HIGH TECHNOLOGY POLICY AND THE SILICON VALLEY MODEL: AN AUSTRALIAN PERSPECTIVE

Stuart Macdonald

Australia seeks to emerge from the depths of recession and to break free from the syndrome of giving ever-increasing protection to a decaying manufacturing sector, by encouraging high technology industry. Silicon Valley, the home of much of the world's semiconductor industry, is often seen as the appropriate model for the development of such industry. For those used to dealing with the siting and encouragement of conventional industry, it can seem that high technology industry, with no heavy raw material input or bulky product output and requiring no large labour pool or local market, in fact has no special requirements at all. Others look to the Silicon Valley model and plan science or technology parks to reproduce the factors they believe responsible for that phenomenon. For example, great emphasis is generally placed on proximity to universities, apparently in ignorance of the very minor role universities played in the growth of the semiconductor industry, and of the great practical divide between science and technology. Vital factors, such as the ready information flow achieved by high mobility of those in high technology industry, are ignored. The Australian situation is complicated further by competition among the States to attract high technology industry, a competition that tends to emasculate national policy. Yet this situation is really just a local representation of what is happening internationally among countries and among regions within those countries. This desperation to leap blindly into high technology, whatever it is and whatever the cost, by following a model that is scarcely understood, is unlikely to produce the huge rewards so many policy makers anticipate are so readily available.

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MILK AND HONEY AND VENTURE CAPITAL

Australia, in common with most other countries, is currently beset with a whole host of economic ills: high technology industry is seen as an instant panacea for almost all of them.[1] High technology is to create employment,[2] to re-vitalise Australian industry, to increase Australia's international competitiveness,[3] to secure Australia's long-term industrial future.[4] For the last government, a high technology prescription was judged to be a restorative for even a failing election campaign.

There are many who feel that Australia offers almost perfect conditions for the growth of high technology industry. Australians apparently excel at invention,[5] and innovation and manufacturing.[6] The former Minister for Science and Technology was of the opinion that,

> To establish new technology-based companies a country must have a well educated population, a sound industrial base, a stable economy and an adequate pool of capital. Within Australia we have all of these qualities . . .[7]

Apparently, the only ingredient missing from the Australian high technology recipe is venture capital, the yeast to make Australian technology rise.[8] While there is no doubt that little venture capital market has developed, virtually no attention has been paid to the most obvious explanation; that is, that there have been few technological opportunities capable of attracting venture capital.[9] Australia, in common with most other countries, has no obvious comparative advantage in high technology.[10]

DEFINING HIGH TECHNOLOGY

The mistaken belief that Australia is well endowed to launch into high technology industry is encouraged both by naive optimism and by an inadequate understanding of what high technology industry is. "High technology", declares the Australian Department of Science and Technology, ever quick to grasp the nettle, "is a difficult term to define, but its presence in the newly emerging technologies is evident."[11] Some signs are apparently generous research and development (R&D) spending, new products and processes, entrepreneurs with scientific or technological backgrounds, and interaction between technical and scientific skills;[12] but these are indicators rather than descriptors. Technology is simply the way things are done.[13] High technology is high not because it is nearer to God than other technology, but because of the relatively high risk involved,[14] the possibility of high return, its high pace of change and its high information intensity.[15] Those are the characteristics of high technology against which national comparative advantage should be assessed.

GOVERNMENT INTERVENTION

Because high technology is so widely perceived as a powerful, rapid and obvious way to resuscitate national economies, there is little patience with any strategy suggesting market forces should determine the choice of location of high technology industry. Recession and the political attraction of high technology have rendered substantial government intervention in high technology inevitable.[16] High technology, however, is often seen as a small firm, free enterprise activity, not so much because of the importance of the profit motive to the individual, as because of the flexibility and responsiveness that sort of organisation allows.[17] If there is to be substantial high technology activity in Australia, it will not be achieved without substantial government involvement: the clumsy boots of government are unlikely to suit enterprise which is dependent on quick and fancy footwork.

Government intervention in high technology in Australia is likely to take the form of procurement and offset policy,[18] selective R&D grants to industry and stimulation of the venture capital market, but it will be hard to avoid more conventional forms of industry assistance. The spectre of highly-protected high technology industry looms large in Australia. New industry associations actively press for such protection, not only borrowing all the arguments employed by established manufacturing industry, but supplementing them with infant industry arguments, examples of government assistance to high technology overseas, defence considerations and the importance of a high technology infrastructure for the rest of the economy.[9] There is but a small step in Australia from regarding high technology as a wealth-creating activity increasing the prosperity of the economy, to regarding high technology as a cost to be borne for the prosperity of the economy. Perhaps the strongest argument for protection of high technology industry is a second best argument; as long as existing protection distorts the allocation of resources towards traditional industries, high technology industry requires protection to correct that distortion.[20]

In Australia, successful high technology enterprises overseas are often presented as typical examples of the genre, suitable for emulation.[21] They are not, of course; the typical high technology enterprise is highly likely to fail,[22] and there is more understanding of high technology to be gained from studying the failures than from mesmerised adoration of the few successes. Because failure is an integral part of high technology exploitation, high technology policy must be policy to cope with failure; in a sense it must even promote failure, for without failures there will be no successes. Proposed high technology policy seems to ignore the matter of failure. What, for example, is to be done with the 'living dead'? — that graphic American expression for those high technology firms which neither create resources nor gracefully die and free resources, but simply endure. Terminating the living dead in high technology industry and freeing their resources will be difficult while wider policy is so dedicated to the preservation of the moribund in other industries.[23]

