Successful and sustained manufacture has always involved attention to at least these six aspects:

1. **Invention** - the creation of novel ideas about things to make and sell
2. **Innovation** - the adaption of our own or others' ideas so that they become realizable
3. **Process design** - the arrangement of the human and material resources needed for production
4. **Management** - orchestrating the resources available to achieve objectives
5. **Profits** - accumulating capital for further growth and development, and
6. **Improvements** - continual modification of existing products, skills and processes, together with the introduction of new ones, so as to maintain, or improve, the long term viability of an enterprise.

In a colonial economy, where migration swells the population, it is to be expected that many of the ideas and skills, and even some of the means for production, will be imported. It should not, however, be supposed that whatever is done with these resources are necessarily achievements of a lesser order.

Consider, for example, the case of the Barwon Paper Mill on the banks of the Barwon River, west of Geelong. Design work began locally towards the end of 1874 and the mill became operational by the middle of 1878. The proprietors hoped that it would help arrest the decline of Geelong's industrial importance relative to that of Melbourne, and so they spared no effort in constructing something to last, with buildings in solid bluestone so that the mill from the river gave the appearance of a fortress. They also made clever use of water power and a steeply sloping site to achieve economical operation and they brought some of the very best British paper-making machinery half way round the world and got the mill operating at the first attempt.

The enterprise subsequently survived a crippling fire in the rag store in 1884 and the death, just a few months later, of James Volum, a local brewer and principal partner. This whole enterprise took great vision, courage and tenacity but, in the final analysis, even this was not enough. Although the mill initially provided stiff competition for the operators of Victoria's only other paper mill, both mills suffered from being so far from Europe and America, where dramatic changes were then occurring in the technology of paper production.

Paper machines there grew rapidly both in width and length, and this brought about a substantial fall in the unit cost of all grades of paper. Neither of the local mills had the space needed for these kinds of change. The Barwon machine, in particular, remained small by industry standards and, as a consequence, the mill faced intense competition from imports, and its profitability remained marginal for most of its later operational life. Its location outside Geelong, and away from the main transport routes, did not help either and, after surviving for a number of years, it was closed down in 1922 when the local industry was rationalized. It later became an ice works. The irony is that the buildings at Fyansford have survived whereas all traces of those at South Melbourne vanished just a short while ago, presumably to make way for yet another high-tech complex as people-friendly as someone wearing dark sunglasses.

About 50,000 pounds were spent up to 1878 to establish the Barwon paper mill. Most of this money appears to have been supplied by Volum's brewery - as a special form of liquid asset - and that, in turn, was chiefly dependent upon the most significant wealth producer in Victoria in the latter half of the nineteenth century - gold mining.

Mining in Victoria had these five major consequences, amongst others:

1. Firstly, it transformed the landscape. It converted valleys into muddy battlegrounds, as at Forest Creek near Castlemaine; and it replaced sylvan dales with whims and poppet heads and other structures, as on the New Chum line at Bendigo. Whole forests were cut down for machinery foundations, for buildings, and for fuel in boilers so that by 1866, on Ballarat, supplies of structural
timbers had become so scarce that mining engineers were forced to use bricks instead; at first regarded as an inferior substitute. Some of these structures have survived, as on the Berry Leads near Smeaton.

2. Secondly, it stimulated food production both by the establishment of a wide variety of agricultural implement makers, like Nicholson and Morrow, John Bunce, T. Robinson, Hugh Lennon and J. H. Robinson in Melbourne, principally at the top end of Elizabeth Street and around the markets; and John Tynan, Kelly and Preston, George Munro and finally H. V. McKay at Ballarat; and also by the establishment of food processing plants. Highett's mill, for instance, supplied flour to the Ballarat diggings from grain grown on the nearby Barabool Hills. It was a five storey masonry structure with all machinery driven by an undershot waterwheel 43 feet (13.1 metres) in diameter and 9 feet (2.74 metres) wide. This was probably the largest waterwheel built in Victoria, at least until 1883. Although little now exists at this site, we are fortunate that elsewhere mills constructed initially for much the same purpose have survived, as at Anderson's mill at Smeaton, built in 1861 and Day's mill at Murchison, built in 1865. This mill is notable because it still retains much of its milling and other machinery. Not all the grain produced, however, ended up as food. Barley, in particular, was often malted as the first stage in the production of beers which quenched the miners' thirsts in a rather more socially acceptable manner than, for example, the illicit stills and shanties of North-eastern Victoria which supplied a product sometimes claimed, and I quote, "to blind at 50 paces".

