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DEPARTMENT: ANECDOTES

Computer Networking Initiatives in One of the World's Remote Cities

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This article describes some computing initiatives made by members of the University of Western Australia, located in arguably the most isolated capital city in the world. These initiatives center around online and networking capabilities, predominantly arising from the installation, in 1965, of the first time-sharing computer in Australia. This far-sighted, if risky, purchase set the university on a course that led to many more initiatives, encompassing significant computer resource sharing, a ground-breaking online library system, early online education programs, and an early multihost packet-switched network. Most research concerning isolation and innovation suggests that isolation operates as a break on innovation, but the Western Australian experience belies that conclusion.

WESTERN AUSTRALIA MADE A LATE START IN COMPUTING

Perth, the capital city of the State of Western Australia, is often considered to be the most isolated capital city in the world. Regarded by many at the time as something of a "quiet backwater," so it was not surprising that it was not until 1962 that Perth (and hence the whole of the 2.6 million square kilometres of Western Australia) took delivery of its first computer, a Bendix G15, bought by the Main Roads Department to help in the design of freeway extensions and interchanges [28]. It was followed that same year by an IBM 1620 bought by the University of Western Australia (UWA) [19], [28]. This was well after most other Australian capitals (and universities) had acquired computers [17], [18], [19].

Given this slow start, it is perhaps rather surprising that Perth did not long remain quiet in computing. By 1964, the capacity of the university's IBM 1620 was overwhelmed by demand from university and external users, and a search began for a much larger replacement. IBM were convinced that the university would just buy it from their stable, especially since they had just announced their System/360 range, being the first line of computers incorporating the same instruction set and designed for all users large and small [7], [14].

TIME-SHARING COMES TO AUSTRALIA

However, the university's Computing Centre Director, Dennis Moore, was familiar with MIT's multiuser, time-shared computing Project MAC, and believed that this was the way of the future [8], [11], [14]. There were only two companies worldwide at the time offering to sell such computers, though none had yet been sold. These were the Canadian division of the British firm Ferranti Limited, and the Digital Equipment Corporation (DEC) in Massachusetts, USA [1]. IBM did not support time-sharing on its System/360 range until 1970 [7].

The funding of public universities in Australia at the time was split equally between the Federal and State governments, with triennial grants made available for capital items such as computers. The university obtained such a capital grant and issued tenders. There were four contenders—IBM, ICT (later ICL), DEC, and Ferranti. Each made presentations to the university's Computer Users Group [13]. The Ferranti-Packard salesman was very persuasive about the benefits of time-sharing and "almost had the Computer Users Group cheering" for its 6000 model, recounted Moore [14]. He was in fact selling the DEC computer [11], [13]. Designed originally to share computing with equipment operating in laboratories, the PDP-6 was a

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full time-sharing machine incorporating the hardware to do this efficiently [1].

Despite efforts by IBM to reverse the decision, the University resolved to buy a PDP-6. This was an extraordinary decision. Digital Equipment was a small, almost unknown, company; time-sharing was a great laboratory experiment, but there were no systems commercially available and in use in the field; and Perth was the furthest place in the world, the almost exact antipodes, from Digital's factory in Maynard, Massachusetts. When the computer was delivered in May 1965, it became the first time-shared computer to be delivered to Australia [2], and among the first in the world. The foresight and bravery of Moore and Birkett Clews and the university was quite remarkable.

Along with the computer came the DEC systems engineer responsible for developing the time-shared operating system, who proceeded to spend much time refining the software—he sometimes used a camp stretcher so he could work on the computer overnight [14]. Thus, time-sharing was introduced to Australia, incidentally bolstering Digital Equipment's market position there.

SHARED COMPUTING

Numerous terminals were connected to the PDP-6 over telephone lines. These were originally teletypes, adapted from telex machines, operating at 110 or 300 bits per second (approximately 10 and 30 characters per second), but the PDP-6 promised more than just connecting terminals; it was acquired in part to enable a range of laboratory experiments to connect and be directly controlled by the computer. These included a diffractometer and a spectrometer in the Physics Department, an analogue computer and field recorder in engineering, a flying spot scanner in the Crystallography Laboratory, a rat race and a perception laboratory operated by Psychology, and a flying spot scanner in the Pathology Department [14]. In the early days, these devices were interfaced by an electronics engineer, Ian Nicholls, employed by the Centre, who undertook some ground-breaking work [14].