THE SILICON VALLEY MODEL

Because perceptions of what high technology is are unclear, government policies for high technology are necessarily confused. In Australia, high technology policy is confused with key technology policy, which itself is confused with what is called 'sunrise industry' policy, and none has any comfortable place within overall industrial policy.[24] What, then, is appropriate policy for a new sort of activity which appears to lack traditional industrial dependence on local raw materials, local market and convenient labour supply? Perhaps sensibly, precedence is sought, and that area most renowned for its high technology industry is Silicon Valley in California. So the question becomes: What has Silicon Valley got that is so conducive to high technology industry? Delegations of the world's politicians and bureaucrats have been descending upon Silicon Valley for years to fathom its secrets. They leave perplexed, but full of optimism. In Silicon Valley's favour are seen to be pleasant climate, local universities and venture capital: against it are such mundane factors as the high cost of housing, and of labour, and uncertain electricity supply.[25] The conclusion is that almost anywhere can offer conditions just as suitable for high technology industry, and perhaps very much better.

In England, there is said to be a Silicon Valley near Cambridge, an observation based on no more than the location in the region of a handful of small high technology firms.[26] Bradford, in Yorkshire, purports to be an ideal site for microelectronics firms because its workers are "dextrous, skilled, hard-working, cheerful and friendly".[27] In Scotland, Silicon Glen is somewhere between Edinburgh and Glasgow, where a few small Scottish firms have developed a working relationship with the multinationals in electronics.[28] According to the Department of Commerce in Northern Ireland, perfect conditions for an Irish Silicon Valley exist somewhere between Londonderry and Belfast, and a map has been produced to prove the point.[29] In Australia, Silicon Valleys are expected to proliferate. The South Australian government plans one to the north of Adelaide and has published a more detailed map than the Northern Ireland government, which actually shows between which trees each new high technology industry is to be located.[30] Japan is to have a whole Silicon Island built on the advantages of Kyushu; namely lots of clean water, lots of airports and lots of women.[31] In the United States, 4,500 economic development agencies vie with each other in claiming themselves superior locations for high technology industry.[32]

Western Australia too is apparently to have its own Silicon Valley, drawing on the technological resources of the Western Australian Institute of Technology.[33] Both there and in South Australia the assumption has been made that the high technology of the original Silicon Valley has been derived from California's universities.[34] There is also pressure for a Silicon Valley to be established between Newcastle and Wollongong, a prime location said to be very similar to the Californian original in that it has lots of universities, lots of people, and currently dominates Australia's decaying electronics industry.[35] Tasmania too supposedly offers perfect facilities for a semiconductor industry in that it boasts pure air.[36]

There are other Australian sites thought to be perfect new Silicon Valleys: Queensland's Gold Coast, for example, is said to be very similar.[37] However, the location recently most hotly favoured to be Australia's major Silicon Valley, with its own semiconductor fabrication plant, was none other than Canberra. It is not totally clear what there is about Canberra that is so reminiscent of Silicon Valley, nor why the American microelectronics firm, National Semiconductor, should have considered so seriously that precise location for a fabrication plant. According to National Semiconductor, it was because the Government invited the firm following a proposal made by the Canberra Development Board on one of its overseas trips.[38] The responsible Minister later announced that the Canberra location was because the Australian National University was "the only university in Australia which has a unit involved in solid state technology".[39] The arguments seem a little thin, for it is not obvious that the natural advantages of Canberra, any more than those of Newcastle or Wollongong, are those most appropriate to the semiconductor industry. Only the Canberra Development Board ever thought of Canberra as 'Silicon City'.[40] The Minister, however, was exuberant in pointing out the advantages to Canberra of acquiring National Semiconductor. According to the Minister, the plant would have led "to the establishment . . ., without any shadow of a doubt, of an applications industry with a capacity to employ in excess of 100,000 people at the end of the decade".[41]

While the widespread assumption that a Silicon Valley can be anywhere high technology policy makers choose to put it provides ample scope for amusement, there are some very serious consequences of misunderstanding the Silicon Valley model and of failing to appreciate the nature of high technology. Scarce resources are likely to be used inefficiently if the wrong activities are sited in the wrong places for the wrong reasons. Because high technology is seen as a multi-purpose economic nostrum, high technology policy is easily confused with employment, education and, particularly, regional development policy. In Britain, for example, regional development policy has been totally confounded by high technology enterprises choosing to locate in the one area without regional development incentives.[42] In high technology mistakes are likely to involve significant opportunity costs. More obviously, there are costs in terms of rivalries among nations and their regions to attract high technology industries. The world cannot sprout hundreds of new Silicon Valleys, each created oblivious of the others, and each exploiting a presumed comparative advantage in biotechnology, microelectronics and information technology to supply the same international market. The situation has become quite preposterous.

