INVENTION AND INNOVATION IN AUSTRALIA: THE HISTORIAN'S LENS*

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There is a strong body of opinion that Australia's present technological achievement and poor attitudes to high technology development remain essentially 'colonial'. This notion is a misconception. An overview study of some 100 inventors, technologists, and entrepreneurs indicates that vigorous attitudes to innovation prevailed in the Colonies in the nineteenth century and established for Australia some significant technological leads. Lessons from these attitudes both underline the continuing importance of the 'lone inventor' and hold relevance for education, management, and technology policies today.

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Australia confronts us with a paradox. It is widely asserted that we are a highly inventive people — give an Australian a piece of wire and a pair of pliers and he will invent something. Yet there is mounting evidence that, as a country, we rate very low on the world scale of industrial innovation; our manufacturing base is weak, historically and contemporaneously we derive much of our industrial development from imported technology and processes, and we are having immense difficulty in even so much as lifting off the ground to enter the international high technology stakes. Barry Jones, first as Opposition spokesman for Science and Technology and as present Minister for Science, has frequently asserted that the Australian attitude to technology and industrial development remains 'colonial'.

But what, in truth, does this mean? What was the record of colonial activity in the development of indigenous technology? What were the attitudes that prevailed? What are the historical roots of our technological position? And, as these questions are posed by a historian of technology and an analyst of contemporary technology policy critical of the 'ahistorical' approach in policy studies, what light can we glean from the historical evidence in Australia that might assist us in resolving problems of innovation and technology policy today? Having said this, it should be emphasised that this is essentially a paper designed to explore broad indications in the historical data

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and to consider some comparative ideas. It is presented in the hope that it will stimulate criticism and lead to a deeper and more rigorous assault on what seems to be promising and suggestive evidence.

In this exercise, can history serve us? First the ground must be cleared. In looking at innovation in the nineteenth century, this paper does not deal with the quite remarkable amount of *ad hoc* invention, introduction and adaptation of technologies, and entrepreneurial activities that went on in all the Australian colonies since the first pieces of machinery were dumped at Botany Bay, and that led to the sustenance of the settlers and later to the development of diverse local industries that made the growing population of Australia self-sufficient in the commodities of life. Godfrey Linge's large and scholarly work covers this absorbing topic.[1] His book gives powerful reinforcement to what Manning Clark has called "the bush convention — all that making do, that genius for improvisation of the great army of the deprived in the Australian bush".[2] There is more besides, including the important business of coming to grips with a wholly new environment in an unknown country, with new and little understood products, indigeneous timber, coal deposits for making gas, with fibres, the commercial use of flora, and with building small but successful industries in widely dispersed areas of Australia.

The object here is, rather, to deal with questions of invention and innovation that take the country into new orbits, build exports, speed industrial development and move Australia into a significant position to be counted as a technological runner among Western industrial nations. It is worth emphasising this point since Australia occupied that position more seriously at the turn of the nineteenth century than it has ever since.

As the nineteenth century was essentially the era of the individual inventor and entrepreneur, the methodology of the study turns on individuals; 'organisational innovation' does not figure at this stage. Much has been gleaned from a major tool, the *Australian Dictionary of Biography,* prepared by the Australian National University and published in 10 volumes covering, to date, the years from 1788-1939. The volumes contain biographies of key, and its editors claim, 'representative' Australians from earliest settlement to the outbreak of the Second World War: each person features in a volume according to his/her 'floruit' — the time of major contribution to national life. It is true to say that, for the present purposes, the *Dictionary* is not a perfect source. It reflects the established interests of Australian historiography: it is preoccupied with the importance of politicians, governors, magistrates, judges, public administrators and clergymen, and it assigns a lesser importance to technologists, scientists and industrialists, though in the later volumes (covering 1901-39), scientists and technologists are beginning to find a larger place.

Nonetheless, over the period from our beginnings in 1788 until 1901, I have drawn a sample of some 103 who qualify as inventors, technologists and entrepreneurs, and another 180 or so described as engineers. It is a sizeable enough sample from which to draw some themes and ideas about a special category of men and experience in the colonies. This total, of course, includes those who initiated and pushed *local* manufacturing forward, who brought technology to Australia, and conjured up transport, telecommunications and engineering services. But it also provides a smaller sample of approximately 40 figures who were involved with major innovative undertakings.

From these collective entries, what seem to be some quite illuminating conclusions can be drawn about our inventive and innovative background, and certain patterns and trends stand out. These can be specified briefly here:

(i) First, and perhaps less obviously than has been generally admitted, Australian invention and the development of this invention into important innovation rested heavily not only on imported *British* talent of immigrants from England, Scotland, and quite notably from Ireland; but also on Italian, German, French, American and Canadian skills. There was a wide multicultural input into the most promising technological developments in colonial Australia.

