Report to CCTF from the National Measurement Laboratory CSIRO Australia

April 2004

1. UTC(AUS)

The history of TA(AUS) and UTC(AUS) over approximately the last 2000 days is shown in Figure 1. NML's present policy is to maintain UTC(AUS) within 1 microsecond of UTC. The calculation of TA(AUS) was terminated on 30 June 2003.

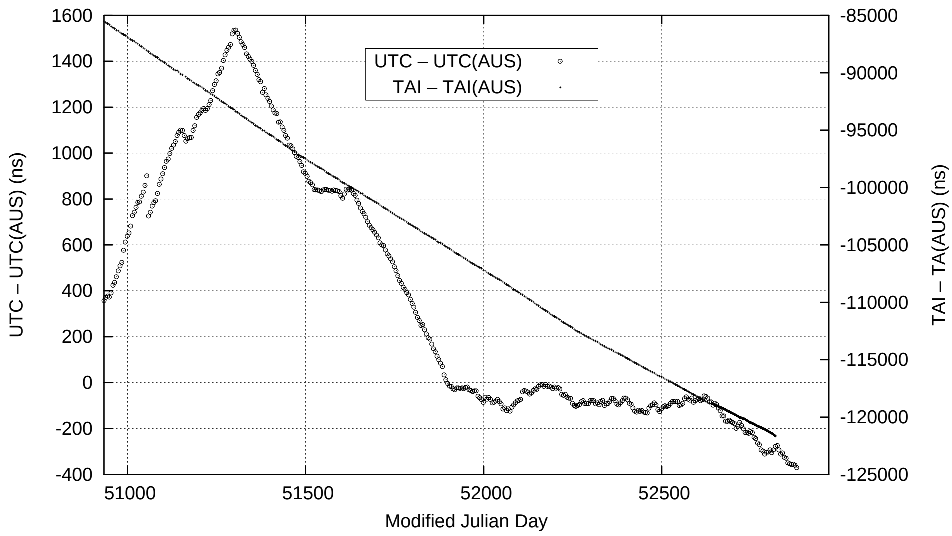

Figure 1: History of UTC(AUS) and TA(AUS) from May 1998 to November 2003.

MJD	***Date***	***Event***
51057	*1 September 1998*	*Step due to phase divergence between the clocks NML1141 and Orr207 between the date they were synchronised and the date the output of NML1141 was designated UTC(AUS).*
51162	*15 December 1998*	*NML1141 failed and was replaced by NML299 as the representation of UTC(AUS).*
51303	*5 May 1999*	*A steer was applied to the frequency of NML299 to cause UTC(AUS) to approach UTC at a rate of 5 ns per day.*
51530	*18 December 1999*	*A spontaneous frequency change in the output of NML299 occurred.*
51635	*1 April 2000*	*A steer was applied to the frequency of NML299 to re-establish the trend of UTC(AUS) towards UTC.*
51878	*30 November 2000*	*NML340 replaced NML299 as the representation of UTC(AUS), pre-empting the imminent failure of NML299.*
51899	*21 December 2000*	*A steer was applied to the frequency of NML340 so that the frequency of UTC(AUS) approximates that of UTC with minimal offset between the two time-scales.*

Table 1: Significant events affecting UTC(AUS).

2.Network Time Protocol (NTP) facilities

NML maintains timing facilities (figure 2) in Brisbane, Adelaide, Hobart, Melbourne and Perth, in addition to its primary facility in Sydney.

The remote (outside Sydney) facilities consist of a clock (Cs in Melbourne, Rb elsewhere) maintained on-time with respect to UTC(AUS) using NML GPS common-view (GPSCV) time transfer hardware and software. The remote systems are monitored and maintained from Sydney via an Internet connection. The remote facilities provide GPS integrity monitoring and Network Time Protocol (NTP) services.

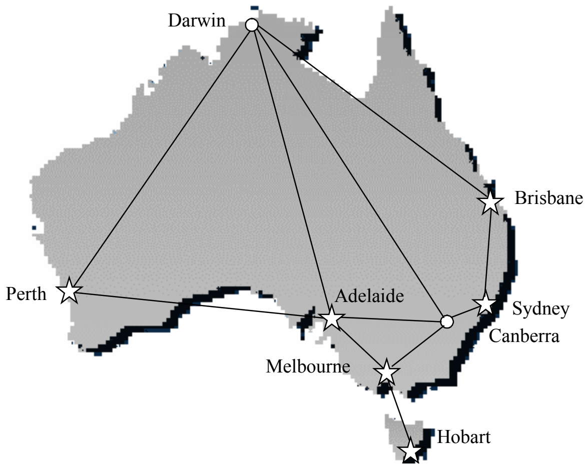

Figure 2: Remote timing/NTP/GPS Integrity monitoring servers in Australia – existing (✰) and planned (❍)

2.1 Network traffic problems

In the second half of the 2002 calendar year, a rapid increase in usage of the servers was noticed (figure 3). This increase was of concern, since if it continued at the same rate the charges for network traffic on the servers would have become unacceptably large within 12 months.