THE REAL SILICON VALLEY*

It is time to shatter some illusions about Silicon Valley and to attempt construction of a more realistic Silicon Valley model for high technology policy.[43] The real Silicon Valley is the hub of the world's semiconductor industry and is the home of firms producing much of the world's supply of semiconductors. Not only is the semiconductor industry the archetypal high technology industry, but on its products are dependent most other high technology industries.[44] Silicon has been the only semiconductor of commercial importance for the last 25 years — ever since the industry dropped germanium and the scientific community wandered into a wonderland of compound semiconductors whose myriad properties could be explored forever.[45] No industry illustrates better than the semiconductor the fundamental difference between

* Quotations in this section are from interviews with people in universities, industry and government who have an active interest in the semiconductor industry.

science and technology.[46] The semiconductor industry was founded upon a single scientific invention — that of the transistor in 1947 — and has become a technological and commercial force increasingly distancing itself from basic science.[47] By 1972, of $36 million spent by the American industry on basic semiconductor research, $29 million was spent by Bell Laboratories and IBM, neither of which sold components on the open market.[48] In policy discussion about such industries as the semiconductor, it often seems to be forgotten that they are high technology industries and not high science industries. There is a vital difference. The major participants in the innovative process are such people as accountants, managers and salesmen — not high-status scientists and engineers.[49] Technology is information, technological change an information process; it is myopic to see that process as the preserve of an elite of information workers to the exclusion of other workers in the information sector. In as much as high technology is particularly information intensive, any assumption that scientists and engineers and conventional R&D have a cardinal role to play in high technology industry results not so much from myopia as blindness. High technology industry is non-scientific, even anti-science in its desperation to avoid problems and undirected enquiry; it seeks the quickest and easiest route possible through what is so expressively termed 'black-box technology'. The aim is to make the box work for someone, and to avoid ever having to open it.

> There began to be an awareness [c. 1960] that solid state physics had left the laboratory and had begun to be part of the factory. In other words, the engineers and technologists were by and large no longer listening to the basic scientists and really weren't even very much interested in what the basic scientists were doing.

> Many people in the semiconductor side of R&D, like myself, are very concerned about the areas where we have made conclusions which happen to be right conclusions to get some product out of the door — and maybe it's the best thing since sex, I don't know — but we are very concerned because we don't understand what we have done to do this . . . We look for 'fixes' to accomplish a solution to a problem.

> While down at the level of holes and electrons in the active part of the semiconductor we have to have a pretty good grasp of what's going on . . . it is absolutely commonplace in the structure elsewhere, whether in the attachment of the die to the header or in the fabrication of the package, to have significant technical areas where we don't really understand what we are doing on any deep theoretical level.

> There hasn't been a whole lot of search for a replacement for silicon for years now . . . I would say rather that there is a wide-eyed recognition in the industry that we haven't begun to apply the technology we have.

If anything kills the golden goose, it's the fact that it's been too successful. There are so many things you can now do with what has been invented that industry and technology can't keep up. They have so much to do to exploit what's been done . . . and there's so much to do in improving this from a technological point of view that there's just no need for spending money on finding new devices.

The original American semiconductor industry was located on the East Coast rather than the West, and particularly in the Long Island and Boston regions. Geographers used to take almost as much delight pointing out the locational advantages for electronics firms of Route 128 around Boston as others do now in analysing the locational advantages of Silicon Valley.[50] The Boston area offered proximity to universities just beginning to offer courses on solid state physics, its banks were said to be generous in their attitude towards venture capital and the area was generally sufficiently civlised to retain skilled manpower.[51] More importantly, the East was the location of the eight large and established electronics companies which dominated both the valve market and early efforts to manufacture semiconductor components. Such huge companies, with their large and formal research laboratories, were responsible for providing precious experience for semiconductor manpower.[52] They were also responsible for failing to recognise the potential of the transistor, for seeking to preserve their interests in the mature valve technology, and for displaying a suffocating indifference towards their few young employees who knew anything at all about semiconductor technology. Unlike their employers, such employees were well aware of the technology's importance and consequently of their own temporary value.[53] They left to form their own firms, and many went West.

In the early days, top management did not appreciate the uniqueness of those relatively few engineers and scientists who understood semiconductor devices. Moreover, they frequently put electronic engineer managers in charge of their semiconductor operations that didn't know a thing about the chemistry and metallurgy of semiconductor devices . . . For about a year, we had a going-away party every Friday.

The first semiconductor company in the San Francisco area was that founded by William Shockley, one of the inventors of the transistor, at Palo Alto in 1955. The previous year, Shockley had tried to sell his services for $1 million over three years to Raytheon, one of the large established electronics firms on the East Coast.[54] Negotiations came to nothing and Shockley left Bell to establish Shockley Semiconductor Laboratories as a subsidiary of Beckman

Instruments; the location was Shockley's home town.[55] The firm never really flourished. In 1958, it changed its name to Shockley Transistor and became a manufacturing unit producing, in a quasi-university atmosphere, sophisticated diodes tested to well beyond military specifications.[56] Shockley's undistinguished commercial career would be of little interest had his scientific reputation not attracted to his firm some of the very best young talent from the East. Doubting Shockley's commercial acumen, a group of eight abandoned Shockley Transistor in 1958 to found their own company — Fairchild Semiconductor.[57]

Fairchild is the mother hen of Silicon Valley and has been responsible for dozens of spin-off firms, most of which have located nearby. At an industry conference held in 1969, of 400 semiconductor men present, less than two dozen had not worked for Fairchild at some time.[58] Though Fairchild is in the doldrums now and has recently been taken over by the giant French multinational, Schlumberger,[59] its location in Santa Clara County, rather than Shockley's nostalgia for his home town, best explains the local proliferation of semiconductor firms and the appellation 'Silicon Valley'. Its founders, frustrated by Shockley's pre-occupation with four-layer diodes, sought backing from Fairchild Camera and Instrument to develop the planar process, originally for the batch production of discrete devices, but ultimately as the production process which made integrated circuits commercially feasible.[60] By 1968, there were at least 25 semiconductor firms in Silicon Valley,[61] and no fewer than 41 had been started by Fairchild employees who thought they could do better than remain with Fairchild — and who were not always correct.[62]

> The top few people in the company have the opportunity of making a great deal of money if they are successful, and I think this provides the motivation to work night and day and to really just out-perform the competition . . . I wouldn't have left Fairchild except for the prospect of making some money. I just wouldn't have done it because that was interesting too. I had a good job and a good future there.