(ii) Secondly, this migrant talent and its ideas stream flowed into diverse, often idiosyncratic fields of creative invention, as the mood struck the individual inventor, sometimes following from experience at home, but more often from seemingly more whimsical inspiration in a new land. This inventive breed emigrated to the colonies for assorted personal reasons; for new opportunities, in response to the gold rushes, even (as in the case of American and European mining managers and engineers) as a result of direct invitation. They fertilized a wide area of inventive development across food canning, refrigeration, windpower, irrigation, hydraulic railway brakes, light projectors, vehicle headlights, motor transport, and even tanks.

(iii) Most significantly, one pattern emerges. All successful migrant inventors came from backgrounds of strong technical education and expertise. Some were skilled and knowledgeable artisans, but, predominantly, most had engineering, mechanical or scientific education grafted onto their original education. They came with university degrees, with experience in 'go ahead' mechanical establishments, from entrepreneurial undertakings in Britain, Europe and North America, and they brought drive and knowledge to the remote colonies.[3] This aspect of Australian development has been seriously underestimated; that is, the sense of the collective technical manpower which fostered domestic manufacturing, to become, according to Butlin, the fastest growing sector of the Australian economy in the last quarter of the nineteenth century.[4] Australia was not reared on the shoulders of 'tinkerers and adapters' of the Manning Clark romantic myth — although that was evident in many aspects of adapting imported technology in the colonies. Rather, Australia's capacity at the close of the century to produce for itself at the opposite end of the world, and to export products and ideas, came from a considerable input of technical expertise.

(iv) A somewhat different pattern of invention emerges about the indigenous rather than the immigrant inventor. Born and educated in the colonies, he appears to have responded most directly to a set of environmental factors and needs. These men are found predominantly inventing and innovating in agricultural technology, in the use and development of local products; they were strongly represented in the timber industry and in the pulping of Australian hardwoods; they are found meeting transport challenges with heavy machinery and special heavy track wheels in rough country, and, in general, responding to problems generated by distance. They were also important in contributing to modifications and improvements in various technological fields, most notably in agriculture, with its special demands for new machinery to cope with difficult scrubby terrain, to relieve labour shortages brought on by gold rushes, and to supply cereals for a growing population. Australian-born inventors were also active innovators in developing a range of pastoral mechanisation, including shearing blades and mechanised sheep pens. Both in agriculture and the pastoral industry, they gave the Australian colonies an international technological lead. Again, these inventors and innovators also had strong technical backgrounds. In the earlier decades of the century, they educated themselves in the egalitarian Mechanics Institutes and in libraries stocked with literature brought from overseas. Increasingly they were trained in a number of technical institutes and Schools of Mines; later still they were engineering graduates from the Universities of Melbourne and Sydney.

(v) For both the indigenous and the emigrant inventor, the characteristics that marked success were the solid technical background of the inventor, his capacity to gather financial backing from his own diverse efforts or from backers, his ability to take up ideas (both scientific and technical) already available in his particular line, his tenacity in the face of initial difficulties or failure, and his ability to innovate through the demonstration and dissemination of his idea.

A few examples of both imported and indigenous Australian inventors will give the flavour of the nineteenth century experience. Lancashire-born Thomas Sutcliffe Mort, pioneer of refrigeration, arrived in Sydney in 1838 aged 22, having been educated in a British grammar school and in a thriving industrial company.[5] He rapidly accrued capital as an auctioneer and as a promoter of railways and a foundry. From the outset, Mort was a man driven by a vision of opportunities for Australia. He teamed up with the French engineer, E.D. Nicolle, who had trained in French and British engineering works, emigrated to Australia in 1853 and eight years later patented an ice manufacturing process dependent on evaporation of ammonia.[6] Mort and Nicolle began experimentation freezing carcasses in a small factory; they carted country-killed meat to Sydney and established a large freezing works near Sydney and an abattoir at Lithgow. Nicolle called on basic scientific work being developed in France, while Mort harnessed Nicolle's experimental skills, and added enormous energy, drive, and organisation to gather investors. He showed remarkable tenacity over a long period and a readiness to renew efforts when the process of refrigeration proved difficult. His input was, in his own words "unremitting toil, increasing anxiety and mental strain, and merciless expense". In 1878 a ship was chartered to take a cargo of meat worth £100,000 to Britain, but fitting up was delayed, and it sailed without the cargo. Although Mort died that year, his evolutionary process was capitalised on one year later when the SS *Strathleven* carried 40 tons of frozen beef and mutton to Britain, all discharged in excellent condition. While Andrew McIlwraith headed the successful syndicate that carried meat export forward, it was Mort's innovation and entrepreneurial leadership that formed the basis of successful innovation.