Other agencies around Perth, including CSIRO and the technical divisions of various government departments, had drawn on the capabilities of UWA's IBM 1620. With the advent of the much more powerful PDP-6 in 1965, along with its time-sharing and remote connectivity capabilities, this usage burgeoned, encouraged by the university who saw this sharing almost as an obligation given the remoteness of Perth. This laid the groundwork for the high degree of collaboration and sharing that characterized public sector computing in Western Australia for many years to come, paving the way for the creation of the Western Australian Regional Computing Centre in 1972 (see below).

This acquisition of a revolutionary and architecturally pioneering computer system allowed a wide range of novel applications to be developed, in particular running online experiments in laboratories around the university. This was exemplified by the Department of Psychology, one of whose fields of research was in visual perception. Being able to use the computer in real time to control images that human subjects were allowed to see, and how they perceived them, enabled significant advances in understanding the human perception system [30]. This led subsequently to the invention of the Betagraph, a visual display system that relied on the human eye and brain's ability to fill in missing information, as when a moving car is perceived through a picket fence [30]. Controlling such experiments by computer is widespread today, but it was a new experience for researchers in the 1960s. Similar advances were made in the fields of crystallography, physics, and physiology, among others.

LATIN INSCRIPTIONS

Not all uses of the PDP-6 were based on its online capability, though that was often exploited at different stages of the project. An example was Professor E. John Jory's creation in the early 1970s of an index to all the inscriptions found on ancient monuments around Rome. These had been accumulating since 1862 into Volume VI of the *Corpus Inscriptionum Latinarum* (*CIL*). The solution was to create a key word in context (KWIC) index, but much of the data entry and program development was undertaken online. The data entry took well over two years, the main problem being that the inscriptions were two to three thousand years old, and every inscription entered produced something new to be programmed for, because there was no standard format. Resolving these issues with Jory able to access the data online from his office shortened the project considerably.

When the index's 7315 pages were published in 1975 by the Academy of Sciences of the German Democratic Republic, Jory received international recognition. Since the appearance of Jory's KWIC index, computer applications and databases have had a major influence on epigraphic studies [8], [10].

UNIVERSITY OF WA FORTRAN TRANSLATOR, UNIWAFT

Another project which did not altogether rely on the online nature of the PDP-6 was the development of a

Fortran compiler. The PDP-6's standard Fortran compiler produced correct, fast, and reliable code, but it was unsuitable for teaching purposes: it was slow to compile, produced arcane error messages, and stopped analyzing ("parsing") the program at the first error encountered. Of course, the online nature of the PDP-6 meant that many users could develop and test their Fortran programs online. However, the volume of students wishing to do so outstripped the computer's capacity to support them simultaneously. The goal was therefore to develop a fast Fortran compiler that would have rich error messages and which undertook as much parsing as possible at each attempt. The result, released for the start of the 1971 academic year, was a system called Uniwaft—University of Western Australia Fortran Translator. It was itself written in Fortran, which made coding the system that much faster—and eased its transport to subsequent computers [22], [24].

The system was extended in 1972 to WA State high schools, called Miniwaft, using specially prepared preprinted punched cards. Chads on these were pushed out using a paper clip, based on a similar arrangement developed at Monash University [31].

ONLINE EDUCATION

The potential for online teaching presented by the PDP-6 was not missed, even though systems like Uniwaft and Miniwaft were batch processing systems. Before 1977, there was no department of computer science at UWA, but Centre staff were active in the Australian Computer Society, with the WA Branch having been founded by the then Director, Dennis Moore [19]. Staff was keen to promote this new computer architecture and its implications for the future of computing. A series of professional development seminars was launched, with some using the PDP-6 [23], [26]. In particular, a simple database package, Data Management Package (DAMP), that implemented the CODASYL-linked database architecture, was used to teach database architecture. In one of the first examples of online education in Australia, students (in this case, Computer Society members) created an online database and interacted online with their data [26].

THE FOUNDATION FOR THE WA REGIONAL COMPUTING CENTRE, WARCC

One of the consequences of having a time-shared computer, featuring online connections on campus and off, was that the technical divisions of many government departments were able to connect to it remotely. UWA encouraged this sharing and established charges for computer use in order to ensure equitable access. Many of these external organizations in any case had close ties with the engineering or scientific disciplines within the university, who, like the Computer Society, ran regular professional development seminars for their alumni. Accordingly, considerable use was made of the PDP-6 by organizations like CSIRO, and the technical divisions of the Main Roads Department, the WA Water Authority, and the State Electricity Commission. In addition, a number of private engineering consultancy firms also became customers.