Mobility is high in the semiconductor industry, particularly among the newer and smaller firms and these clustered in Silicon Valley. It is high because the rewards of changing employers can be great when commercial success is dependent upon the rapid mastery of a new technique. But it would be a mistake to imagine that all the rewards are financial. There is apparently great satisfaction to be gained from the development of the technology itself, especially when that technology has profound social and economic implications. There is also satisfaction in the degree of independence technological expertise provides, particularly when it allows the individual to set up his own firm. Large corporations seeking to enter the industry by purchasing successful small firms have often failed to appreciate the importance of this individual motivation. When Ford took over General Microelectronics in order to obtain its new MOS (metal oxide semiconductor) technology, the small firm's technologists left to a man and formed their own new and thriving company, leaving Ford with a rather expensive building.[63] It will be interesting to see whether the large, diversified corporations now scrambling to buy young, high technology firms will encounter similar difficulties.[64] The industry's experts have long been keenly aware of the nexus of technical and commercial application which determines success in high technology. The original established valve companies with their large, formal R&D laboratories could not adapt to what is now called 'the California style of business'. In the fifties, these large companies performed most R&D, they attracted most government R&D support, they invented most and acquired most patents — and still they lost the semiconductor market to new firms. Those new firms, and other small firms, are now as important in the semiconductor market as ever; indeed, it seems that more new firms entered the Californian industry in 1981 that in any previous year.[65]

> I had a tremendous rapid change from being the president of a little company that was totally entrepreneurial to selling that to, and becoming part of, a large organisation. You really can see why these companies just cannot be successful because they insist that the semiconductor operation operate in exactly the same manner as they run a steel mill . . . Large companies' control mechanisms don't let them do something until it's obvious and by that time it's too late.

> The parts of the business where big companies have been successful in the past have been those areas where the technology was not moving rapidly . . . They do all right if the technology is mature and not changing, but it's the small companies who have been the ones who did all the innovation.

> As long as there are possibilities for major new breakthroughs, there is going to be a role for small, new firms, I would argue, coming in and taking advantage of that because the big, established firms are going to want to concentrate more on the proven technology where their scale has some sort of advantage.

Paradoxically, there is a concentration of semiconductor firms in Silicon Valley because mobility of experts in the industry is so very great. A move to another firm is very much easier when it does not entail selling a house, changing the children's school and leaving behind close friends and associations. The industry's most valued manpower is that which has both a thorough grasp of the very latest technology and also a mastery of the commercial constraints bounding the industry.[66] Such men are rare, and firms have paid dearly for weakness in one talent leading to the sale of devices that cannot be made, or the manufacture of devices that cannot be sold. The latter has been the most common falling for it is natural to assume that the technology is the hard part of the business; it is certainly no harder than living with a rapid succession of steep learning curves producing decreasing price with increasing experience. There are few such semiconductors experts and those there are can name their own price. When Lester Hogan left Motorola for Fairchild in 1968, he was offered an annual salary of $120,000, an interest-free loan of $5.4 million to exercise an option on 90,000 shares at $60 each, and a further allotment of 10,000 shares at $10 each. By late 1968, his paper profit was $2.5 million.[67] Both individuals and firms in the semiconductor industry regard high mobility, and high potential rewards by such means as stock options, as normal. Leading semiconductor men have worked for many firms and only when large groups have left *en bloc* have firms protested.[68] Firms and individuals alike are fully aware that mobility — information 'on the hoof' — is the main means by which technology transfer is effected in the semiconductor industry, and both cause and consequence of the rapid technological change upon which the prosperity of firms and individuals is dependent.[69]

> Many of us, at least in this industry, start out as technologists, or engineers and then we become more and more interested in the business or economic aspects of any particular corporation. Semiconductors allow you to do both.

> Most good people like to see their ideas go someplace besides into a memo. They like to see it come out as a product . . . You would be surprised at the number of professional people who do not work for the almighty dollar. I mean that really work for self-satisfaction.

> I was absolutely amazed at the number of engineers who were interviewed for jobs on the development side who wanted to meet the marketing guy. They wanted to have some assurance that their zippy ideas that were running around in their head were going to in fact get marketing push. Now where do you find that elsewhere?

> The semiconductor world is populated by almost rich professional managers who took jobs with a nice salary expecting to become millionaires with the stock option they got and every one of us has somewhere in a dresser drawer stock options worth garbage and not that much money in the bank.

The semiconductor industry's most valuable information is, for all practical purposes, personal property.[70] Semiconductor firms make great show of security precautions, but what is called 'back-office' co-operation flourishes behind 'front-office' display. The industry's experts know each other well and informal consultations are frequent. Information is exchanged for other information, which both accelerates the pace of technological change in the industry and enhances the career prospects of mobile experts. Firms do not discourage such information exchange, knowing full well that finding solutions to their own problems is often dependent on it, and that information can be bought only with other information. Companies in the industry adopt the Bell philosophy towards staff mobility — that it is only by losing good people that you gain other good people. Moreover, as long as contacts between employees and ex-employees are maintained, there is much to be said for a system which lets another organisation pay for your experts.