F.Y. Wolseley, an Irish immigrant who arrived in Victoria in 1854, by persistent experiments across 20 years, devised and successfully developed a mechanised sheep shearer.[7] Wolseley involved a number of technically skilled partners and patented a variety of machines which evolved into an effective mechanised shearer, first demonstrated in 1886. It incurred strong Luddite resistance from both shearers and graziers. But diffusion of information of the new technique followed widespread demonstration of the machine throughout eastern Australia from 1885, "pitting it against the blades". The speed and financial returns to shearers of the machine slowly converted them, and by the end of the century machine shearing had become the rule. It revolutionised the wool industry in Australia and established a technological lead.

Wolseley's experience reveals several features of the nineteenth century inventive enterprise. He himself was not a technically trained inventor, but rather a 'technical outsider' who called in technical talent to develop and later demonstrate his idea. In 1889, he left the colonies to set up the Wolseley Sheep Shearing Machine Company in Birmingham, England, both serving his adopted country and moving back to the industrial centre to capitalise on an international market for his machine. But mobility and exchange of talent continued. The year of his return, Wolseley sent Herbert Austin (later Baron Austin) from Birmingham to serve in his workshops at Goldsbrough Mort, Melbourne, in order to improve the overhead gear of the shearing machine. Ideas flowed two ways — from the metropolis to the colonies, and back to the metropolis. Austin returned to Birmingham four years later, his engineering work in Australia complete, and designed and made the first Wolseley motor car, starting his own Austin Motor Company in 1905. The colonies gained — and lost.

With Mort and Wolseley's inventions in Australia, patenting played a crucial part. Although the practice of patenting was always controversial in terms of loss and gain — and in some colonies, such as South Australia, a specific Bill had to proceed through Parliament before any patent could be taken out — patenting was an essential ingredient in the successful evolution of refrigeration techniques, and in the various modifications and adaptations of the perfected sheep shearing machine. It was expensive; patents had to be registered in all colonies to afford protection. But it was an extensively used mechanism in the progressive development of agricultural machinery in the colonies — although John Ridley did not patent his original and major innovation, the stripper harvester. In agricultural technology, patents and the diffusion of information about development by patenting throughout the colonies, was a significant influence in generating modifications and improvements. To find support for the importance of patents in stimulating major technology in the period, it is worth looking at the experience of two of the most fertile Australian inventors, but less-than-successful innovators — Lawrence Hargrave of New South Wales, and Henry Sutton of Ballarat, Victoria.

Hargrave's creative record scarcely needs to be recounted since his image, and that of his heavier-than-air flight models, is handled constantly on the $20 note. A failed innovator, Lawrence Hargrave has become a national hero. English-born, he arrived in Australia to join his family at the age of 15; worked at the Sydney Observatory and in the Australian Steam Navigation Company, and joined several exploring voyages to New Guinea. With his scientific mind, he was profoundly influenced towards aeronautical research by the movements of waves, insects and birds he observed. From the 1880s until his death in 1915, Hargrave designed and modelled an astonishing range of heavier-than-air machines powered curiously by india rubber, compressed air, and clockwork; he made some 90 cellular kites and soaring machines; and he built some 33 engines, including his important radial rotary airscrew engine, which passed into aeronautical development.[8] Through this long regime of unremitting experiment and research, drumming up his own fuels and mechanical resurces, Hargrave contributed detailed accounts of his inventions in papers to the Royal Society of New South Wales and in correspondence with aeronautical experimenters and journals abroad. "If there is one man more than another who deserves to fly through the air", the Chicago aeronaut, Octave Chanute, pronounced in the late 1890s, "that man is Lawrence Hargrave of New South Wales".[9] But Hargrave did not fly through the air, except for a brief few minutes at Stanwell Park; and his elaborate models, embodying the soaring surfaces that, like his aerial screw engine, flowed into international aeronautical progress, now rest in the Sydney Power House Museum. Why? Two reasons stand out. Hargrave, committed to a scientific ethos, believed in the free flow of unfettered knowledge; and he failed to draw from his environment the technical support system for innovative success. A Social Darwinian with a faith in the survival of the fittest and in the originality of his own models, Hargrave opposed patenting. In contrast, the successful Wright brothers patented each of their evolving aeronautical techniques and improvements (some benefitting from Hargrave's research): they approached the governments of France, Germany and Great Britain for support; they formed a syndicate with a French manufacturer for the rights of their machine in France and obtained a contract from the US War Department's Signal Corps; and they safeguarded their patents by taking legal proceedings against infringers. They kept their major improvements a close secret, informing the *Aeronautical Journal* only after successful trials had taken place.

