

The imaging industry

Early days....

Capturing images and sharing them is something human beings have been doing for thousands of years. Whether it is crude paintings on the walls of caves or beautiful portraits from Renaissance Italy the underlying desire is the same – to take an image and make it available to look at repeatedly and to share it with others. So not surprisingly there has been a long stream of innovation around meeting this basic human need – from painting tools and techniques through to different styles and media.

One strand dates back to some of the earliest experiments with a device called the 'camera obscura' – basically a pinhole camera. Early scientists knew that it was possible to see an image of something if you used a sheet of cardboard or wood with a hole punched in the centre. Light would travel through the hole and if you placed a sheet or some other flat material to act as a screen a certain distance behind it the image of the thing outside could be projected on to the screen (although it would be upside down). This novelty effect drove a number of them to experiment with ways of capturing the image – to preserve the picture in some form which others could see and share.

Photography in the sense of a solution to this challenge was born around the turn of the 19th century. Understanding optics had developed so the theory about how light rays moved and created the image in the camera obscura had improved significantly. Technology in the form of glass lenses meant that it was possible to see the image much more clearly and even to make it larger. And developments in chemistry allowed a much wider search for ways to capture and store the image itself. In particular exploiting the observation that some substances physically altered their structure and behaviour on exposure to light.

A British scientist, Thomas Wedgwood was the first person to try to integrate the image creation and capture worlds; he experimented with various surfaces such as paper and leather coated with silver nitrate. He managed to capture shadows of things placed in the surfaces but found that it was more difficult to take the output from the camera obscura because the resulting images were too faint. There was also a problem of these images darkening and fading over time. But his early ideas, reported in 1802, led others towards similar experiments and in 1816 a French researcher, Nicephore Niepce succeeded in capturing images made by a small camera using silver chloride rather than silver nitrate. He still had the problem of darkening and fading over time and the images created were the reverse of the real thing, with the darkest areas lightest in the image and vice versa. They were the earliest photographic negatives.

He began looking at other light reacting chemicals and in 1826 finally made what is accepted as the world's first stable photograph. It used polished pewter as the surface and this was covered with bitumen which hardened when exposed to light.

The capture of the image took several days but when the remaining bitumen was washed off using a petroleum solvent, the resulting hard areas remained and captured the image. Subsequent experiments and refinements reduced the time taken to expose the plates and improved the image quality but it was still a slow process.

The next step was taken by his partner Louis Daguerre who looked again at silver-based salts, particularly silver iodide. One experiment used mercury vapour to help improve the image significantly and the idea of 'developing' an image using a different chemical to that involved in its capture was born. In 1839 a demonstration of the entire process was made to the French Academy of Sciences; it used the silver iodide process to capture the image, mercury vapour to develop it and then a wash with salt solution to remove the remaining silver iodide and 'fix' the image as a stable picture.

Importantly the French government bought the rights to Daguerre's process by giving him and his son pensions for life; in return they made the knowledge freely available and so on 19th August 1839 photography became available to the world. Not surprisingly this opened up the gates for a surge of experimentation and refinement of the core ideas and techniques.

Amongst these experiments was work by the Englishman Henry Fox Talbot who had already been working on his own approaches to photography in the 1830s. He looked at alternative processes for developing and fixing images, eventually using sodium thiosulphate ('hypo') to fix the images. He also developed the calotype process which allowed multiple copies of prints to be made from a single negative by contact printing. Unfortunately although he developed this in 1840 he spent much of the rest of his life fighting lawsuits to defend his ideas rather than developing them further.

Other workers looked at different surfaces and how to coat them, including the idea of using emulsions containing various chemicals for image capture; by the 1840s there were several alternative emulsion on glass plate processes available in Europe and the USA. Many of these processes formed the basis for entrepreneurial ventures, companies set up to exploit the emerging market for photography. With these came an increasing number of legal battles around intellectual property rights which were driven by a recognition of the huge potential market which photography could open up.

This surge of invention led to improvements in key dimensions like the time taken to capture and develop images, the portability of capture materials (moving from glass plates to papers and films) and the parallel developments in camera technology.

Growing the market for photography

The potential for photography was clear – it offered a way of capturing and fixing images which could be scaled and represented a powerful alternative to painting as a labour and time intensive approach. Louis Daguerre's ideas found an early market in portraits and 'daguerreotype' images proved immensely popular amongst the growing middle classes in Europe. By the 1850s studios were offering daguerreotypes for as little as 50 cents, opening up the market further.