Inevitably, it was not long before the capacity of the PDP-6 was sorely tested. Initially, various upgrades were made (e.g., additional memory, magnetic tapes, and disk drives for storage and program "swapping"). But by 1970, it became clear that a major upgrade or replacement would be required [8], [14]. As indicated above, major purchases of this kind were funded on a triennial basis by the Australian Universities Commission (AUC), an agency of the Australian federal government. For the triennium 1970–1972, the AUC had ruled that it would only support grants to universities which were prepared to share computing resources, in order to take advantage of the economies of scale available at that time for large computers. Discussions ensued between the universities and colleges in all the Australian capitals to attempt to reach agreement. However, only in the case of Western Australia was agreement reached: A heritage of the sharing that had been happening there for several years. No university in any other city received a computer grant in that triennium [19].

In order to set this arrangement for sharing on a more formal basis, it was agreed to set up the Western Australian Regional Computing Centre (WARCC), housed and managed by the University of Western Australia, under the direction of a Board of Management made up of representatives of the major users (see [8, Section V]). The primary users would consist of the UWA, other tertiary education institutions, state government departments, and statutory authorities, and the CSIRO, serving in particular their scientific and engineering computing needs. The computer would be expected to support local batch processing, remote batch processing, and remote interactive processing (the role of direct computer-controlled laboratory experiments by that time had largely been taken over by minicomputers). The Centre would operate along commercial lines, charging all users (including the university) according to the computer time

FIGURE 1. Reconstructed IBM 1620 console [photo credit Alex Reid].

used, and all expenses (including staff salaries) would be met from this revenue. The university would provide accounting and some administrative services, along with power, cleaning, space, etc., and would bill the Centre accordingly. Computer charges were to be set at a level that would cover all expenses, and also to allow the accumulation of a small reserve for purchasing additional equipment.

WARCC officially came into existence on 1 January 1972, after over two years of discussion and negotiation [8], [13], [14]. With $A470,000 available from the 1970–1972 Triennium, and the prospect of similar funding available from the 1973–1975 Triennium, proposals were received from Digital Equipment Corporation for a PDP-10 (a later version of the PDP-6) and Control Data Corporation for a CDC 6400. In the end, and after some time, the decision was made to purchase a Cyber 72 (a later model of the 6400) from CDC, which was delivered to the Centre, by then housed in a new extension to the university's Physics Building, in August 1972 (see Figure 3).

FIGURE 2. The PDP-6 after delivery to UWA, L to R: DEC Australian sales manager Ron Smart, UWA deputy vice-chancellor professor John Birkett Clews, UWA Computing Centre director Dennis Moore [photo credit UWA].

FIGURE 3. Front entrance to WARCC, UWA [photo credit UWA].

The Cyber 72 was the most powerful computer yet installed in WA, and was among the most powerful in the country (see [8, Section V-E]). It had 60-bit words (compared with the PDP-6's and PDP-10's 36-bit words), and all peripheral input/output activity (e.g., disk drives, tape drives, card reader, printer, remote communications) was handled by multiple peripheral processors, so that the main central processing unit was dedicated to calculating, at which it excelled. The 60-bit words gave it very high precision in arithmetic calculations, which greatly pleased the scientists and engineers among its users. This Cyber 72 was later upgraded to a Cyber 73, and subsequently to a Cyber 720. Curiously, and presumably for marketing purposes, the Cyber 72 was in fact identical to the Cyber 73, but incorporated a circuit designed to slow it down; upgrading it to a Cyber 73 involved simply removing that circuit (and the payment of additional funds). The computer ran the SCOPE (later NOS/BE) operating system and provided a wide range of scientific and other software. The Uniwaft Fortran compiler was transported to the Cyber with little difficulty.

Soon, many terminals and a good number of remote job entry systems were connected to the Cyber from across Perth. The PDP-6 had been transferred to WARCC in 1972, and its time-sharing feature was still very much favored for certain applications. In due course, therefore, it was decided to replace it with a compatible, but much faster PDP-10 with its KA10 CPU. Use of these systems continued to grow, and

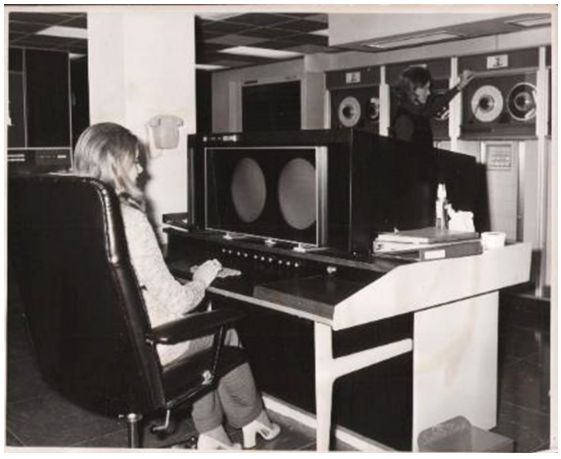

FIGURE 4. The main console of the cyber72 [photo credit UWA].

