3D PRINTING

A REVOLUTION IN THE MAKING

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► Additive manufacturing could be the key to a new world of niche markets for New Zealand companies

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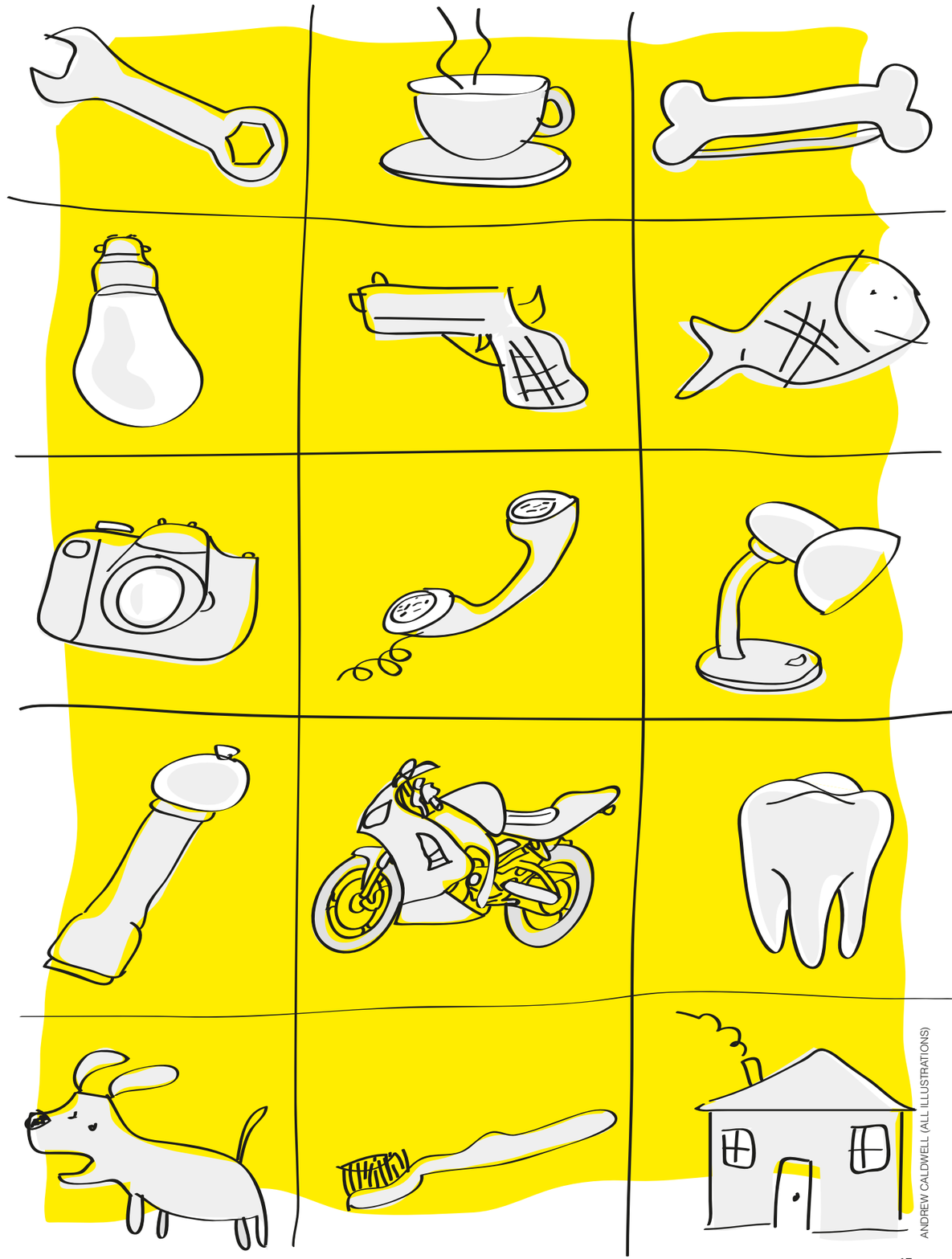