Two significant differences emerge. The Wrights had entrepreneurial talents which Hargrave lacked (his tentative efforts at British backing brought no returns), and the American inventors profited from a more involved and more diversified manufacturing backing than the lone Hargrave enjoyed. "There are few people in Sydney", Hargrave remarked to a friend in the late 1890s, "who can think of my work without a smile". The remark undoubtedly has a contemporary ring for some lone inventors today. But importantly for this study, Hargrave lacked the mechanisms to link his work with contemporary industrial and political processes. As an inventor he was cramped and constrained by the conservatism of his environment. Centrally, amid an already inhibiting isolation, he could not, or would not, enlist entrepreneurs. There was none among his contemporaries, he acknowledged, whom he could trust — "the inventor readily becomes the pigeon of the speculator",[10] and his resourceful inventive skills were lost to his own country despite their fertilization of aeronautical technology abroad.

Similarly, local-born inventor Henry Sutton, an eclectic and imaginative designer of a range of nineteenth century 'high technology', eschewed the patent system to the national cost. Educated through his early and extensive reading of the technical literature at the Ballarat Mechanics Institute (later School of Mines), he spawned a score of promising inventions in the 1880s and 1890s — mercury air pumps, a host of new telephone designs, an embryonic television device for relaying the Melbourne Cup to Ballarat, light bulbs and carburetters. Alexander Bell visited his Ballarat establishment in 1910 to see his private telephone scheme in place. But Sutton also believed in the free flow of information as a gift to science. He patented little, although sixteen of his twenty original telephone designs were patented by others overseas. The *Australian Dictionary of Biography* describes him as "a gifted innovator and developer", in the van of many experimental areas overseas.[11] The description, however, is loose. Sutton, professionally involved in the family music business, lacked the motivation to lift his ideas into the arena of technological development.

These negative aspects of some key inventors are instructive for our times. We should not dismiss them in revering our technological pioneers. Several themes and patterns emerge from the broad biographical overview:

i) Innovation and diffusion of technology was spurred by patenting an invention. Gusts of adaptation in certain areas can be traced through the detailed registers of colonial patents, with gaps and spurts at times from colony to colony. Patenting, hence, encouraged and underpinned many modifications, improvements and new departures in product, process and design.[12]

ii) Conservatism of the environment, a reluctant attitude to new ideas and risk aversion acted as a serious brake on some major national innovations.[13]

iii) Entrepreneurial attitudes and skills — the 'entrepreneurship' of gathering finance and marketing the product — were a most conspicuous feature of successful nineteenth century innovation.

iv) 'First failure' among inventors followed by renewed efforts and motivated search for entrepreneurial backing could lead to important innovation.

v) However, 'first failure' among a spread of technically trained immigrants led *not* to renewed efforts and the development of promising ventures, but to the diversion of talent to the colonial public service. This emerges as a striking feature of nineteenth century Australia, where, for example, a remarkable number of engineers who came to the colonies to try their hand at manufacturing and innovative development, fell back after their first venture, declined further risk-taking, and found their way into high posts in the colonial railways, telegraph, water and other technological departments of the public service. The public sector benefitted; Australia made strides in telegraph and railway extension, in long line telephony, bridge building and port construction using technologies and know-how adapted from countries overseas. But potential inventors were lost to the private, manufacturing sector. Evidence of the numbers who followed this pattern suggests a distinctively Australian phenomenon at a time when colonial governments were increasingly committed to 'colonial socialism' and to shifting responsibility from private enterprise to burgeoning public utilities.[14] Colonial bureaucracy hence provided an important safety net for highly educated technologists and engineers who were unwilling, or unable, to take a chance on prolonged innovative risk. This fate of human talent is very different from the scene in North America, where the brightest skilled and technically trained migrants persistently fuelled expanding private enterprise.

The development of Australia's mining sector illustrates two crucial points. Nowhere did the conservatism of the management environment prove more constraining to major early innovation; and nowhere did a change in management attitude play a more dynamic part in bringing Australia to the forefront of mining technology. Mining in the leading colony of Victoria was, as Geoffrey Blainey indicates, *ad hoc* and uninterested in new techniques.[15] The cradle that rocked the alluvial gold from Australian rivers was improvised in the Sacremento Valley in the United States. Copper mining in South Australia was stoutly founded on traditional patterns brought in by Cornishmen. Such approaches worked well for a long period in the light of the richness of Australian ore deposits, but, as surface metals diminished, a lack of knowledge of metallurgy, physics and chemistry in the mining industry became increasingly significant. Australian mine managers were slow to look for better extraction techniques and, as Blainey suggests, metallurgists who tried to experiment were often thwarted by frugal directors.