3. Thirdly, it stimulated, directly or otherwise, the development of the railway network. This resulted in some notable civil engineering structures like the Saltwater Bridge of 1857 on the Williamstown railway where the central span was 210 feet, the longest of any rail bridge constructed in Victoria, with the iron work supplied by William Fairbairn and Sons of Manchester. Also the Moorabool viaduct on the Geelong to Ballarat railway had 10 spans of 130 feet each, 115 feet above the river, and was completed in 1862 to the design of the famous British railway engineer, Isambard Kingdom Brunel; and the Taradale viaduct of the same year on the Bendigo railway, 5 spans of 130 feet each and 120 feet high above Back Creek.

4. Fourthly, it became the means for achieving a measure of social cohesion. Although in the early stages some cooperative parties and mining companies appear to have been constituted on essentially ethnic and/or political lines, as is suggested by such names as Albion, British Columbia, Garibaldi, Great Republic, Independent and New Constitution. Others, like the Cumberland, Durham and Cornish, and the National, suggest at least the beginnings of other kinds of social relationship. This became rather more evident amongst the mining communities of Gippsland whose relative isolation forced groups otherwise disparate into at least the appearance of solidarity. This is particularly evident from surviving photographs of a group of working miners and syndicate members lined up outside a battery building at Sunnyside in 1897 and pretending not to notice the retorting of the gold going on in the foreground; and, perhaps more dramatically, by the gathering of a large group of Omeo residents and shareholders to mark the occasion of the opening of the Mount Wills South tin battery in 1892.

5. Finally, mining led directly to the establishment of foundries and engineering workshops in many of the principal centres and these, in several important respects, laid a firm basis for manufacture and further economic development within Victoria. Although a mining company could initially afford to equip itself with imported machinery, as the Port Phillip Company seems to have done at Clunes, it could rarely afford the delays involved in getting additional pieces from Britain once operations had commenced, and such delays could hardly have been tolerated where they involved the repair or replacement of worn components.

Consequently, workshops which may have started initially for repair purposes soon found themselves making new pieces of plant and equipment. On Ballarat, for example, the Phoenix Foundry, which began as a blacksmiths' shop in 1854, was, by the middle of 1857, making cast iron pipes, pumps and boring machines for the deeper lead mines. The Victoria Foundry, established by August 1856, seemed to be ready to make steam engines from the outset, although they appear to have been kept busy at first making pump columns. Finally, the Soho Iron Works, established also in Ballarat in October 1860, had made several stamp batteries, pumps and a steam engine by June 1861.

The ability of these early engineering works to move quickly from repair work to manufacture of mining and other machinery was crucial to the maintenance of gold production in Victoria once the rich surface shows had been rushed and exploited.
Such production can be considered in two distinct phases. In the first of these there is a spectacular increase in recorded annual output up to the end of 1856, when production peaked at just over three million ounces. This is followed by a much longer period of gradual decline until 1919, when mining in Victoria was almost at a standstill. The second period is less sensational, but over 80 per cent of the 75 million ounces of gold won here was produced during this period and by other than the hand methods which had characterized the first period of mining. If mining had continued as it had begun, then it is questionable whether it would have lasted more than a decade, and with its demise there would have also been lost all opportunity to transfer the great wealth then being conferred into other productive activities.

In 1851 Victoria had only two small foundries, both in Melbourne, and operated separately by Langlands and Fulton, the very partners who had established the first foundry there in 1842. A decade later, there were some thirty important foundries and engineering workshops, chiefly in Ballarat, Bendigo and Castlemaine, as well as in Melbourne. Up to 1870 what they, and others, produced can be considered in these four categories:

1. The manufacture of simple items of machinery and plant which did not require a great deal of sophisticated or expensive production equipment. This applied particularly to boiler works like the one established by John Hickman senior in 1851 on the south bank of the Yarra River just downstream from what later became Duke and Orr's dry dock. In these works imported flat plate was rolled and riveted to produce Cornish fire tube boilers in sizes up to 7 feet (2.14 metres) in diameter and up to 40 feet (12.2 metres) long.

2. The development of machinery and plant to suit the oftentimes quite special needs of the mines. For instance, Langlands Foundry in Melbourne made several sectional steam engines for the mines at Woods Point in 1864. These engines could be brought in by pack horse from Jamieson in pieces and then bolted together on site. Langlands did the same thing for stamp batteries as well. The reputation for innovation and robust manufacture acquired at this time enabled Langlands to gain a near monopoly on the supply of machinery to Gippsland miners for almost a quarter of a century.