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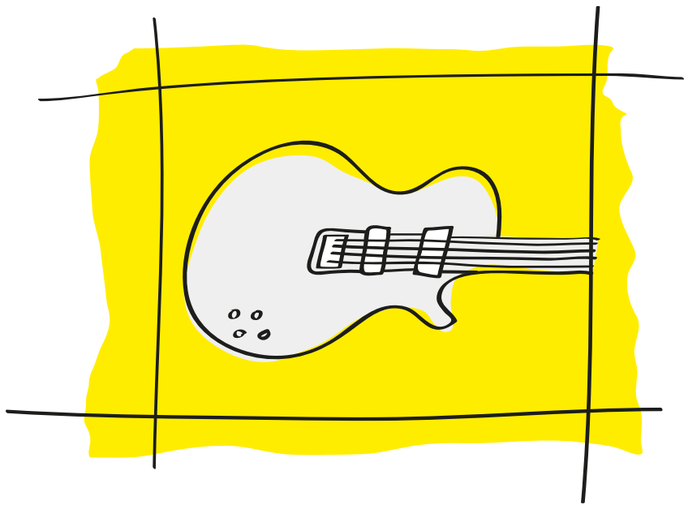


CONSIDERED BY SOME to be the next industrial revolution, 3D printing has emerged as a highly popular manufacturing tool for users from all backgrounds.

THE POTENTIAL impact of this new technology on New Zealand manufacturing should be seen in the context of the country's remoteness and small size. These characteristics, in particular, compromise the ability of manufacturers to reach the scale needed to compete in the global market. A recent Ministry of Business, Innovation and Employment (MBIE) report on high-technology manufacturing concludes that New Zealand has strengths in research and product development, short manufacturing runs, and the manufacture of high-value products, but that high-volume manufacturing is moving to lower-cost countries, closer to international markets. About a third of potential New Zealand exporters cite distance to markets as a major barrier to entry—particularly when they are looking to mass produce goods. However, there is great potential for New Zealand companies to make products aimed at niche markets that are mostly untouched by large, international companies.

3D printing allows small businesses and start-ups to take innovative ideas to market without the high set-up costs associated with traditional manufacturing. It provides entrepreneurs and 'makers' with the tools to create prototypes and consumer-ready goods close to the customer and at a relatively low cost—a standard 3D printer, for example, can now be purchased online for around $2000. Businesses and individuals without such a printer can readily access the technology via firms that offer 3D printing as-a-service, and which not only provide printable files but also offer the option of printing them on partner-network printers. One such firm, 3DLT, also offers its products through online retailer Amazon.

An internet search of 3D printing yields thousands of articles and blogs relating to additive manufacturing technologies across the globe. From orthodontic braces and bio-printed transplantable human organs to aircraft parts and self-replicating 3D printers, the world has witnessed groundbreaking achievements with the increasing popularity of this technology. 3D printing has given manufacturers a new tool for making things, including objects that were previously impossible to produce, and it has the potential to transform the way in which people from every industry and background operate. As with any technology, however, additive manufacturing has a number of limitations that should be considered before a decision is made to adopt it. These will be discussed later.

In 2013, the McKinsey Global Institute predicted that by 2025 the economic impact of 3D printing could reach US$230-550 billion per year. We believe that New Zealand manufacturers can capture some of this gain through the innovation and enhanced manufacturing processes made possible by 3D printing. The new technology can improve the prospects for import substitution, and mitigate the tyranny of distance that at present limits many companies to exporting products such as commodities, for which responsiveness isn't crucial.

WHAT IS 3D PRINTING?

ESSENTIALLY, 3D printing—or additive manufacturing—entails splitting a three-dimensional model into very thin horizontal layers using CAD (computer-aided design) software, with each cross-sectional layer 'printed' successively until the entire object is built *(see sidebar: Additive Manufacturing Technologies)*.

Additive Manufacturing Technologies

STEREOLITHOGRAPHY (SLA)

uses ultraviolet lasers to cure or solidify polymer resin. Guided by the instructions from a selected CAD file, a beam of ultraviolet light is directed over the liquid polymer, solidifying areas it contacts and creating the first layer of the three-dimensional object. This layer, which sits on a tray within the vat of resin, is then incrementally lowered, allowing subsequent layers of liquid polymer to be solidified on top of it.

FUSION DEPOSITION MODELING (FDM)

is conceptually very similar to the process used by inkjet printers, but with the extrusion nozzle depositing melted material, rather than ink. Plastic filament passes through a heated nozzle, which can stop or release the flow, while a motion control system follows the path created by the design file for each cross-sectional layer.

SELECTIVE LASER SINTERING

uses a high-powered laser to melt powder-form material, once again in a layer-by-layer process. The laser traces out the first cross-sectional layer to melt and fuse the granules together. A new layer of powder is then laid over this and the process is repeated to build the entire model.

Adapted from descriptions by Chuck Hull, the inventor of 3D printing, and Ken Vartanian, the marketing director of 3D-printer manufacturer Optomec.

