was born. The world's time now beats to atomic seconds, with all the advantages of uniformity they bring. Atomic clocks today offer, almost inconceivably, accuracy to one second in 15 billion years, which is more than the estimated age of the universe. But earth-rotation time continues to be measured, too. Whenever this is predicted to differ from atomic time by one second, the world's timekeeping community prepares for a leap second.

Back in 2015, the traders of Wall Street had good reason to worry as the leap second approached. On the previous such occasion, in 2012, the global reservation system of the airline Qantas failed, leading to worldwide disruption. Major web networks including LinkedIn and Reddit also crashed. The problems were all soon fixed, but calls to abolish leap seconds, which had first been heard in the late 1990s, became more persistent. Hiroki Kawai, the head of trading systems at the Japan Exchange Group, noted as the event approached that "as systems continue to be more and more connected, it's becoming harder and harder to predict just what the impact could be and how big."

THE DISPARITY BETWEEN ASTRONOMICAL TIME AND ATOMIC TIME HAD TO BE BALANCED

As it transpired, the 2015 leap second, as well as one inserted in 2016, passed without a major hitch. But time scientists meeting at a conference in November 2022 passed a resolution to call time on the leap second, and delegates at the World Radiocommunication Conference in Dubai are likely to agree to the move in late 2023.

One thing is sure: the earth will continue to turn and to keep its own time, however imperfect. Even as it diverges, slowly, from the official time on our clocks and wrists, astronomical time is a fundamental measure of humankind's place in the universe. ❖