WARCC with it, with regular upgrades of the main computing equipment funded by the growth in usage and thence revenue (the PDP-10 was replaced by a DECsystem-10 with a KL10 CPU in March 1980). At the same time, the WARCC diversified its services into applications software programming, networking, minicomputer support, and subsequently microcomputer sales and support, and facilities management (e.g., housing and operating the State Health Department's computers).

By 1990, WARCC had a staff of over 100, an annual turnover of $A10 million, and was highly regarded throughout the State (see Figures 5 and 6 [27]). Indeed, the Public Accounts and Expenditure Review Committee of the WA State Legislative Assembly strongly recommended the WARCC model of computing for the rest of the WA public sector [29]. Ultimately, however, mainframe computers became uneconomical in this environment, and by 1992 those at WARCC were decommissioned, with the Centre's diversified

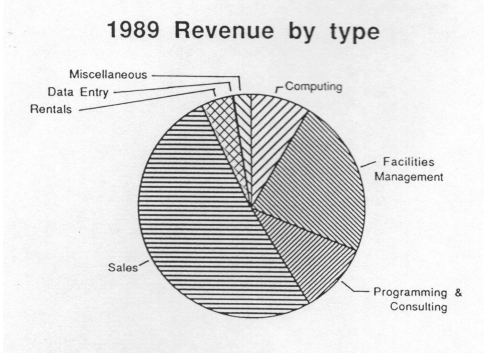

FIGURE 5. WARCC sources of revenue 1989 ([27, p. 1]).

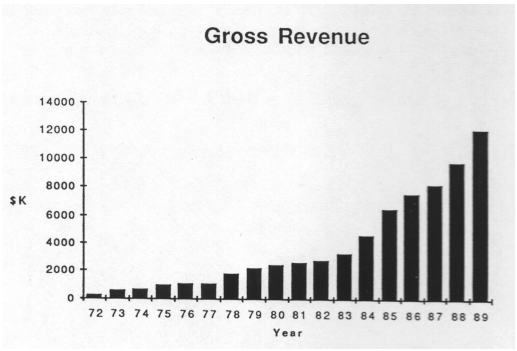

FIGURE 6. WARCC revenue growth 1972–1989 ([27, p. 1]).

activities ensuring its continued economical operation [32]. By then, WARCC had been operating successfully for 20 years, with gross revenue growing at an annual compound rate of 25% (see Figure 6), a testament to the networking among public-sector computer users in WA, seeded by what the PDP-6 had initiated.

LIBRARY CIRCULATION SYSTEM, LOANLY

Inspired by the power of online systems, David Noel, the systems librarian in the University Library, had a vision for a loan system where library users recorded their loans themselves using online terminals [15]. Some public libraries in the U.K. had embarked on this course, but no university or college libraries worldwide could be found to have attempted this. The volumes in the UWA library had already each been equipped with an 80-column punched card, which provided the title, author, and basic identification data; students and staff of the university had identification cards that resembled abbreviated, plastic, punched cards containing their unique staff or student number.

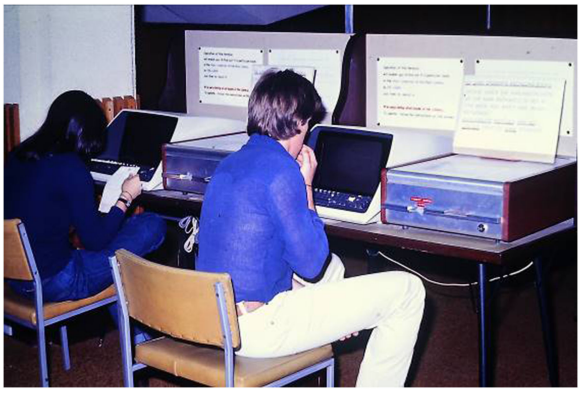

FIGURE 7. LOANLY users at work [photo credit UWA].