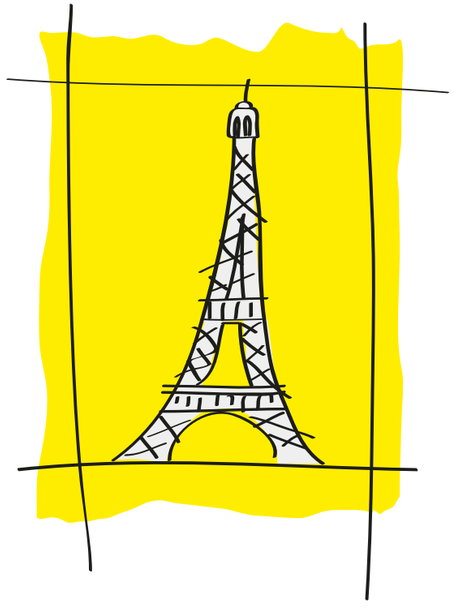
THE CURRENT SITUATION

DOMINIC BARTON, global managing director of management consultancy McKinsey & Company, told the *Wall Street Journal* in June 2014 that the bold claims made for additive manufacturing may prove justified, noting that it was included in the top 12 technologies deemed by the McKinsey Global Institute to have a potentially disruptive economic impact over the next decade. He went on to say: "Additive techniques are being used to create intricate, low-volume parts, including medical implants and difficult-to-cast parts for aerospace products. We see great potential for 3-D to speed up and improve mold making. But for high-volume manufacturing, additive methods are still too slow".

Low set-up times and minimal configuration requirements drastically reduce the time it takes to build prototypes or manufacture small batches.

A more forthright proponent of additive manufacturing is Robert Plant, Director of the Intelligent Computer Systems Research Institute at the University of Miami. He believes that additive manufacturing has the ability to "enable agile manufacturing to occur, in essence the manufacture of any item, anywhere and in any volume". He notes that additive manufacturing would enable localised manufacturing and would cut labour and transportation costs.

However, despite additive manufacturing being particularly suited to situations involving low production volumes and high levels of complexity, traditional manufacturing methods remain highly relevant for large-scale production runs. Depending on the business strategy, each manufacturing method can be advantageous, and in some circumstances performance could be improved by combining the two. Additive manufacturing technology should be considered an alternative tool for manufacturing small volume batches, where customisation, flexibility and localisation are desirable.



EXPLOITING THE BENEFITS OF ADDITIVE MANUFACTURING

Six environments are especially ripe for additive manufacturing:

•• Low-volume production

One significant drawback of 3D printers is their relatively low speed. This gives traditional manufacturing methods the advantage where large quantities are involved. However, as they require little configuration, 3D printers can begin manufacturing any design, simply by receiving the design file and appropriate materials. Low set-up times and minimal configuration requirements drastically reduce the time it takes to build prototypes or manufacture small batches. Another reason for favouring the technology for low-volume production is the cost and availability of suitable raw materials. Currently such printers are limited to using plastics and some metals and these are often far more expensive than materials for traditional manufacturing. As the use of 3D printers becomes more widespread, the range of materials is likely to expand and the cost to reduce.

•• Customisation

3D printers allow for extensive customisation due to their ability to switch to new printing jobs with very little human intervention. They permit cost-efficient on-demand production, meaning that customers can provide specifications for an item before it is printed without adding to the overall cost. 3D printing is thus highly suited to prototyping, which has been one of its main applications to date. In contrast, traditional manufacturers have advantages in standardisation and mass-production, where costs can be distributed across large quantities.

•• Localised production

3D printers operate using digital design files that are easily and instantaneously shared. As a result, production can take place locally, all over the world. Companies that previously had to manufacture products at a distance—even in foreign countries—are now able to bring production home. The ability to share design files globally dramatically cuts lead times as well as transport and other inventory-related costs. The economics of localised production may be further improved by the minimal labour requirements of additive manufacturing, which removes the cost advantage of making goods in low-wage countries.

•• Highly complex designs

Following CAD 'instructions', 3D printers are able to build intricate and geometrically complex designs, layer by layer, yielding greater strength-to-weight ratios. The additive nature of 3D printing means an object of high geometric complexity—for example, one with many hollows and curves—can be printed with the same level of ease as a simple solid block. This could be highly attractive to consumers looking for replacement parts which are often difficult or impossible to source. Where the part required is difficult to reproduce using traditional means of manufacturing, the benefit of owning a 3D printer is even greater. Design files sold online allow anyone to print what they need, when they need it, and at a significantly lower cost.

