TIME-RELATED ACTIVITIES AT THE ROYAL GREENWICH OBSERVATORY

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The Royal Greenwich Observatory (RGO) has a long history of involvement in timekeeping which began in 1675 when Charles II established an observatory in Greenwich Park to provide the astronomical foundations of a practical method for finding the longitude of ships at sea. The widespread acceptance of the methods developed at Greenwich led in 1884 to the adoption of the Greenwich meridian as the international zero of longitude, and of mean solar time on the Greenwich meridian (GMT) as the basis of the international system of time zones.

More recently the RGO has played a significant part in the development of modern timekeeping. For example, RGO worked with the National Physical Laboratory in the initial evaluation of the caesium frequency in terms of an astronomical timescale, and participated in the international coordination of time signals in the early 1960s and in defining the new UTC system that was introduced in 1972. RGO has operated commercial caesium-beam clocks in-house since 1966 and has collaborated with the US Naval Observatory (USNO) in monitoring Loran-C signals for timing purposes since 1969. In the 1970s we collaborated with the US Naval Research Laboratory in time-transfer experiments using the Navigation Technology Satellites which were precursors of the Global Positioning System, but we have found it progressively more difficult to obtain staff and resources for this kind of work. The difficulties arise partly from changes in the technological basis of precise timekeeping, and partly from changes in the responsibilities of the Observatory, the objectives of its sponsoring agency and the level of funding of this agency relative to the demands now made upon it.

Today the RGO, which is now based at Herstmonceux Castle in East Sussex, is an establishment of the Science and Engineering Research Council (SERC) within the Department of Education and Science. It is still involved in updated versions of its original objectives through the continuing work of HM Nautical Almanac Office and through satellite laser ranging (SLR), which has recently replaced classical astrometry as our operational technique for monitoring the rotation of the Earth. At present we also operate an ensemble of six caesium-beam clocks in a closely-controlled environment, and we use the independent timescale formed from them in our SLR activities and as a reference in monitoring four Loran-C signals, which still provide our operational external timing links. The Loran results are sent weekly to the USNO, which has provided some of the receivers and uses our measurements and others for precise control of the frequency standards at the transmitters. The clock and signal data are sent to the Bureau International de l'Heure for use in the formation of International Atomic Time. We also provide the time signal used by the British Broadcasting Corporation (BBC), issue Time Service Circulars concerned with Earth-rotation parameters, Loran-C reception and timescale adjustments, and respond to general enquiries about time and related matters.

But the primary role of the RGO is now defined as the provision and support of facilities for research in ground-based optical astronomy for use by British astronomers and their collaborators; its overriding priority is the construction and operation of observing facilities at the new Spanish Observatorio del Roque de los Muchachos in the Canary Islands.

The Time Service is now in competition for resources with major projects in the Council's future research programme, of which only a diminishing proportion can now be adequately funded. In these circumstances it has proved difficult to resist the following arguments:

a) The techniques of precise timekeeping are no longer based on astronomy; timekeeping using atomic clocks has become a branch of metrology with important technological applications, and its continuation and further development are more appropriately the responsibilities of metrological centres like the National Physical Laboratory or of major end-users such as the defence services.

b) The Global Positioning System now provides a timing reference that is accessible worldwide and seems likely to be adequate without correction for all but the most demanding applications. The GPS and other satellite-based systems can now provide, in collaborative mode, remote access to some of the most stable clocks currently in operation. Although astronomers require very precise access to a uniform timescale for research on, for example, gravitation or the physics of pulsars, it is no longer technically necessary for the RGO to maintain an independent atomic timescale for astronomical purposes. Such a timescale based only on an ensemble of standard commercial clocks now provides a form of insurance against the breakdown of international collaboration and an ability to detect some possible kinds of operational error, but it is otherwise less valuable than the international scale which can incorporate data from more clocks and advanced frequency standards as these become available.

In consequence it seems inevitable that the atomic-time aspects of the Greenwich Time Service will obtain only minimal in-house support in the future. Our continuing involvement in precise timekeeping seems likely to be linked to the needs of the satellite laser ranging system which we have operated at Herstmonceux with remarkable success since 1983 October. Despite the infamous British weather it has proved to be one of the most consistently productive SLR systems in the world. It has now replaced the photographic zenith tube as the British instrument contributing data to the international services monitoring the Earth's rotation. It is also of current or potential value in several other fields such as geodesy, geophysics and the calibration of space-borne instrumentation, but its future will remain secure only while we are able to demonstrate a lively interest within the UK in the scientific analysis or practical application of the data that it provides.

The accuracy of SLR systems is ultimately limited by uncertainties in the correction for propagation delay through the atmosphere and is unlikely to be better than 1 cm. Since satellites of interest may have velocities relative to the instrument of order 10 km/s or ranges of order 10 000 km we must ensure that our observations and those made elsewhere can be dated in terms of a common timescale with uncertainties substantially less than 1 μs and that time-intervals are measured with an accuracy better than 1×10^{-9}. These requirements should be comfortably within reach through GPS, which is in routine use at most SLR installations and is now available to us through Austron's generous gift of a GPS timing receiver for use in the Greenwich Time Service. Our established Loran-C links will provide redundancy. The "University of Maryland" timer within the SLR system generates an internal timescale with a resolution of 50 ps which is in principle accessible for precise time transfer, but at present we have no plans to use it for that purpose.

I hope that RGO will continue to contribute to the integrity of time-dissemination systems within Europe by monitoring and reporting the relationship between a smooth local timescale and the signals of GPS and Loran-C, but even this may prove difficult because of staff reductions and the SERC's recent decision to move almost all of the RGO's UK-based activities from Herstmonceux to Cambridge before 1990. At present the future location of the SLR system is still undecided.

QUESTIONS AND ANSWERS

GERNOT WINKLER, UNITED STATES NAVAL OBSERVATORY: I have a question on the slide. I don't understand why the average RMS residuals are largest for the total. You reported 5.1 cm and 1.7 cm. The largest number was in the total, 6.2. How could that be?

MR. PILKINGTON: I didn't put all the other stations on the slide. I didn't intend to dwell on this, but we have a third generation system, other systems do not necessarily have the same precision. The entire world wide system depends on a well distributed set of stations.