The cause of the excessive traffic on NML's NTP servers has been identified as an American company which has sold many thousands of cheap ($US48) domestic network router units with the IP addresses of the NML NTP servers hard-coded into their firmware. Analysis of received traffic indicates that most of these units are in the USA and Japan, with almost none in Australia. The company involved , after being contacted by NML, has issued firmware upgrades via their website, but this is not expected to reduce the traffic in the short term because the owners of these devices are unlikely to notice any problems and will not normally be motivated to install the upgrade.

Efforts were made to reduce the traffic by enlisting the cooperation of Internet Service Providers (ISPs) in blocking this traffic in the USA and Japan. However no interested response or cooperation was obtained. The previous Internet addresses of the Sydney, Melbourne and Perth servers were abandoned in early 2003, and since then most traffic to these addresses has been blocked at our request at the point of entry into Australia by telecommunications service providers. The existing servers were given new addresses and the service was re-established immediately thereafter.

To prevent a recurrence of this misuse, access to the NML NTP system is now granted only on request to individuals and organisations who provide the IP addresses of the computers which will access the NTP servers (up to 3 IP addresses per organisation). The servers will no longer respond to unauthorised time requests, whereas they previously responded to all requests. Users are being warned that it may in future be necessary to charge an access fee to maintain the service. To date, approximately 250 individuals and organisations have requested and been granted access to the service. The fan-out effect of this is very large, since many of these organisations (eg: universities) maintain NTP servers connected to the NML system which in turn provide UTC(AUS) to many thousands of computers and services on their internal networks.

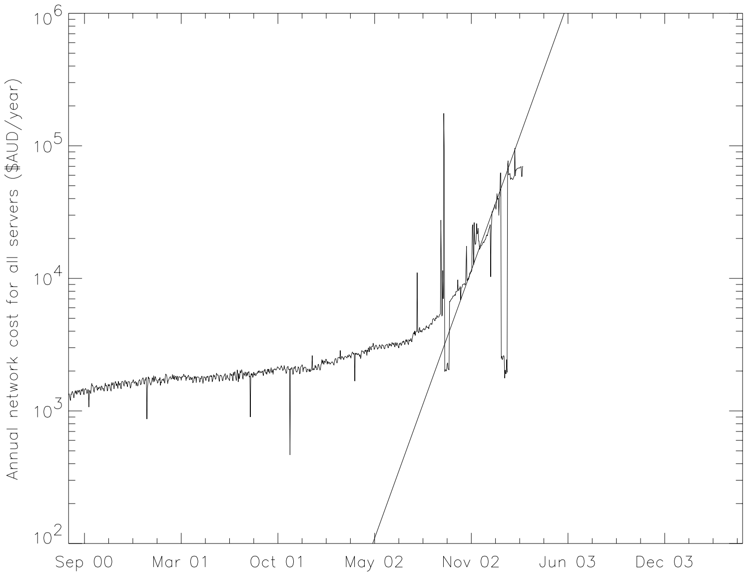

Figure 3: Network traffic expressed in terms of charges ($AUD 22/GB) on NML's national NTP network, showing the rapid increase beginning in mid-2002. The system was relocated to new IP addresses in early 2003 to avoid incurring very large traffic charges. The straight line is an extrapolation.

3. Asia-Pacific Metrology Program (APMP) Activities

NML has developed a portable version of its dual frequency GPS Common View time transfer system under contract to the Telecommunications Laboratory (TL), Taiwan. After calibration at SYRTE in March 2004, this system will be circulated among APMP laboratories to calibrate their receivers. Being a dual frequency system, it also generates carrier-phase RINEX observation files, which can be post-processed to calculate the coordinates of APMP laboratory antennas with centimetre-level accuracy.

4. Two Way Satellite Time Transfer (TWSTT)

NML's C-Band TWSTFT link with NIST's Fort Collins facility was extended to include the Telecommunications Laboratory (TL) in Taiwan in September 2002, and a three-way comparison was conducted for several months. Some difficulty was experienced in maintaining the comparison owing to limited availability of satellite bandwidth. This comparison was discontinued in April 2003 due to problems with the ageing MITREX modems, and data quality issues which may be partly due to ionospheric dispersion effects (the corresponding delay can be many ns at C-band frequencies, compared to sub-ns at Ku-band). The expense of maintaining the comparison was not considered justified until these issues were resolved. It may be possible to use dual-frequency GPS data recorded at both TL and NML to improve the estimation of total electron content (TEC) along the line-of-sight to the geostationary satellite, with a consequent improvement in the accuracy of a post-processed correction for ionospheric delay. NML is currently exploring this possibility via a collaboration with Dr Luigi Ciraolo of CNR Florence and Dr Ljiljana Cander of the Rutherford Appleton Laboratory in the UK.