When geologist and mining expert Gustav Thureau was sent by the Bendigo mine owners to study mining methods in California and Nevada in 1877, he discovered how backward Australian mining was.[16] Yet few mine owners bothered to read Thureau's report. It was the Broken Hill Proprietary Ltd's decision to import experts from the mining fields of the Rocky Mountains in 1886 that brought about a significant change in colonial mining approaches and linked Australia to a new powerhouse of attitudes and skills. Although the first board members of BHP were all pastoralists (and more than half, including chairman W.P. McGregor, emigrant Scots), their decision to send

William Wilson, a newly appointed board member versed in mining, to the United States that year to recruit the best mining managers money could buy was, writes Blainey, "the most momentous decision in Australian industrial history".[17] In Nevada, Wilson located the engineer and metallurgist, William H. Patton, superintendent of Consolidated Virginia. The company worked the famous Comstock mine, one of the world's deepest and most productive, where Patton had played a part in conquering bad ventilation, high temperatures, underground fires and shifting ground. Wilson signed him up as general manager of BHP at an annual salary of £4,000, twice the remuneration of the highest paid Australian politician. In Colorado, Wilson recruited German academic metallurgist Herman Schlapp, a product of the Royal Freiburg School of Mines, and brought him to BHP as the first of many metallurgists, mine managers, and skilled miners to be recruited from the Rockies. Schlapp created the largest smelters in the colonies (using fifteen furnaces and nearly a thousand men) and paved the way for Australia's lead in a new kind of mining technology.

In Tasmania, Robert Sticht, versed in the smelters of Colorado and Montana since graduating from the famous German mining school at Clausthal, and an expert in pyritic smelting, reached Mt Lyell and created smelters that proved a milestone in copper metallurgy.[18] Similarly, the spectacular success of Kalgoorlie's 'Golden Mile' depended on the presence of a number of young metallurgists imported from the Rockies and, increasingly, from training in Australia's Schools of Mines. The cross-fertilization of technical mining know-how had begun.

Such importation of high technical talent had a marked impact on Australian mining innovation. From the 1890s Australia witnessed an upsurge in experimental metallurgy that heralded a technical awakening. Conservative mining management was replaced by science-based, technically educated managers. No longer could the view be maintained, expressed by the Victorian Legislature as late as 1889, that a certificate of competence could not be demanded from mine managers because that would penalise men who had reached an age at which it was difficult to learn. With key mining management, Australia would consolidate a level of sophisticated metallurgical mining techniques that established her as a leader in this technological field.

What then, in sum, can we derive from nineteenth century experience that is telling and instructive, and has meaning for the critical problems of technological innovation and development in Australia today? The most significant message is, undoubtedly, the pertinence of a strong, technically trained manpower to initiate, project and sustain technological invention and innovation; a wide distribution through the manufacturing system of engineering talent; and the presence of highly qualified entrepreneurial managers. Contemporary observers tend to use the term 'colonial' dismissively in the context of technology. Yet the colonial period embodied many critical ingredients for innovative leadership in manufacturing that are lacking, or have been diminished, in the 1980s. From a broad biographical overview it would seem that the characteristics that distinguished the successful nineteenth century invention/innovation experience centred on skills and attitudes that contained:

a) high motivation of the participants;
b) a marked level of technical training from an educational base or from experience in industrial engineering works (many Scottish-Australian manufacturers of note, for instance, were from the 'engine-room of Scotland', the industrialised lowlands[19]);
c) entrepreneurial abilities that enabled inventors to link with investors and entrepreneurs; and 'technical outsiders' to harness inventors, creative technologists and engineers; and
d) an ability on the part of both inventors and innovators to fill innovative niches and to market and promote techniques and products in which Australia could establish a technological lead.

What part did government play? In the nineteenth century, colonial legislatures were variously, if minimally, linked with the promotion of invention and innovation. Patenting was a mechanism by which inventions were registered in the annual *Parliamentary Votes and Proceedings* of each colonial legislature and by which inventions, their modification and improvement could be traced. That patenting was judged important is seen in the fact that the patent examiners and commissioners in each colony were leading public servants and scientists of influence. Occasionally a parliament offered a bonus or 'premium' to individual inventors for a specific invention or adaptation — usually in agricultural machinery — for which there was a perceived need. There were the staged colonial, intercolonial, and international exhibitions of the last thirty years of the century at which local inventions and machinery were displayed to prime further inventive ideas.[20] There was an unsuccessful attempt in the Victorian Parliament initiated by Samuel Bindon in 1865, to appoint a Minister of Industries and Instruction,[21] and, again in Victoria, a Technological Commission was established in the 1880s, to stimulate technical education and disseminate information. But the broad effect of government intervention was primarily to create a climate of popular interest in technological progress and to prompt the efforts of ingenious individual inventors.