> Most of the intelligence interplay that goes on in the industry is through guys quitting and whoring themselves to competitors . . . If I developed something that I thought was key to my business growth, the last thing I would do is give a paper on it.

> I have people call me quite frequently and say, 'Hey did you ever run into this one?', and you say, 'Yeh, seven or eight years ago. Why don't you try this, that or the other thing?' We all get calls like that.
> We all know each other. It's an industry where everybody knows everybody because at one time or another everyone worked together.

Patents do not play their traditional role in the semiconductor industry: firms patent extensively, but largely as a book-keeping exercise, to establish rights to an information portfolio.[71] Individual firms are commonly anxious to allow other firms — particularly less successful firms — access to their latest technology, for most customers insist on the availability of a second or even a third source of components as insurance against the uncertainties of the semiconductor production process. Nor have universities and government incentives played the role in Silicon Valley so generally assumed for them.[72] There is an information flow between universities and the semiconductor industry, but most of it is from industry to university, not *vice versa*. To imagine otherwise is to reveal an inappropriate adherence to the linear model of technological change and to leave unexplained the furious pace of change in the industry over thirty years. That pace of change is the key to an understanding of the semiconductor industry. Secondly, it is commonly assumed that government support has long provided the industry with research and development impetus. It is undeniable that an assured government market for expensive new products still low on the learning curve was of paramount importance. It is equally true that much government-funded research was misdirected and actually disadvantaged recipient firms.

> Most of the good basic work in semiconductor device physics is done in industry today . . . it's not done in universities.

> Recently I have been shocked to find out that what we were doing to one or two significant figures back in the 1950s is still going on [in universities], but people have three significant figures and are looking at every little bump of the band structure and are just as passionately interested in it.

> I think all these ideas [for early integrated circuitry] essentially had to be simplified for the people who were funding the things and it's quite possible — from my own experience — that the Military didn't really understand what the details were. In fact, I'm quite sure they didn't . . . All that you had to do was wave the Russian threat and you could get money.

> With very few exceptions, the major motivation behind technology development cannot come from the Military . . . the major motivation, I feel, is the commercial one . . . I would say that the research that was motivated by getting to a given end result was far more productive than the research that was carried on for the sake of carrying on research. A lot of the military directly-funded research was the latter. I would say that the Military created more motivation for doing research by creating a market for advanced products . . . The main reason we stayed clear of military involvement was because I thought it was an affront to any research people to say that you are not worth supporting out of real money . . . In a sense the military funding made whores out of all the research people. You were dealing with a critic of the research you were doing who was not capable of critiquing the work . . . There are very few research directors anywhere in the world who are really adequate to the job . . . and they are not often career officers in the army.

In this dynamic and informal milieu that is the semiconductor industry, the importance of geographical proximity is paramount. That is not to say that semiconductor firms cannot prosper without it. Motorola in Phoenix and Texas Instruments in Dallas exist in splendid isolation, with few local spin-off firms. Silicon Valley is conducive to the activities of the semiconductor industry precisely because there is now so much semiconductor activity there. The firms and their expert individuals, while competing fiercely, are deeply dependent on each other. Only the semiconductor industry itself, with its established infrastructure of equipment suppliers, associated high technology firms and sources of venture capital which actually understand the industry, is special in Silicon Valley.

It would be a mistake to assume that ready communications are a characteristic of the semiconductor industry wherever it might be. Conditions were unsuitable in the original established valve companies and neither do they appear to be conducive in many of the non-American companies in the world's semiconductor industry.[73] A typical example would be the research and development department of one of Europe's largest firms, which does not hire experienced technologists from other semiconductor firms for fear that this would damage the promotion prospects of those recruited straight from university. In non-American firms, the industry's experts place a high value on pension rights, superannuation schemes and job security. This non-American industry offers the American little competition and generally struggles to maintain a foothold in even its own domestic markets. Only the Japanese, with government-imposed information flow between industry and both universities and government research laboratories, do rather better than this. In Australia, where science is unsullied by the needs of industry and industry is cosseted from the realities of the world outside, there is now little semiconductor industry left. Even the Australian ethos that a man has a right to make a profit no matter what he does, or how badly he does it, could not save an industry that less than ten years ago was still making semiconductor components using 1950s technology and, despite its tiny market, used 1000 per cent effective tariff protection to manufacture a greater range of components than nearly any other country.[74] The Australian *reductio ad absurdam* is the very antithesis of Silicon Valley.

> We don't recruit men from other companies. We don't look for them. We recruit in general . . . young people because if you recruit people who are already advanced then you block the promotion prospects of your own laboratory. It's difficult enough as it is to get on in research so you don't block their progress by recruiting somebody — only in exceptional circumstances . . . In the States they are much more callous about this. They will tell a man to go. We have never told a man to leave.