Consequently the library commissioned WARCC to develop this system, with custom-built terminals for reading book and borrower cards from a U.K. company. A DEC PDP-11/40 was selected, and programming began at the start of 1973. Despite some setbacks, a working system was implemented by mid-1975 [15], [25]. This integrated the records of books that had been borrowed with records of all the books in the library's collection. This enabled remote catalog enquiries: if sought items were on loan, they could be recalled by the enquirers themselves online. Thus was implemented a radical, self-charging, university circulation system and described at the time as "trend-setting" [4], [16]. Its name, LOANLY, was a homophonic nod to the character in the very popular, if bleak, TV spy series *Callan*. A caricature of Lonely was used in promoting the system.

Some valuable lessons about the nature of online systems were learnt through this project and conveyed to the Australian computing community through a lecture tour conducted by Alex Reid, together with a lead article in the *Australian Computer Bulletin* [20].

Of course, circulation control is just one of many applications of automation in libraries. Since it is perhaps where library staff time could save the most time, it has generally been the first function to be automated. Other applications followed, including acquisitions, catalog maintenance, serials management. Initially developed independently, commercial providers overtook in-house applications in the mid-1980s with comprehensive software systems like URICA and LIBERTAS [4], [9].

PACKET-SWITCHED NETWORKING

Based on its early start in data communications, connecting ON- and OFF-campus remote terminals to a central computer over telephone lines, WARCC soon realized that data communications networks represented significant potential. Initially, the focus had been upon hardware developments, to facilitate connecting terminals. These included the design and construction of modems (to enable reliable transmission over long distances), and multiplexors—-to enable sharing of communications links by several terminals [13]. In the late 1960s and early 1970s, the cost of telephone lines in Australia was relatively prohibitive—in part due to its long distances, but also due to the monopoly enjoyed by the Postmaster-General's Department (later Telecom), which was not only the sole provider but was also the regulator. For example, the Computing Centre staff had developed modems for use ON-campus, but was unable to get them approved for use off-campus [8], [14].

The problems encountered in licensing data communications equipment was one reason why hardware initiatives gave way to the use of software to enhance data communications capabilities. The main reason was however the flexibility that software afforded, and it was clearly going to be a much more fruitful approach in the long run. Several networking projects were initiated, starting with the clustering of remote terminals. Some computer manufacturers already had "terminal cluster" systems, but they were very expensive and not particularly flexible. It was decided instead to buy small minicomputers (e.g., the DEC PDP-11/10) and program them to emulate these terminal clusters. This relatively simple adaptation increased staff competence in communications software that opened up many more possibilities [21].

At that time (1973) WARCC operated a Cyber 73; it also still ran the PDP-6 then the PDP-10. It had become obvious quite early on that these two architectures complemented each other rather well—one being a powerful batch processor, with the other ideal for remote multitasking. Neither firm's machines could undertake both modes well together.

A PDP-11/10-based terminal cluster system was installed at the Western Australian Institute of Technology (later, Curtin University) to connect the institute to the WARCC PDP-10. It was also found beneficial to replace the terminal handling system on the PDP-10 with a similar minicomputer, emulating the DEC-supplied interface. Beyond the significant savings, this move more importantly opened up the opportunity to adapt both sets of emulators to accommodate traffic destined for the Cyber as well as the PDP-10. The Cyber relied heavily on remote job entry (RJE) systems, which provided a card reader and printer, and a communications link to the Cyber: This enabled remote users to submit their jobs to the Cyber using equipment on their own premises. These RJE systems were also expensive, and replacing them by much cheaper emulators had the added benefit that these could be programmed to perform other functions. One of these was to turn them into conversational RJEs (CRJEs), whereby remote users could develop their programs interactively, submit them to the Cyber for processing, and interact online with the results [13], [21].

Another challenge which proved to be simple given the background of the WARCC Network team, was interfacing the Cyber and DECsystem-10 directly with each other, so that data files could be moved between the two systems. It had become clear that the ideal

way to manage data traffic between computers and end-user devices was to employ "packet switching." As early as 1974 the Centre's staff began researching the technique, but trod very cautiously in view of others' failure in this field. By 1977 packet switching had become fairly well-established overseas, e.g., with ARPANET (precursor to the Internet [6], [12]) connecting some universities and research laboratories in the USA, but it was not extended to Australia. The monopoly data communications provider in Australia, Telecom, had plans for a common packet-switching service, but was slow to implement them [3], [19].