When we enter the twentieth century, we move increasingly away from the role of the individual inventor to a developing government infrastructure of laboratories for research and development, multinational involvement in Australian manufacturing industry, and the gradual appearance of some R & D in local private sector firms. Team and 'collective' research assume increasing importance over the performance of the lone inventor and entrepreneur. The new century offers a very broad landscape, but focus will be on some features that illustrate pertinent trends.

Certainly World Wars I and II gave strong impetus to the individual inventor, a point recognised by government in the establishment on both occasions of the Australian Inventions Board. A number of industries grew out of our enforced isolation from vital imported supplies (cable making and the timber pulping industries were important cases). There were the inevitable incidents of failure to grasp important breakthroughs. Adelaide-born Lancelot de Mole had invented a tank in 1912 which he submitted to the Defence Inventions Board, but, failing to attract assistance, he took its specifications to England in 1917. A cruder tank was already in the field and, while de Mole's tank never heard the sound of battle, it was pronounced "a brilliant invention which accomplished and surpassed that put into use in 1915". He had failed, however, it was said, "to show a causal connection in making the invention with the user of any similar invention in Government".[22] Hardly a promising criterion of invention at the height of war!

The Depression also proved a stimulus to the individual inventor. Overseas patents registered in Australia fell away significantly, but local inventors became more active. As Encel and Inglis claimed in 1966, "some of today's successful entrepreneurs embarked on their careers during the 1930s in this way".[23] Clearly they represent a cluster of innovators whose experience deserves closer scrutiny.

The Second World War fostered a spread of important invention and innovation to meet critical needs,[24] some of which flowered into new manufacturing industry after the war. But postwar wastage was, again, immense. An interesting source has appeared that sheds new light on the waste of embryonic high technology industry and highly trained scientific talent in postwar Australia in the memoirs and recollections now being published by Fellows of the Australian Academy of Science.[25] One deserving of note is the account of optical research carried out at the Munitions Supply Laboratory at Maribyrnong, Victoria, which, with the special training and expertise of Australian physicist, J.J. McNeill, became the base of a major precision instrument industry in Australia. McNeill spent the early years of war gaining knowledge of technical optics in Britain.[26] His two year study in London at Imperial College from August 1939, presaged a clear plan for the future establishment of an optical industry in Australia. With direction from McNeill in London, eight Australian scientific laboratories[27] were involved in the design of a wide range of instruments from which prototypes were made, and many scientists and technicians were trained in high precision optical work. Hence, in Australia the knowledge was there, workshops were geared, and a potential high technology industry of precision optics awaited development. But managerial and entrepreneurial skills were crucially missing ingredients. "Looking back", Bolton reflects in his survey of the McNeill story, "it is probable that an error was made in Australia in 1938 in not setting up a private corporation supported by the scientific laboratories facilities at the Munitions Supply Laboratory and elsewhere to develop an adequate technology for the manufacture, modification and repair of optical instruments". MSL was not staffed by persons with a production background and outlook or the marketing techniques such a high technology industry required. A private corporation could have moved more quickly than the Munitions Supply Laboratory before the war to secure skilled tradesmen and instrument designers from overseas. By the war's end, "Australia had a laboratory at MSL and first-class associated workshops which could have contributed very significantly to an Australian industry in precision optics". But, by then, skilled tradesmen and designers were virtually unobtainable in the postwar period and the effort of Australia was significantly smaller than that being put into the instrument industry by other countries. McNeill retreated into academia and a major opportunity for Australian industry had been lost.

The major infrastructure for scientific and industrial research established in twentieth century Australia was the CSIR (Council for Scientific and Industrial Research, 1926) and CSIRO (Commonwealth Scientific and Industrial Research Organisation, 1949-). It has been instructive to find from the biographical sample that the Advisory Council of Science and Industry, CSIR's precursor from 1916, located and usefully assisted a number of Australia's lone researchers. For a decade it served, in part, as an enabling source for individual invention. With the growth of central organisation of government science, this emphasis shifted. Research teams became the dominant innovative resource built up — initially in biological fields in CSIR — by chiefs of divisions imported from Britain. While both the Munitions Supply Laboratory and CSIR helped set the stage for government industrial research development immediately before the war, the thrust did not sustain broadly-based innovation after the war. As Stubbs summed up the industrial scene in 1968, "sheltered from overseas competition, dependent on a small market and beseiged by powerful trade unions, Australian industry had dangerously hardened its entrepreneurial arteries with excessive costs and insufficient innovation".[28]