3. The complete transformation of imported mining technology. The Cornish stamp battery was an antiquated contrivance not unlike that featured by Georg Bauer in his sixteenth century treatise on metallurgy. This was turned into a precision crushing machine, principally by the Victoria Foundry at Ballarat. They used cast iron frames instead of timber, metal guides for the stamper stems, cast iron mortar boxes, and surface hardened cams or wipers which revolved the stamps as they dropped and so minimized the wear on the rubbing surfaces.

4. The development of new technology. This was most evident on Ballarat with the conversion of the wooden, ground-level and horse-drawn puddling machine, a device apparently unique to Victorian mining, into an elevated, self-cleaning and steam driven system made principally of cast and wrought iron, and into which the washdirt could be tipped automatically; with the puddlers arranged in tiers one above the other, and the sluices below, all for ease of discharge. Such a transformation was really only possible with the very closest cooperation between the mining companies and the local foundries; and it resulted in dramatic improvements in productivity which enabled the deep lead mines on Ballarat to prosper even on relatively poor grades of dirt.

In the period between 1859 and 1870 the annual value of all machinery imported into Victoria was reduced about fourfold at current prices, whilst the annual value of imported iron and steel almost doubled. In March 1870 there were at work on the Victorian goldfields over 6,000 stamp heads crushing quartz, almost eleven hundred steam engines, about a thousand pumps and over 2,000 puddling machines, of which more than 300 were of the automated variety. Mining consumed more power than any other industries in Victoria at that time, and more than twice as much as all the manufacturing industries combined. Although there would still have been a large amount of imported machinery in use, almost without exception new mining machinery was being made locally.

The great majority of the steam engines used for mining purposes in Victoria had a single horizontal cylinder in which the steam was used only once and was then exhausted to atmosphere. This was not the most efficient arrangement, but it saved the expense of a condenser, particularly where the water used was of rather dubious quality. These engines were offered in a range of cylinder sizes up to 24 inches in diameter. As the very largest sizes were built within a year or two of the first engines being made locally it can only be supposed that the foundries quickly acquired the casting patterns, the foundry capacity,
and the machine tools necessary. For example, by 1859 the Phoenix Foundry could melt 7 tons of iron at any one time, and by October 1861 the Victoria Foundry was advertising they could make engines of 100 horsepower, when the average size was about 20.

The only engines not made locally were large beam engines. These were single cylinder vertical engines, fitted with condensers, specifically designed for mine drainage, and installed in a solid masonry building with a characteristically solid beam wall which supported the heavier pieces of machinery. They were the most efficient pumping engines available at the time and their construction required considerable experience in the casting, handling, machining and assembly of large and massive components.

At least 40 of these engines had been installed on mines in Victoria by 1907. In 1861 the largest of these had a cylinder 30 inches in diameter and a stroke of 108 inches, but as the mining companies developed the wetter sections of the lead systems their need for even larger engines increased rapidly. By 1867, for example, the Great North West Company on Wendouree Swamp, Ballarat, had a 32 inch by 48 inch, and a 40 inch by 120 inch engine at work pumping nearly three millions gallons per day without making any impression on the water level in the mine. By 1870 they had imported an 80 inch engine, but went broke before they could instal it.

Other companies, however, persevered with engines of this size. At the Duke and Timor mine an 80 inch engine was installed in 1873. The beam wall, which is nearly all that now remains, was made of solid dressed granite blocks 6 feet square and 3 feet deep. A year before, the company had sought to interest local foundries in large engine manufacture. Langlands, then the leading foundry in Melbourne, declined to tender because it would have required them to import too much specialized machinery. Eventually, only one tender was received but this was almost double the price of an engine made in England, where the market was then particularly depressed.

In 1872, probably the only Victorian engineering establishment with the capacity to make one of these large engines was the Union Foundry at Ballarat. Despite having undertaken some repairs on several of the large imported beam engines operating nearby, the foundry probably lacked both the patterns and the experience necessary to construct a complete engine. Another opportunity for the company to test their abilities did not arise until 1884, when the Berry No. 1 Company started operations on the leads system north of Ballarat. The foundry then offered a 70 inch by 112 inch engine and their tender of 3,500 pounds was only accepted after the doubting Thomases had insisted that the foundry should post a bond of one thousand pounds in case their engine would not perform to the satisfaction of the company.