Camera developments (like Levitsky's invention of the bellows camera in 1847 which allowed sharper focusing) helped fuel this demand by allowing much greater variety of poses and scenes. Professional photographers began to emerge and their work appeared in newspapers and magazines – for example documenting in pictures the Crimean War or recording the construction and later disassembly of the Crystal Palace in London for the Great Exhibition. Travel photography became another early application with professionals taking what were, in effect, holiday pictures of their tourism in exotic or interesting places. Levitsky also pioneered the idea of studio photography, using the new technology of artificial electric lighting to create new effects and highlight his subjects.

Emergence of the dominant design

Part of the challenge in meeting the growing demand lay in the limitations of the glass plate processes and this pushed experimentation towards making cameras and capture technology more portable and robust. George Eastman, working in the USA, developed a process in 1884 which used a dried gelatin coated on paper which replaced the bulky stock of plates needed for the professional photographer to carry round. By 1888 he had combined this with a simple camera and began to market his Kodak camera with the slogan "You press the button, we do the rest". In 1900 he launched the Kodak Brownie camera and effectively ushered in the era of mass-market photography, making this technique available to anyone. They would take the pictures in a roll of film and then bring it to his Eastman Kodak Company who would process the images and deliver back a set of prints to the customer.

The Brownie camera sold for \$1 and film costs 15 cents a roll, bringing photography to the reach of everyone. Other developments supporting the growth of the mass photography industry followed; for example home developing and printing equipment for the enthusiast and compact versions of processing equipment to allow the growth of local facilities and services around developing and printing photographs.

Continuing market growth

The era of mass-market photography began with the Brownie and the industry grew rapidly with many entrants and an expanding market.

The market also segmented into specialist areas; for example the First World War had introduced the idea of aerial photography and specialist camera and film technology grew up around that application. X-rays were pioneered during the late 19th century and the medical imaging world grew around technologies to support this new application.

In 1891 Thomas Edison developed the motion picture camera and by the early 20th century the film industry had emerged with a demand for professional equipment which eventually cascaded down into the domestic marketplace with home movie cameras and film.

Continuing technical developments and the rise of a research-led industry

Photography represents a classic example of the twin sources of innovation at work – market pull and technology push. In the early days it was technology which created new possibilities but it was the recognition of the potential market demand which fuelled much of the growth of the industry. Early entrepreneurs recognized the need to build links with scientists and to monitor developments along the technological frontier, feeding in new ideas to the growing industry. But they also saw the importance of picking up demand signals and finding ways to solve problems created by the needs of a growing number of photographers. This led to an increasing interest in R&D; for example George Eastman employed his first research scientist to support his work back in 1886 to help him commercialize his ideas for a transparent film base. In 1912 the Rochester R&D lab was established under the direction of Dr Kenneth Mees with the explicit task of developing the technologies to support the industry.

Research efforts focused on some key emerging needs for refinements and extensions to the core process. In particular one of the limitations to photography had been its ability only to reproduce in black and white. Attempts to develop colour photography date back to the early 19th century but significant technical obstacles persisted. In 1861 a method based on work by the Scottish scientists James Clerk Maxwell was demonstrated using different emulsions to react to different images produced by lenses with colour filters on them. It was a clumsy and time consuming process but proved the principle. However other work – for example on creating emulsions sensitive to the whole colour spectrum – helped improve the pathways towards effective colour photography.

By 1907 the first commercial process – the Autochrome plate – was available using a complex emulsion and equipment but it was not robust or simple enough for the mass market. It remained based on screen plates and the province of specialists and professionals in niche markets and it was not until the 1930s that colour photography became available for the mass market. Kodak's 'Kodachrome' film used the same basic ideas of complex emulsions but made it possible to produce

16mm movie film in 1935 and 35mm slides for projection in 1936; these opened up the era of home colour photography.

Another growth area was in movie films. 1889 Kodak had developed the idea of roll film which put them in a strong position to capitalize on wider developments; in particular when Thomas Edison created the first motion picture camera in 1891 Kodak could move into the movie film business.