Meanwhile, talk of a Western Australian Regional Computer Network started to gain momentum, again with some caution, lest some agencies felt that this was a political move to grab control of public sector computing [8], [13]. But no one could deny the logic that, in a state as large as WA, and with such a scattered population, it made sense for public sector entities to share communication lines to remote centers. While the political investigations continued, with the State government, for instance, collecting data on traffic volumes and projections, WARCC continued to investigate the technology.

Overall, the goal was to devise a networking environment, which would rationalize the diversity of communications links required, while providing a vehicle for both terminal and file traffic between multiple hosts and other networks.

Computer suppliers were canvassed, but few rose to the challenge. Ultimately, only DEC's offering, DECNET, seemed promising, and WARCC launched a project to experiment with it. It was found to be surprisingly straightforward to connect the DEC-10 at WARCC with one that by then had been installed at WAIT. By the spring of 1977, a packet-switched multihost network had been installed between WARCC and WAIT that employed a 4800-bps synchronous line rented from Telecom, using PDP-11/40-based DN87 interfaces in front of each DEC-10 [21]. It performed remarkably well. The team then interfaced WARCC's Cyber to this network through emulation—making the Cyber look like a DEC-10 to the network and the network look like a standard terminal cluster to the Cyber. No changes were made to the operating systems of either the DEC-10 or the Cyber—an important requirement to minimize future support.

By the beginning of 1978 the Cyber had joined this fledgling, packet-switched, multihost network. The next phase of expansion was to connect PDP-11 computers at various agencies across Perth. This proved surprisingly difficult, as it was discovered that there were two incompatible versions of the DECNET

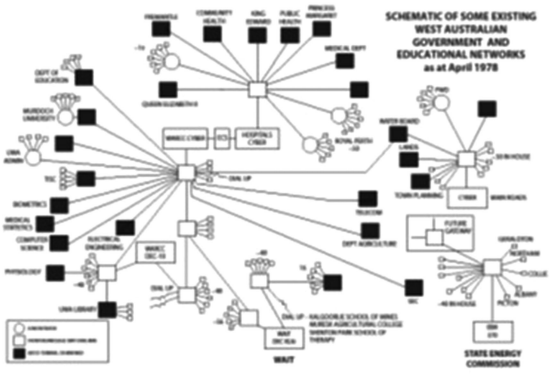

FIGURE 8. WA regional network in 1978 (from [13]).

software and protocols. In the end, the same approach was taken as with the Cyber, that is making the PDP-11s look like DEC-10s to the network; the first such link was installed early in 1978 on the PDP-11/34 at the Nedlands College of Advanced Education over a 2400-bps line. The network expanded rapidly, with a CRJE being connected, as well as the Cyber 172, at Main Roads Department, along with various other minicomputers and terminal clusters. Toward the end of 1980, when CSIRONET became operational, a two-way gateway based on a PDP-11/40 was installed. Work continued on connecting other public-sector computers, such as the Interdata 8/32 at Murdoch University, and various IBM systems that were installed across the public service, as well as gateways to other national and international networks, such as ARPANET [21].

Thus, what appears to be the first packet-switched multihost network in Australia came into operation by early 1978 (see Figure 8). It was recognized that there were several overheads in employing packet-switching (as opposed to use of devices like PABX's), but it was clear that this was the path of the future in view of its flexibility and versatility, and this has indeed been borne out by history. Interestingly, as with ARPANET, one of the chief benefits of this regional network was the widespread uptake in the use of email [21].

EPILOGUE

Research findings from a variety of sources (e.g., [5]) suggest strongly that isolation impedes innovation. However, the evidence from the projects described in this article, originating in arguably the world's most isolated city, would seem to belie that formulation. The cited research is based on patents and start-ups, but those are only one measure of innovation. No patents were sought from any of UWA's initiatives, and there were no notable start-ups, with one significant

exception—Monte Sala, whose work is described elsewhere in this issue.

The simplest explanation of why so many notable initiatives arose at UWA is the early start, which it gained in online systems and networking through its bold purchase of Australia's first time-shared computer. All the initiatives described have at their core the online paradigm and demonstrate a progressive realization of computer networking. The networking went beyond physical data communications to foster the close-knit networking of computer users throughout the city of Perth. At the time of these developments, Perth was a city of half a million people, but has since quadrupled in population. It has lost the characteristic which led Dennis Moore to observe that it was small enough for people to be able to talk to each other, but large enough to support technical initiatives [13], [14]. Now that further developments of networking, in particular the Internet, have shrunk distances worldwide, Perth can no longer be considered a "backwater"—if indeed it deserved that epithet 60 years ago.

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