•• Fast-paced, unpredictable business environment

Additive manufacturing can provide the flexibility and adaptability to help companies remain competitive in a rapidly changing market environment, and at a relatively low cost compared with alternative manufacturing methods. For example, the modification of existing products and the development of new ones, including prototyping and small batch runs of highly customizable products, can be simplified. Companies with a low-volume, high-customisation strategy are better able to make rapid modifications and keep up with the constant change in customer expecta-

tions. Furthermore, as they are able to carry smaller inventories (if any), switching between products can be achieved with lower levels of obsolete goods and fewer write-offs. This is a huge advantage where the demand or trend, is highly unpredictable.

•• Small start-ups, entrepreneurs
For entrepreneurs or start-up businesses, the impact of additive manufacturing is related to market entry barriers. Chris Anderson, a former editor-in-chief of *Wired* magazine and a recognized supporter of the 3D printing industry, considers the greatest barrier entrepreneurs face in entering the consumer goods market is the cost of manufacturing. Additive manufacturing significantly reduces this barrier by largely eliminating the initial cost to set-up and reconfigure machinery and to source materials for prototypes.

ADDITIVE MANUFACTURING IN NEW ZEALAND

PROTOTYPE MANUFACTURING costs are a significant barrier to entry for businesses looking to expand their product lines, and for entrepreneurs trying to bring their ideas to life. Relatively remote in geography and small in size, New Zealand holds little power in international markets for common manufactured goods. In order to compete globally, New Zealand must target niche markets, representing specialty products originating from, or unique to, this country. Catherine Beard, the Executive Director of Manufacturing New Zealand, supports this view. She believes that New Zealand manufacturers cannot compete with the cheap labour and materials available in countries such as China and India. Relatively high labour and materials costs in New Zealand lead local manufacturers to focus on high-quality, low-volume niche production. This is evident in the statistics. According to MBIE, small businesses dominate the country's industries, with only one per cent of enterprises having more than 50 employees. MBIE also finds that small businesses in New Zealand are increasingly engaging in innovation activities. Additive manufacturing could further this engagement and provide new opportunities for innovation.

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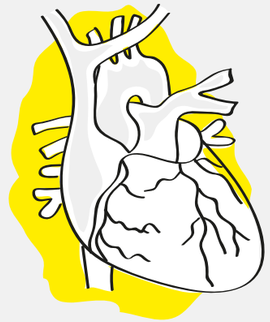
Wellington-based 3D-printing company Ponoko is an online manufacturer that facilitates the purchasing, selling, sharing and making of 3D print designs. Founded in 2007, Ponoko now has digital manufacturing hubs in California, Berlin, Milan, London, and Wellington. Industry specialists consider Ponoko to be a major driver for the 3D printing industry worldwide. Co-founder Derek Elley believes that over the next five years the application of 3D printing in New Zealand is likely to shift from producing prototypes and experimental hobbyist items, to making consumer-ready, sellable products direct to market.

The world is already beginning to see the expansion of 3D printing beyond prototyping (*see sidebar: Some Applications*). Elley further expects that New Zealand consumers will increasingly rely on distributed on-demand manufacturing companies. The challenge for additive manufacturers and service providers such as Ponoko will be to meet growing and changing market needs.

Even at this early stage in their development, 3D printers and the associated materials for manufacture are readily available at low cost. Makerbot's Replicator 2, for example, currently retails for little more than $2000. Considering how easily they can be obtained and operated, 3D printers may find their way into the average household, much as computers have done. At present, however, lower-end printers have a long way to go in terms of accuracy and product integrity (rough edges and weak structures are common issues), and therefore are better suited to hobbyists and tech-lovers.