Since that time, the record of Australian manufacturing industry and Australian innovation in a competitive world has declined. We could now truthfully be styled a nation of 'adapters and importers'. We lack entrepreneurial drive: and it is no secret that research carried out in our major statutory bodies (CSIRO, the Defence Science and Technology Organisation, and the Australian Atomic Energy Commission) does not flow adequately into creative indigenous development. This failure, moreover, continues in the face of repetition of a message which has strong underpinnings in our comparative nineteenth century success. In 1965 the report of the famous Economic Committee of Enquiry (the Vernon Report set aside by government) stressed the importance of 'highly trained personnel' in contributing to the raising of technical and managerial standards and the creation of a climate of enquiry and innovation. As the report underlined, their presence develops "skills and attitudes which were essential for increasing productivity and growth".[29]

Fourteen years later, another excellent report, that of the Senate Standing Committee on Science and the Environment into Industrial Research and Development in Australia — the Jessop Report[30] — based on extensive enquiry into Australian firms and statutory instrumentalities, pinpointed the besetting problem of Australia's indigenous R & D. It noted the inadequacy of our key technical manpower arising from the disequilibrium in the training in our universities between basic and industrial research; it pressed for linking Australian researchers more closely by visits and conferences, and the use of scientific and technical liaison officers to tap data flows abroad; it highlighted the need for closer links between statutory bodies and industry; and importantly, it questioned managerial attitudes to R & D that have held back progressive approaches in Australia. The special need for improving management in private sector R & D in Australia has now become a central and urgent message of all reports, national technology strategy papers, and consultancy documents issuing from government. Its very re-iteration is disturbing, while its neglect mirrors what Barry Jones now characterises as Australian industry's 'technological cringe' against locally produced innovation.[31]

What, then, does the historian's lens focus? Some broad conclusions can be drawn. Importantly, the concept of multiculturalism as an influence stemming from immigration only after World War II is patently simplistic: Australian enterprise, industry, science and technology derived large inputs in the colonial period from European, North American and Asian, as well as British migrants.[32] Secondly, these migrants brought vigorous attitudes to manufacturing enterprise in the colonies. In irrigation engineering, mining, in agricultural and transport machinery, they drew on international data and developed innovative schemes in which they were world leaders. The colonies exported not only Australian primary resources, but also high value-added goods. There was a clear absence of an attitude that has now become deep-rooted, that Australian innovation is fully recognised only when it has been exploited by industry abroad. Nineteenth century inventors and entrepreneurs demonstrated an assertive technological approach. True, time lags in successful innovation were sometimes long. Yet it is here that an entrepreneurial tradition dug deep roots. Successful innovation followed tenacious backing, confidence in the endeavour, mobility, and readiness in the face of great hardship to take risks. There is considerable testimony to entrepreneurial skill in gathering finance, and marketing the product — too rare an ingredient in industrial innovation today. Contemporary attitudes would undoubtedly benefit from an injection of pioneering confidence to reduce Australia's prevailing stance of risk-aversion. As Macdonald has pointed out, "Risk-aversion seems to be endemic in Australia and had infiltrated even the most unlikely places".[33] Industrial success and 'niche finding' for success attaches to enterprises where managers see opportunities despite risk, and find satisfaction, not only from financial gain, but from explorations in areas where the frontier will not be accessible forever.[34]

While adventurous management and high calibre technical skills powered colonial technological and industrial growth, both appear to be in inadequate supply today. We need a larger upgraded technological workforce in industry, including trained computing scientists, and engineers widely interlaced (in the fruitful Japanese manner) through industry and on the factory floor. Australia is critically short of engineers and low (when compared with other industrial countries) in its trained technical manpower. Engineers graduating each year in Japan number 629 per million people; in Germany 292, in the United Kingdom 250. In Australia the annual figure per million population is 146. Moreover, we continue to rely for a percentage of our engineering talent on immigration of engineers from countries overseas.[35] This situation provides an interesting, if surprising, continuum with our colonial past. There is, too, a present argument for the training of more broadly-oriented engineers in preparation for their contribution to the moulding of industry. The question of the most relevant management personnel for innovative industry remains in debate. One innovative experiment, at a traditionally conservative university, however, is that launched by visiting Professor Ian Lin at the Mechanical Engineering Department of Sydney University where, at the Centre for Engineering Management and Innovation, part-time, self-funding courses are offered to engineers from industry covering the development and management of new ventures, their strategic planning and marketing, and workshops that focus on fresh attitudes and team co-operation.[36] Other approaches find expression in some Institutes of Technology. Their importance is clear. For a country eager to foster sunrise industries and to launch value-added exports,tunnel vision, lack of technological understanding, or too narrow and timid a technical and managerial outlook are all out of place. As one venture capitalist noted recently on the A.B.C., 'from a purely commercial standpoint one would choose to support a company with good management and marketing more than good ideas'.[37]