A REALISTIC SILICON VALLEY MODEL FOR HIGH TECHNOLOGY POLICY

Such analysis produces a very different sort of model for high technology policy. It describes industrial activity in which information resources are more important than any others, in which the thirst for information is so insatiable that each enterprise is dependent on the information resources of other enterprises. For high technology industry, traditional information channels are too slow and restricted to supply fresh information; that must consequently be acquired through the individuals who carry it, and constantly replenished from that mobile source. Silicon Valley is outstanding in high technology industry because the participants in that industry acknowledge information as a fundamental resource and have adapted to cater for it.[75] The point has generally been missed by those who would plant Silicon Valleys wherever there is a vacant patch of industrial land, and who expect them to flourish with sufficient patent protection, government largesse and proximity to universities. Of course, the Silicon Valley way is not necessarily the only way. The Japanese have shown that microelectronics can thrive in completely different circumstances, and other high technologies might prove to have requirements beyond those of microelectronics. However, there is much of value for national high technology policies in the Silicon Valley model; at least, in the correct Silicon Valley model. In the bizarre version that now seems to be so widely excepted there is only the prospect of chaos, waste and ultimate disappointment.

NOTES AND REFERENCES

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2. The last Minister for Science and Technology declared that young high technology firms created 59 times more employment than mature industries. D. Thomson, *Hansard*, Representatives, 14 December 1982, p. 3395. See also Australian Academy of Technological Sciences, *Developing High Technology Enterprises for Australia (Espie Report)*, Parkville, 1983, pp. 24-5. Both neglect to consider unemployment caused by failed high technology firms: their comparison is of all mature industry with only successful high technology firms.
3. D. Thomson, 'Official opening' in Department of Science and Technology, *Finance for Technology Ventures*, Australian Government Publishing Service, Canberra, 1983, pp. 3-5.
4. Department of Science and Technology, *Science and Technology Statement 1981-82*, Australian Government Publishing Service, Canberra, 1982, preface.
5. "Our record of invention is excellent, but unfortunately our history is littered with projects that have not reached fruition or have been lost to other countries". Thomson, 'Official opening', *op. cit.*, p. 3. See also Stuart Macdonald, *The Individual Inventor in Australia*, Report to Industrial Property Advisory Committee, Department of Economics, University of Queensland, 1982.

6. The Australian Scientific Industry Association aims "to exploit the undoubted quality of indigenous innovation and manufacture for the benefit of the scientific industry and Australia", ASIA information leaflet, 1983.
7. Thomson, 'Official opening', *op. cit.*, p. 4. This strange notion seems to have come from Laurence Hartnett, 'Introduction to the forums' in Department of Science and Technology, *Creating High Technology Enterprises*, Australian Government Publishing Service, Canberra, 1981, pp. 1-2.
8. For example, the last government referred to the proposals of the draft Espie Report as "a most significant catalyst in the revitalisation of Australian industry". D. Thomson, 'Development of high technology industry', *Commonwealth Record*, 21-27 February 1983, p. 253.
9. The inability of Australian technology to attract venture capital from overseas, and BHP's purchase of coal resources from GEC to allow the latter to enter high technology in the US suggest the same conclusion. See 'High technology has corporate predators licking their chops', *Economist*, 19 February 1983, pp. 67-8. The new Labor government's venture capital initiatives and the recommendations of the recent Espie Report, *op. cit.*, are welcome in that they will help overcome imperfections in the venture capital market, but they will not — as the Espie Report came to realise — compensate for Australia's fundamental technological deficiencies. See Denys McCullough, 'The Australian venture finance scene. A management advisor's view reflecting on the Espie Report', paper delivered to Hi-Tech 2 Seminar on Venture Finance, Brisbane, 13 April 1983.
10. See Ken Gannicott, *Australia's Technological Comparative Advantage and Research Planning*, Report to Policy Evaluation and Analysis Unit, Commonwealth Scientific and Industrial Research Organisation (CSIRO), 1981, p. 29. However, the Minister for Science and Technology has stated, ". . . in the area of high technology industry, comparative advantage is not bestowed, rather created." B. Jones, 'Keynote address', Management Technology Education Conference on Sunrise Industries, Sydney, 31 May 1983, p. 7.
11. Department of Science and Technology, *Creating High Technology Enterprises*, *op. cit.*, p. 31.
12. *ibid.*
13. See D.M. Lamberton, S. Macdonald and T.D. Mandeville, 'Productivity and technological change: towards an alternative to the Myers' hypothesis', *Canberra Bulletin of Public Administration*, 9, 2, 1982, pp. 23-30.
14. More properly uncertainty if risk is taken to be calculable.
15. See Stuart Macdonald, 'The need to succeed', *Journal of General Management*, 4, 3, 1979, pp. 74-83.
16. See Robert Kaus, 'Can creeping socialism cure creaking capitalism?', *Harper's*, February 1983, pp. 17-22.
17. See Ernest Braun and Stuart Macdonald, *Revolution in Miniature. The History and Impact of Semiconductor Electronics*, Cambridge University Press, Cambridge, 1982; Roy Rothwell, 'Small and medium sized manufacturing firms and technological innovation', *Management Decision*, 16, 6, 1978, pp. 362-70; Arnold Cooper and Albert Bruno, 'Success among high technology firms', *Business Horizons*, 20, 2, 1977, pp. 16-22. Some large organisations have cast their own smaller venture units in order to achieve this flexibility, though often the venture groups become ossified too. See Edward Roberts and Alan Frohman, 'Internal entrepreneurship: strategy for growth', *Business Quarterly*, 37, 1972, pp. 71-8; Dan Dunn, 'The rise and fall of ten venture groups', *Business Horizons*, 20, 5, 1977, pp. 32-41.