Although Kodak was a strong early player in the technology-led field others also played a key role. One was the scientist Edwin Land who was intrigued by his 3 year old daughter Jennifer's question 'why can't I see the pictures?' which he had just taken of her birthday party. He developed an 'instant camera' which allowed her to do just that and set up the Polaroid corporation in 1937 to develop the idea. In 1948 the first commercial Land camera went on sale and the company began to open up the market for this application. (Although this was the landmark application which grew the market for instant photography the origins of an instant camera were earlier, with the development of a laboratory version by Samuel Shlafrock in 1923 who combined camera and darkroom into a single process).

Instant photography grew rapidly and other companies entered the field to compete with Land's Polaroid corporation; the market place became a battleground for intellectual property rights arguments and Kodak eventually lost a long-running legal dispute which resulted in their having to withdraw their version of instant film from the market and pay damages to Polaroid.

The emergence of digital imaging

Electronics had emerged as a key technology in parallel with the development of photography, moving from the earliest generations of valves back in the late 19th century to an increasing array of solid state devices following the invention of the transistor in 1947. Inevitably the two worlds would come closer and in 1957 the first breakthrough towards digital imaging took place. The idea of scanning photographs into computer memory had existed as a possibility and in this year it became a reality when a team led by Russell Kirsch at the US National Institute of Standards and technology succeeded in scanning a photograph of Kirsch's son; it was primitive, with a resolution of only 176x176 pixels but it proved that computer imaging could work.

The major limitation of this approach was that it needed a large computer and memory to support it but by 1969 developments in semiconductor devices were moving to solve this problem. The charge coupled device (CCD) emerged from Bell Labs and opened up a new era in memory technology; one of the first applications of this 'bubble memory' was in developing a simple 'picture phone'. The CCD offered the possibility of transferring charge across a semiconductor surface and so could

be used to capture an image; like the use of silver salts a century before this opened up the possibility of a new generation of photography.

Many companies began work in this and by 1973 Fairchild Semiconductor were able to release a commercial CCD which could form images of 100 x 100 pixels. Kodak was an early entrant, seeing the potential of the technology and in 1975 had developed a colour sensor CCD; by 1986 they had mastered the technology sufficiently to offer the world's first megapixel (1 million x 1 million pixels) sensor.

Kodak is credited with producing the world's first digital camera in 1975; it was slow (taking 23 seconds to process an image) and low resolution but it proved the technological concept and heralded in a new era in photography. Others quickly entered and the industry grew; importantly it brought in many new players from different sectors. For example Apple launched its 'Quicktake' digital camera in 1994 (although this was actually a Kodak product with an Apple branding). But Kodak remained the early leader; in 2005 it was the top selling digital camera maker in the USA with sales of \$5.7bn. However it quickly lost this lead; by 2007 it had fallen to fourth place and by 2010 to seventh.

The speed with which digital imaging replaced conventional film was impressive; from its inception in the early 1970s it quickly took over and by 2004 Kodak withdrew from selling conventional cameras. It closed its film businesses in 2009.

The rise and fall of the industry

From its early days in the laboratories of scientists in the 19th century photography quickly grew to become a huge global business with the rise of many large corporations. Kodak was established at the turn of the century and by 1962 had sales of over \$1bn and worldwide employment of 75,000 people. Competitors; by 1981 the sales were \$10bn and employment 120,000. Its share of the US film market in 1976 was 90% and it had 85% of the camera market; without question it was the dominant global brand.

But although large and committed to strong market and technological research these companies found the transition from the world of physical film (and the underlying 'wet' chemistry involved in its manufacture) to the new world of digital imaging to be difficult. Despite early technological presence – Kodak invented the digital camera and pioneered the semiconductor technology supporting it – the key film industry giants found it hard to compete. Following a decline in fortunes Kodak embarked in a major restructuring in 2003 which led to the closure of 13 manufacturing plants and 130 processing laboratories, and cut its workforce by 47,000. By 2001 Polaroid had gone into Chapter 11 bankruptcy and Kodak followed in 2012.

Despite being technologically strong in the new fields of digital imaging all the major players have experienced difficulties in making the transition to new business

models. Kodak is continuing to struggle with redefining itself as a player in the printing industry – see the case study elsewhere on the Portal – whilst Fujifilm has become prominent in very different fields like cosmetics (again see the case study elsewhere on the Portal). Polaroid is still active in the main business with a new product – The Polaroid Cube – launched in 2014.

These examples highlight the ways in which companies can re-use their deep technological competencies based on years of accumulated knowledge – but also the difficulties in the strategic management of innovation involved in doing so.