In the event the engine was made ready for duty well before it was needed, and when put to work in September 1885, it operated without any trouble at all. This engine was significantly larger than any made in Victoria up to that time and it marks a high point in the development of mechanical engineering in Australia. For it signifies that in a little more than 40 years after the first foundry had been started here with the most rudimentary of equipment some establishments had assembled the facilities and mastered the skills necessary to make what were then regarded as pieces of high technology. The engine house at Berry 1 survives in reasonably intact form and a well worn pathway to it from the roadside suggests that it gets its fair share of visitors, though I wonder how many realize its full significance.

Over the next twenty years a certain exuberance can be detected in a series of about ten large engine installations across the central goldfields. These installations were neither simply copies of imported machinery, nor merely the work of one specialized foundry. What is perhaps most noticeable is that the time delay between the appearance of a particular kind of installation elsewhere around the world and its appearance on the central goldfields is substantially reduced, compared with only a decade or so before. For example, the first horizontal triple expansion steam pumping engine was installed in Britain in 1893. But Austral Otis supplied such an engine to the Delegate River Hydraulic Sluicing Company in 1892, and within two years there was another such installation, this time by the Phoenix Foundry for the Duke United Company to the design of George Richards, a Ballarat engineer.

Such developments did not go altogether unnoticed, even amongst contemporaries. Firstly, the Ballarat foundries at least vied with each other in displaying their very latest machinery to the public before ever it was transported to the mines. Secondly, by 1871, in
a period when the importation of machinery into Victoria reaches its lowest point, the value of machinery exported from Victoria becomes an entry in the official statistics. Whilst the value of imports exceeded that of exports, as they did between 1871 and 1893, it is possible to explain this all away as merely the re-exportation to other parts of Australia, or elsewhere, of machinery imported into Victoria from other countries. But from 1864 onwards it is also possible to find references to machinery made in Victoria specifically for export. After 1869 the number of these references increases quite dramatically.

Although much of this export trade was to other parts of Australia, there was a certain amount of trade to South Africa, to India, and to what we now refer to as "the Pacific rim countries". After 1893 the value of machinery exported is sustained consistently above that of imports and this undoubtedly assisted the recovery of some engineering manufacturers when the local markets were severely depressed. Although these statistics are not available after 1901, it is evident that for some establishments, like Thompsons of Castlemaine, the supply of orders from outside Victoria were a major component of total business and that a small but not insignificant portion of that external trade was for overseas orders. Thirdly, by 1870 the established foundries and engineering workshops had begun to train the second generation of immigrants (like Delbridge, Ferguson, Rigby and Young) and to provide positions for overseas apprentices (like Harkness, Johnson and Nixon) before they established their own operations; and they had begun to diversify into other areas of engineering and to supply steam machinery to other branches of manufacturing such as breweries, brick works, candle factories, gas works, pipe making factories, wool stores and woolen mills.

The Phoenix Foundry at Ballarat, for instance, and Johnson's, Langlands, Robison Brothers, Sloss and Son, and Wright and Edwards in South Melbourne made rolling stock, points and crossings, bridges and other structures for the railways. Mephan Ferguson, Robert Fulton and Langlands made cast and wrought iron pipes for water supply and sewage disposal. Austral Otis supplied steam engines for driving the lighting plant at the Melbourne Centennial Exhibition, and the boilers and steam engines for the Spencer Street and Richmond power stations. Thompsons at Castlemaine and later Austral Otis supplied the first and last steam engines for the Spotswood pumping station. Anderson, Black and McCall; David Forman; Johnson's; and Langlands in South Melbourne, because of their proximity to the river, turned to ship repair and ship construction. Anderson's, Austral Otis and Langlands supplied most of the machinery for Melbourne's cable tram network and both Austral Otis and Peter Johns made hydraulic lifts.

These latter two developments were crucial in fashioning the future shape of Melbourne. The cable tram network with its system of engine houses became one of the most comprehensive in the world. This consolidated the urban sprawl initiated by the suburban railways. The hydraulic lift allowed high-rise buildings in the centre of Melbourne for the first time and these, like the Rialto and Olderfleet buildings in Collins Street, and the Tea House in Clarendon Street, South Melbourne became pointers to the future.

The growth of Austral Otis, in particular, was explosive. It began as a partnership between Hughes, Pye and Rigby in 1878 at a small site in City Road, South Melbourne. Within a decade a limited liability company had been formed which employed 300 people and had a turnover of 250,000 pounds. In 1888 it began the third phase of its expansion into these buildings on a four acre site in Hanna Street (now Kingsway), South Melbourne. Despite some attempts at modernization, the Kavanagh Street facade still retains most of its original appearance. Yet the special significance of the site seems to have been totally ignored in all recent conservation studies of the area.