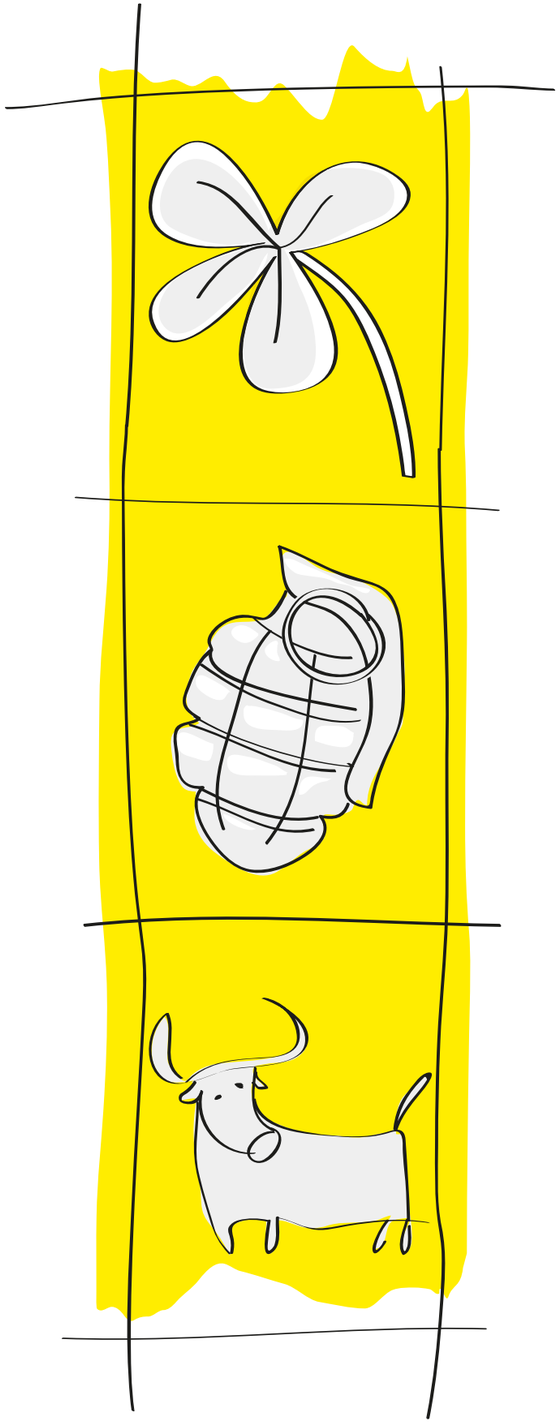
Some Applications



- **In 2003, US-based aircraft engine supplier GE Aviation successfully printed a single-component jet engine fuel nozzle that was 25 per cent lighter, and up to five times stronger than its previous design, which consisted of 25 assembled components.**

- **San Diego-based bio-printing company Organovo is currently working on the creation of functional human tissues using additive manufacturing technology. Organovo expects to reveal the world's first 3D-printed liver sometime in 2014.**

- **In early 2012, Belgian manufacturer Layerwise used titanium powder to print a transplantable jawbone for an 83-year-old patient. The metal jaw was made to exactly fit the patient's bone structure and was finished with a bio-ceramic coating. 3D-printing of such bone replacements could mean shorter waiting times, lower costs, improved accuracy, and greater success rates for patients.**



Government Initiatives

The government has demonstrated a commitment to additive manufacturing. In 2013 it awarded $12.7 million to the NZProduct Accelerator, a partnership of six universities, Callaghan Innovation, and Scion that aims to develop, among other things, capabilities in advanced manufacturing. In 2014, one of the themes of the National Science Challenge—'Science for Technological Innovation'—was the development of next-generation additive manufacturing technologies. New Zealand has natural advantages when it comes to extending the materials used for 3D printing beyond metal and plastic to biological materials. In particular, we can extract, modify, and print biopolymers from resources including lignin, cellulose and collagen.

THE FUTURE OF ADDITIVE MANUFACTURING

AS 3D-PRINTING technology advances and spreads, it will likely accelerate trends in manufacturing and supply chain strategy toward the localisation of production. This, in turn may reduce the distance-to-market barrier for New Zealand firms. Additive manufacturing remains a relatively new technology and there is still much to learn. For this reason, the country should continue to invest in research and development for 3D printing applications in manufacturing. (*see sidebar: Government Initiatives*).

However, while additive manufacturing may be highly appropriate for New Zealand, there is no reason that large, low-cost manufacturing nations such as China will ignore it. In fact, the Chinese government has already invested heavily in 3D printing technology—including the creation of clusters and innovation centres in cities such as Nanjing, Qingdao, Sichuan, Wuhan, and Zhuhai.

Breakthrough applications of 3D printing have already occurred around the world and New Zealand companies such as Ponoko are contributing to this transformation of manufacturing. New technologies encourage new ways of thinking, and from new ways of thinking we find new ways of doing things. New Zealand has much to gain from participating in this revolutionary shift in manufacturing. 3D printing technology mitigates some of the barriers and limitations we face and as such, we should explore and exploit the new opportunities it affords. ■

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KEY TAKE-OUTS

- **New Zealand's small size and distance to markets are major barriers for manufacturers.**
- **3D printing, or 'additive manufacturing', offers small businesses and start-ups the tools to create prototypes and consumer-ready goods close to the customer and at a relatively low cost.**
- **New Zealand should continue to invest in research and development for 3D printing applications and exploit the opportunities it presents.**