18. Both programs have recently been reviewed by a Parliamentary Committee, which failed to be impressed. ". . . the Committee is unable to come to any clear conclusion about the effectiveness of the offsets/A.I.P. progam. In fact, the evidence suggests that no-one is in a position to come to any such conclusions . . . what technology is transferred depends on the public sector's current needs, which may have little relationship to what technology transfer is desirable for Australia as a whole." House of Representatives Standing Committee on Expenditure, *Commonwealth Government Purchasing*, Australian Government Publishing Service, Canberra, 1981, p. 47.
19. E.g., Australian Computer Equipment Manufacturers' Association, *Submission to IAC Inquiry into Computer Hardware and Software . . .*, Melbourne, April 1983. See also J. Durie, 'High technology claims government has abandoned it', *Australian Financial Review*, 12 August 1981, p. 17.
20. One Australian high technology entrepreneur expressed the situation succinctly, ". . . I find it irrational to refuse these debilitating handouts, which are so easily obtained. As a salve to the conscience I use the fact that my taxes contribute to this endless pool of money, and that refusal would be a disadvantage against the competition which accepts". D. Webster, 'How an Australian computer systems manufacturer can survive in the face of international competition', paper delivered to DEC Users Symposium, Sydney, July 1980.
21. E.g., "The high growth rate and economic success of technology ventures in the U.S. is renowned." Thomson, *op. cit.*, p. 5.
22. On the high risks involved in high technology enterprises in the United States see David Brophy, 'The venture capital investment market in the U.S.', paper presented to Hi-Tech 2 Seminar on Venture Finance, Brisbane, April, 1983.
23. For an assessment of the preserving influence of protection on the Australian electronics industry see G.A. Rattigan, 'Opening address' in Australian Academy of Science, Science and Industry Forum, *From Stump-Jump Plough to Interscan*, Canberra, 1977, p. 11.
24. For an example of total confusion of key technology policy, sunrise industry policy and high technology policy see Department of Science and Technology, *Submission to Industries Assistance Commission Inquiries into Computers etc., Metal Working Machine Tools and Robots*, Canberra, May 1983.
25. See M. Chase, 'Electronics companies move out of 'Silicon Valley' ', *Australian Financial Review*, 25 March 1980, p. 28; 'Sand in the works for Silicon Valley planners', *Australian Financial Review*, 16 April 1980, p. 20; 'Delicate bonds: the global semiconductor indusry', *Pacific Research*, 11, 1, 1980, p. 6.
26. 'Silicon Valley comes to Britain', *Economist*, 11 July 1981, pp. 83-4.
27. *Punch*, 5 May 1982, p. 3.
28. 'Scots on the move — into the microchip age', *Economist*, 15 August 1981, pp. 19-20.
29. *Economist*, 22 August 1981, p. 11.
30. Department of Trade and Industry, South Australia, *Technology Park Adelaide*, Adelaide, April 1981. The project has been referred to as "the first Australian answer to America's Silicone [sic] Valley" (*Australian Stock Exchange Journal*, June 1981, p. 230, which glorious example of the failure of the financial community to keep abreast of modern technology says much about the inadequacies of Australia's venture capital market.
31. 'Silicon Island — tomorrow's world leader?', *Japan Quarterly*, 29, 4, 1982.
32. E.g., 'The Maryland high-tech phenomenon', *High Technology*,

September/October 1981, special advertising section. See also, 'America rushes to high tech for growth', *Business Week*, 28 March 1983, pp. 50-6.

33. J. Poprzerzny, 'Institute plans 'Silicon Valley' industrial park', *Australian*, 12 August 1981, p. 11.
34. The assumption is very common; see, for example, William Henkin, 'Silicon Valley: incubator of high technology', *Economic Impact*, 41, 1983, pp. 43-9.
35. V. Gledhill, 'High technology industry in New South Wales', *Australian Computer Bulletin*, September 1981, pp. 22-7.
36. M. Townley, *Hansard*, Representatives, 25 March 1981, p. 716.
37. R McKilliam, 'Opening of new ERA', *Brisbane Courier-Mail*, 15 September 1981, p. 22. Queensland itself is said to be peculiarly appropriate for high technology industry because of its "bright people" and "established reputation". L. Edwards, 'Keynote address', paper delivered to Hi-Tech 2 Seminar on Venture Finance, Brisbane, 13 April 1983, p. 5.
38. National Semiconductor, *Media Release*, 24 March 1981.
39. M. Hodgman, *Hansard*, Representatives, 26 March 1981, p. 951.
40. B. Buchanan, ' 'Silicon City' plan for developing Canberra', *Brisbane Telegraph*, 9 June 1981, p. 30.
41. M. Hodgman, *Hansard*, Representatives, 26 March 1981, p. 951.
42. Martin Walker, 'The boom that's by-passing the new towns of Britain', *Guardian*, 26 April 1982, p. 15. See also Alfred Thwaites, *Some Evidence of Regional Variations in the Innovation and Diffusion of Industrial Products and Processes within British Manufacturing Industry*, Discussion Paper No. 40, Centre for Urban and Regional Development Studies, University of Newcastle upon Tyne, 1981; Peter Large, 'Councils worry over location of UK 'silicon valley', *Australian*, 21 November 1978, p. 18. "If a graduate from Stanford comes down Silicon Valley explaining he has just invented the wheel, a Californian venture capital firm will computer run the OEM (original equipment makers') list and say 'if you can get bulk orders from any two of the following 879 firms that might be interested in buying this thing called a wheel, we will take stock options in you'. If a British graduate invents the wheel, he will get a generous government grant to establish a factory for making it on top of a Welsh mountain that has not got any roads; he may then advertise it in the Sledrunners' Gazette". 'How to cut employment', *Economist*, 28 May 1983, p. 15.
43. The importance to present US government technology policy of understanding the development of the semiconductor industry is stressed in Richard Levin, 'The semiconductor industry' in Richard Nelson (ed.), *Government and Technical Progress*, Pergamon, New York, 1982, pp. 9-100.
44. See David Stout, 'The impact of technology on economic growth in the 1980s', *Daedalus*, 109, 1, 1980, pp. 159-67.
45. A. Gibson, *Progress in Semiconductors*, Heywood, London, 1956, p. 4; Institute of Physics and the Physical Society, *Report of the International Conference on the Physics of Semiconductors*, London, 1962, p. 901.
46. Stuart Macdonald, David Collingridge and Ernest Braun, 'From science to technology. The case of semiconductors', *Bulletin of Science and Technology in Society*, 1, 1981, pp. 173-201.
47. Stuart Macdonald and Ernest Braun, 'The transistor and attitude to change', *American Journal of Physics*, 45, 11, 1977, pp. 1061-5.
48. Braun and Macdonald, *op. cit.*, p. 141.
49. See Stuart Macdonald, 'Technology beyond machines', in Stuart Macdonald, D. McL. Lamberton and Thomas Mandeville (eds), *The Trouble with Technology*, Frances Pinter, London, St. Martin's Press, New York, 1983 (forthcoming), pp. 26-36.