The research role of the engineer has also been recently stressed. ASTEC's report to the Prime Minister recommending reforms to relate CSIRO more directly to industrial innovation and swing its research emphasis away from scientific disciplines to 'emerging industry sectors', indicates that the long-standing classification of the CSIRO 'research scientist' should now be expanded to 'research scientist/engineer'.[38] The point is emphasised further in the report's proposal that CSIRO researchers should be rewarded for other than their published contributions to the Organisation's purposes.[39]

Such shifts are significant, though it is doubtful if any change to the structure of our national colossus of R & D can help bring Australia out of its doldrum of technological stasis. Reinforced rather by a historical glance, it may be necessary to look in our contemporary technology policy to the presence of the lone inventor. Across 1978-82, Macdonald carried out a study on the research of the individual inventor. From a sample of some 600 individuals he found that, while a significant precentage of these had tertiary and postgraduate degrees and some 40 per cent ran small firms, they were fundamentally unguided, out of touch with advanced information in their fields, and many were working in unpromising areas.[40] His study also revealed that, from a further sample of 223 formal research units consulted, only 2 per cent of these firms and organisations had collaborated with individual inventors, although some 20 per cent had taken out licences from such individuals.[41] Macdonald concludes that "The significance of the individual inventor may be greater in a small country", but that these individuals have a significant need for appropriate 'networks' that encourage them to consider areas of market need rather than their own perceived needs for an invention, and that link them with ongoing public and private sector R & D.

While a variety of commonwealth and state government mechanisms has been set in place in recent years to spur individual business enterprise and innovation,[42] the lone inventor requires a special environment where his ideas can be appropriately perceived and evaluated and harnessed to relevant parts of the innovative process. In such conditions his particular abilities could be captured and, as in the nineteenth century, used as a valuable Australian resource. The advent of inventors' clubs, or venture capital clubs, in Britain and America point a route. In America, venture capital clubs have spread widely in recent years joining entrepreneurs, investors, corporate managers, and service providers with inventors, lawyers, and accountants in an informal atmosphere where ideas, ventures, finance and accounting approaches are brought in touch. The club aims to be "a marketplace where one goes to find the venture capital infrastructure";[43] their atmosphere is informal, and they encourage interaction and confidence among members. The mechanism of the five minute forum' enables each member to make a short announcement of what he wants. An inventor may describe his latest idea, an out-of-work executive announce his availability, and a venture fund representative present the kinds of investments and the funds he seeks. This form of 'networking' has not only led to promising ventures; its cumulative effect is to promote greater openness and confidence among the fairly inturned breed of inventor, and to alert others to new management skills. In all fields, the club movement has proved facilitating.

The idea now finds expression in Australia. The Melbourne Entrepreneurs Network, set up in 1985, adopts a similar pattern of operation.[44] In Brisbane, an inventors club has recently been formed where individual inventors can come together informally with entrepreneurs, financiers, lawyers, academics and public servants to bridge gaps and barriers between groups and meld new processes of innovation.[45]

"I have a personal belief," one Melbourne entrepreneur set down his purpose, "that, as a nation, we do too much importing. I wanted to get back to making products. You have to be prepared to take risks and to persuade others to share those risks if you are going to succeed as a new company. It's an experience which is not for the faint hearted and it can certainly be lonely at times".[46] The passage would find pertinent echoes a hundred years ago. "One of the striking features of the nineteenth century", Godfrey Linge summed up in his *Industrial Awakening,* "is the importance of the role of a couple of hundred individuals who turned out to be the right man in the right spot". With their key qualifications of enthusiasm, application, tenacity of purpose, and a capacity to link necessary human and material factors, they conceived genuine innovations and "changed the way things could be done".

On the national front, the Australian government also needs a changed perspective on the ways things are done. Perhaps, now, instead of looking traditionally to Sweden, Japan and Europe for models for an Australian technology approach, we might, in a period of critical technology depression and lag, turn to the 'seige' country of Israel where remarkable strides have been made, under pressure for mere survival, to raise profitable high technology industries of world class.[47] It is tempting to pose the question, "Is Australian invention like our national emblem, the emu, a flightless bird?" The answer for the nineteenth century is a decided no. It would seem that in the later years of the twentieth century, the bird may need to be subjected to some severe psychological pressures to get it airborne again.

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