An instant in time

How the atomic clock revolutionized time-keeping.

Splitting the Second: The Story of Atomic Time
by Tony Jones
Institute of Physics: 2000. 199 pp. £14.99, $19.99

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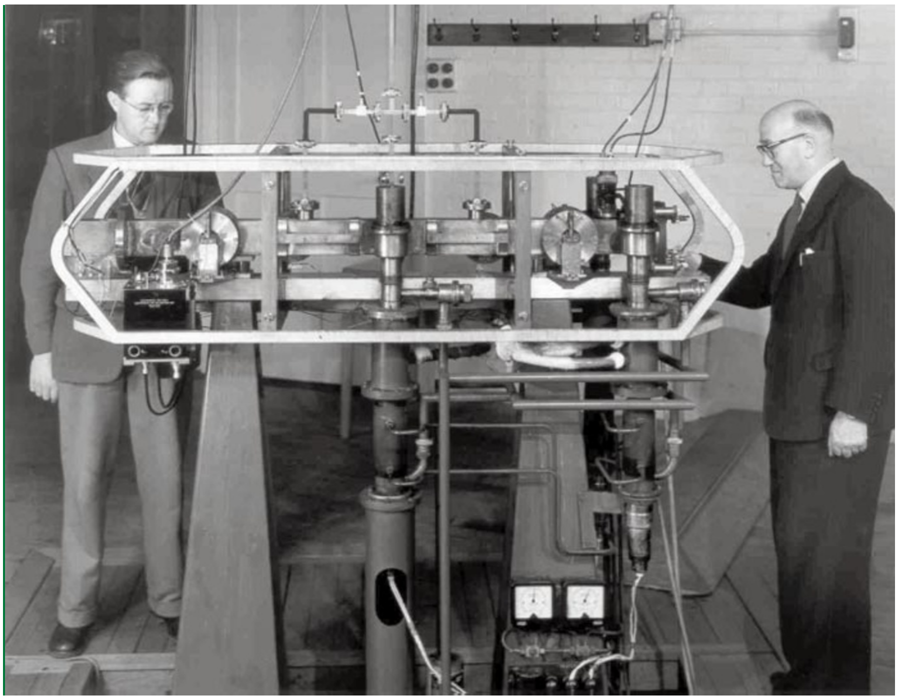

Clocking on: Parry (left) and Essen with their caesium atomic frequency standard.

By the mid-1950s astronomical timekeeping had achieved unprecedented accuracy, based on a deepened understanding of planetary and terrestrial dynamics and the development of the quartz crystal clock. In 1952 the International Astronomical Union introduced a new timescale — ephemeris time, based on the motions of the planets — and in 1956 it redefined the second in terms of the length of a solar year. But the 1950s also saw the start of a revolution in timekeeping that in a single decade wrested the second from the astronomers and made ephemeris time obsolete.

The revolution was precipitated by the creation of the atomic clock, a device so unclock-like in appearance and operation that it was every bit as unpalatable to astronomers in the 1950s as John Harrison's mechanical chronometer was in the eighteenth century. *Splitting the Second* recounts the events of this revolution, the subsequent progress in atomic clocks and the many applications of timekeeping, few of which were dreamed of when atomic clocks were created.

The possibility of an atomic clock was first suggested in 1945 by the Nobel prizewinning physicist Isidor I. Rabi in a throwaway remark during a speech to the American Physical Society. A number of US groups picked up on his suggestion, but the first working atomic clock was created in the United Kingdom. In 1955, Louis Essen and John Parry operated a caesium atomic beam clock at the National Physical Laboratory in Teddington. The device was actually an atomic frequency standard, but the term atomic clock has become generally accepted. The Essen–Parry clock achieved an accuracy of one part in 10 billion (1 in 10^{10}). Refinements over the decades have increased the accuracy by a factor of close to 10,000. Recently, the fountain clock, a new type of clock that exploits laser-cooled atoms, achieved an accuracy of close to 1 in 10^{15}.

An obvious question is why anyone would want such high accuracy. The book addresses this question by demonstrating that as timekeeping improved, new applications steadily arose. The most spectacular of these is the Global Positioning System, which is finding fresh applications almost daily, from aiding the navigation of ambulances and cars to measuring the drift of continents.

Accurate time is useless unless it can be disseminated, and *Splitting the Second* describes time dissemination in some detail. The echoes of history can still be heard, for instance, in the continued use of the term Greenwich Mean Time long after it became technically obsolete. The conflict between physicists' and astronomers' time can be detected in the international agreement for time dissemination. The time interval that is broadcast — the second — is physicists' time, controlled by an atomic frequency standard. But to satisfy the needs of astronomy, the timescale is adjusted to keep step with the slightly irregular motion of the Earth by introducing a leap second whenever the astronomical and physical times diverge by more than 0.9 seconds.

In one respect — reliability — atomic clocks cannot compete with astronomical timekeeping. To physicists, who generally care about measuring a frequency accurately rather than knowing the time itself, this is not of deep concern. But if one particular atomic clock, presumably the best in the world, were selected as the primary standard, sooner or later it would need to stop for repairs and the timescale would be broken. Consequently, primary atomic time standards are maintained not at one but at seven laboratories scattered around the world. These constantly compare their clocks both among themselves and with more than 200 secondary standards. The system is cumbersome but the timescale is accurate and reliable.

Jones recounts the historical events that underlie contemporary timekeeping and provides vignettes of the human factors involved in scientific and technological decisions. He makes a valiant effort to explain the science. His explanation of an atomic clock conveys the flavour of the physics and is probably as good as one can do in describing quantum phenomena in everyday language. Some details, such as the operation of a maser, are slightly confused, and some choices seem idiosyncratic. The name of Alfred Kastler, for instance, whose invention of optical pumping has played a continuing role in the development of atomic clocks, appears only in a list of Nobel prizewinners.

The book concludes with speculations on the future of timekeeping. These are not far-fetched, for the field is advancing rapidly. For instance, a method for measuring optical frequency, published too late to be described in the book, has opened the way to clocks that may one day achieve an accuracy in the range of 10^{18}. Anyone who is intrigued by fantastic precision or curious about how we really know the time, or simply likes tales of science and technology, will enjoy *Splitting the Second.* ■

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