By 1900 Victorians at least were claiming that their State was the manufacturing centre for Australia, with the heaviest concentration of engineering industries in South Melbourne. The rise of South Melbourne to prominence was both due to a local source of foundry sand on cheap land close to transport, the wharves and the city, as well as the progressive centralization of industry which occurred during the first two decades of this century. This contraction of activity can be attributed firstly to the collapse of gold mining in Victoria and to the demise of those engineering establishments chiefly dependent upon it, and also to the pace of technological change: the replacement of the steam engine as a prime mover by the electric motor and the internal combustion engine.

Those establishments which survived did so by focussing their activities upon a much narrower range of products than hitherto (as an early form of niche marketing). Johns and Waygood and Austral Otis, for example, concentrated upon lifts; Thompsons at Castlemaine on pumped sluicing plant; Jaques at Richmond on stone breakers; and Kelly and...
Lewis at Springvale upon pumps and internal combustion engines. Others, like McKay and later Charles Ruwolt, relocated their operations to Melbourne to be closer to their intended markets.

These were leaner times, but as the progress of Charles Ruwolt illustrates, from a small repair workshop at Wangaratta in 1902 to an industrial estate at Richmond, it was still possible to make money in manufacturing. With a design obtained from New Zealand, and at the suggestion of Pearson Tewkesbury, a local dredge owner, Ruwolt, began to make bucket dredges for reworking the alluvial deposits along the Ovens and other rivers in the area. In 1913 he adapted the design for tin mining and secured his first export order. The profits he had derived so far as well as from subsequent orders enabled him to diversify into the supply of a wider range of machinery: for the mines in other parts of Australia, for the manufacture of road making plant, and presses for rubber car tyres and car bodies.

Much of the spectacular engineering in the early part of the twentieth century, however, seems to have been done not by private establishments, but by public instrumentalities. For example:

1. the use in 1916, for the first time, of electric arc welding of track by the Prahran and Malvern Tramway Trust and the subsequent use of the technique by the Metropolitan Gas Company for the fabrication of gas holders at South Melbourne and Fitzroy, and the gas works at West Melbourne - by 1924 the first large all-welded steel frame structure in Australia;

2. the commencement of construction of the Hume Weir, in 1919 - the largest mass concrete dam in Australia;

3. the electrification of the suburban rail network in Melbourne by the Victorian Railways and the construction of Newport power station which, by 1919, was the largest electricity generating plant in the Southern Hemisphere;

4. the exploitation of the brown coal deposits at Yallourn by the newly established State Electricity Commission which was, in 1924 when power was first transmitted to Melbourne, the first large scale use of brown coal outside Germany and the first 132 kilovolt transmission line outside Europe;

5. improvements to the Port of Melbourne by the Harbor Trust with the expenditure of over six million pounds in the twenty year period to 1933;

6. extensions to Newport Railway Workshops which began in 1922 so that by 1930 some 5,000 people were employed, making it one of the largest engineering establishments in Australia, and the subsequent construction between 1936 and 1938 of the “Spirit of Progress” as the first all-steel fully air-conditioned and streamlined train in Australia.

Both private and Government engineering establishments alike were re-invigorated by the threat of Japanese occupation during the 1939-1945 War. Industry found itself having to satisfy previously unheard of demands for engineering equipment, machine tools, aircraft, ships, munitions and explosives, new materials and chemicals. In 1939 Australia made very few of its own machine tools, although there had been a small but thriving production of this equipment in Victoria during the latter half of the nineteenth century. By 1943, however, there were some two hundred manufacturers employing 12,000 people and making some 14,000 machine tools annually for local industry.

At about the same time, in a rare cooperative venture between the University of Melbourne and local industry, a recipe was found for a superior type of optical glass for bomb sights, range finders and telescopes in a fraction of the time that both British and American experts thought would be necessary. The new-found confidence which these and other achievements created carried over into the immediate post-war period when there was a substantial development of Victoria’s and Australia’s industrial potential.

For some of us this is still the recent past and, I suppose, an appropriate point at which to conclude. It has been a rapid and somewhat simplified survey, but I hope that it will be apparent that Victoria has a rich industrial heritage and that, from our present standpoint, we have lessons to re-learn which makes that heritage worthy both of preservation and further study.