NML also maintains a Ku-Band TWSTFT link with the Communications Research Laboratory (CRL) in Tokyo, and in early 2003 the link was upgraded with the installation of a new modem developed by CRL. This link will be discussed in CRL's report.

5. Laser cooled $^{171}Yb^{+}$ Trapped Ion Frequency Standard

Work on the NML 12.6 GHz $^{171}Yb^{+}$ trapped-ion frequency standard has continued slowly, as permitted by the other responsibilities of the Time and Frequency group.

It was reported at the 2001 CCTF meeting that the residual motion of the trapped ions has been well characterised and that Ramsey interrogation times longer than 10 s have been demonstrated, which together should allow a standard of both high accuracy (in the low 10^{-15} range) and high stability ($\sigma_y(\tau) = 5\times10^{-14}\ \tau^{-1/2}$ or better). Later in 2001 we reported the first operation of the laser-cooled standard, obtaining a value for the $^{171}Yb^{+}$ ground-state hyperfine transition frequency of 12 642 812 118.468 5(7)(6) Hz, where the first uncertainty combines statistical and systematic uncertainties and the second is that of a comparison between a reference hydrogen maser and the SI second. This value is in agreement with earlier measurements obtained for buffer gas-cooled ions where the second-order Doppler shift is 180 times larger. The systematic uncertainty of approximately 5 parts in 10^{14} was limited primarily by the homogeneity of the magnetic field within the trap.

Since this result we have concentrated attention on engineering aspects of the ion-trap standard, both to reduce limiting uncertainties and to improve operational reliability. We have addressed the magnetic field homogeneity by removing unavoidable residual fields associated with the UHV chamber and designing a custom vacuum system in the novel non-magnetic alloy CrCu. Manufacturing difficulties encountered in production now appear to be solved and we anticipate imminent delivery of this system. We have also explored alternative methods of generating tunable laser radiation at 369 nm, the wavelength of the $^{171}Yb^{+}$ optical resonance transition, including laser diodes emitting UV in the fundamental. Finally we have also studied the use of photo-ionization of neutral Yb to load the ion trap. This method has several key advantages, notably the reduction of stray DC potentials and the possibility of isotope-selective trap loading. To our knowledge the NPL group were first to load a single trapped Yb^{+} ion by photo-ionization, in August 2003; we were able to load a cloud of Yb^{+} ions of a single isotope for the first time earlier this year.

We believe that with these design improvements no fundamental obstacle remains to achieving the performance levels indicated above, and work is in progress to realise these in the laboratory.

6. GPS Common view time transfer system development – combined timing/IGS station at NML

NML has developed a software extension to allow its Javad-based dual frequency GPS common view time transfer systems to generate carrier-phase RINEX observation files., which can be post-processed using IGS products to calculate antenna coordinates with centimetre accuracy. Using the Javad Euro-160 GPS receiver, which can use an external reference frequency input, allows the system to serve simultaneously as a fully CGTTS-compatible dual frequency time transfer system and an IGS reference station. With the cooperation of Geoscience Australia, the Australian Government organisation that operates Australia's IGS processing centre, NML is constructing an IGS antenna monument which will ultimately serve as an IGS station and Australia's principal GPS common-view link to UTC.

More than 30 NML timing systems are now in operation in Australia and other Asia-Pacific countries, including Fiji, New Zealand, Indonesia, Singapore, Malaysia, Thailand, Vietnam, Taiwan, Japan and the Philippines.

7. Remote frequency reference systems

NML has combined its Javad-based GPS common-view time transfer system with a Stanford-research Rb standard to provide a “turnkey” package which provides a customer with an on-site frequency and time reference system which is operated by NML, and on which NML issues weekly Measurement Reports to establish legal traceabiity. At the time of writing, eight such systems have been provided to customers.

8. Telephone time system

NML is developing a “speaking clock” system to provide audio time information in response to a telephone call from a client. The system is based on the same LINUX platform on which NML’s GPS common view timing systems are based, and uses computer telephony technology. The architecture of the system is designed to satisfy the requirements of legal traceability of the time information at the point of injection into the public telephone system.

The system is scheduled for completion in June 2004.

9. Training courses

NML held a two-day training course in time and frequency metrology on November 2003. This course was well received and an extended version of the course will be held during the next 12 months. If there is sufficient interest an additional course for participants in the Asia-Pacific region will be held at a venue to be determined.

10. Changes at NML(AUS)

In May 2003 the Australian Government announced that it had decided to establish a National Measurement Institute (NMI) by combining NML, the Australian Government Analytical Laboratory (AGAL) and the National Standards Commission. The NMI will provide physical, chemical and legal metrology services from within one organisation.

The NMI will come into existence as part of the Department of Industry, Tourism and Resources on 1 July 2004, and will consist of approximately 325 staff. It is expected that all functions presently carried out by NML will continue without substantial change in the NMI.