50. E.g., E.C. Estall, 'The electronics products industry of New England', *Economic Geography*, 39, July 1963, pp. 189-216.
51. Braun and Macdonald, *op. cit.*, pp. 124-5.
52. J. Tilton, *International Diffusion of Technology: The Case of Semiconductors*, Brookings Institution, Washington D.C., 1971.
53. Macdonald, 'The need to succeed', *op. cit.*
54. 'Semiconductor family tree', *Electronic News*, 8 July 1968, pp. 4-5, 38.
55. 'Biography. Dr. William Shockley', *Solid State Journal*, May 1961.
56. S. Thomas, *Men of Space*, Chilton Publishing, Philadelphia, 1962, pp. 199-200.
57. N. Lindgren, 'The splintering of the solid-state electronics industry' in *Dealing with Technological Change*, Auerbach/Innovation Magazine, New York, 1971, p. 39.
58. 'Silicon summit', *Electronic News*, 29 September 1969, p. 1.
59. US International Trade Commission, *Competitive Factors Influencing World Trade in Integrated Circuits*, Washington D.C., 1979, p. 106; 'The kid whizzed', *Economist*, 2 February 1980, pp. 80-1.
60. Stuart Macdonald and Ernest Braun, 'The invention barrier', *National Electronics Review*, 13, 6, 1977, pp. 112-16.
61. Lindgren, *op. cit.*, p. 34.
62. 'Semiconductor family tree', *op. cit.*; A. Golding, *The Semiconductor Industry in Britain and the United States: A Case Study in Innovation, Growth and the Diffusion of Technology*, D.Phil. thesis, University of Sussex, 1972, p. 249.
63. Braun and Macdonald, *op. cit.*, p. 139.
64. See 'High technology has corporate predators licking their chops', *Economist*, 19 February 1983, pp. 67-8. A high acquisition rate for young firms in Silicon Valley is a major conclusion of A.V. Bruno and A.C. Cooper, 'Patterns of development and acquisitions for Silicon Valley startups', *Technovation*, 1, 4, 1982, pp. 275-90.
65. 'Fortune seeqers', *Economist*, 6 February 1982, p. 65.
66. Macdonald, 'The need to succeed', *op. cit.*
67. 'The fight that Fairchild won', *Business Week*, 5 October 1968, p. 106.
68. For example, when Jean Hoerni, ex-Shockley Transistor, ex-Fairchild, ex-Amelco Semiconductor, ex-Union Carbide, hired half a dozen experts from National Semiconductor to join his new company, Intersil, National Semiconductor secured a consent decree to deter further encroachment. 'Intersil: upstart with talent', *Business Week*, 12 September 1970, pp. 74-6.
69. See Stuart Macdonald, 'Cause and consequence of change in semiconductor electronics' in *Conference on Microprocessor Systems*, Institution of Engineers, Australia, Publication No. 78/13, 1978, pp. 73-8.
70. Stuart Macdonald, 'Personal communication in research and development' in W. Callebaut *et al.* (eds), *Theory of Knowledge and Science Policy*, University of Ghent, Belgium, 1980, pp. 255-71.
71. R. Wilson, P. Ashton, and T. Egan, *Innovation, Competition and Government Policy in the Semiconductor Industry*, Lexington Books, Mass., 1980, pp. 62-4; Stuart Macdonald, 'Patents in perspective' in *The Economic Implications of Patents in Australia*, Australian Patents Office, Canberra, 1981, pp. 21-38.
72. These matters are discussed at length in Braun and Macdonald, *op. cit.*, passim.
73. See the account of the failure of the Scottish electronics industry in Nick Perry, 'Corporate control and the organisation of innovation', paper given to Australian and New Zealand Association for the Advancement of Science Congress, Auckland, 1979.

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