

CMM

INTERNATIONAL

COMMERCIAL MICRO MANUFACTURING

in this issue

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MAM 2019 REVIEW

THE MAGAZINE FOR
MICRO, HIGH-PRECISION AND
MEMS MANUFACTURERS

04
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Technology convergence and integration 2019

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In the near future

A business traveller is woken up by the voice of Alexa, Amazon's smart home assistant, gets dressed and eats breakfast already cooked in an automated kitchen, part of a computerised house. An autonomous-driven limousine arrives exactly on time to transport the traveller to the airport. All personal data on a microchip implanted in the traveller's hand allows for automatic security and luggage check-in, ensuring uninterrupted passage to a first-class seat onboard an Airbus A380plus aeroplane. There is no human intervention but the traveller's progress is continuously monitored and displayed in a central control room.

The traveller's seat on the plane is in a fully automated compartment with access to a variety of multifunctional electronic devices controlled by a voice-activated or touchscreen display. There is a secure personalised global communication system installed, which allows the traveller to have an online business meeting during the flight. The aircraft does have pilots on board but most of the time it is flown by the autopilot. Later versions of the plane will not have human pilots.

Convergence and integration

How would it be possible for the traveller to make such a seamless journey without human intervention? The answer is through convergence and integration of technologies. Many different technologies would have had to be employed and integrated both for the manufacture and operation of the devices used in the computerised house, in the autonomous car, for the passage through the airport and on the A380plus aircraft. The Internet of





► An Airbus 380 cockpit.
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► An illustration of
convergence and
integration. ►

Things (IoT) and artificial intelligence (AI) would be key elements to the interconnectivity and operations of all the systems and devices used.

The A380 has been in operation for twelve years and is the largest and most advanced commercial aircraft in service. It comprises six main sections and around four million individual components manufactured by 1,500 companies in 30 countries¹.

The vast number of active parts have to operate reliably together to produce sustainable functionality. They consist of: thousands of integrated electronic circuits; many multifunctional materials; electronic, hydraulic and mechanical systems controlled by computers and communication systems; and thousands of sensors connected to displays. The aircraft is a totally integrated functional system. Every active component is continuously monitored and failure can be corrected since systems are duplicated many times.

The finally assembled aircraft at Toulouse in France required the six sections from all the suppliers in 30 countries to fit and operate together. It is one of many examples of large-



A less sophisticated but equally good example of technology integration is the smart wristwatch, which is a completely functional standalone product.



scale technology convergence and integration. I have used the Airbus 380 as an example but similar systems functionality applies to most modern forms of transport.

Large cruise ships are operated by integrated control systems. A helmsman with a simple joystick, similar to that found on a games console, can steer a ship into a confined docking space. The engine and speed of the ship can be controlled through a touchscreen on a computer.

A less sophisticated but equally good example of technology integration is the smart wristwatch, which is a completely functional standalone product. It can be used as a mobile phone, as an activity tracker with an incorporated global positioning system (GPS), as a health monitor and a camera, etc. Such watches are miniaturised versions of mobile

phones and contain similar microchip sensors and communications electronics. They have the disadvantage of short operating times owing to limited battery life unless solar-powered batteries are used. That deficiency will soon be overcome as research into the development of all types of new, more powerful batteries for electric vehicles is being actively pursued by many companies.

In addition to the integration of the components and systems in these examples, equally important is their secure connectivity to the communications and social infrastructures, without which seamless operation would be impaired.

Convergence and integration are the essential elements of life and for the formation of everything on which our civilisation depends. For example: molecules connect to form chemical compounds, which then link to form matter; at the point of conception, chromosomes in cell nuclei fuse to form regenerative living cells; cells integrate to form organisms; rocks converge to form planets; people unite to form networks, workable societies and nations, etc.

At the fundamental level of nuclear matter, a fusion or convergence of nuclei in atoms is resisted due to the immensely strong repulsive force between nuclei while powerful binding forces keep the protons and neutrons together. This repulsive barrier can only be overcome at very high temperature when fusion can take place, as occurs in the sun, then immense energy is released. Without that process, the earth and life on it would not exist.

I have outlined some examples where the outcomes of the convergence and integration of technologies are continually producing enhanced functionality across a wide range of human activities.



► A smart wristwatch. ►

Information and communication technologies (ICTs) with biotechnology (biotech)

ICTs and biotech are already inextricably linked. The next stage of convergence of these technologies is already in progress. Biotechnology is multidisciplinary and includes biomedicine and bioinformatics. In the wider context, breakthroughs in genetic medicine and medical diagnostics—affording improved treatment of disease and healthcare practice—are now occurring regularly, due, in part, to the convergence with ICTs. AI, with high-speed algorithms and access to vast databases to collect and analyse medical data, is now driving advances across all fields of medicine.

Fundamentally, there is some way to go to match the complexity of the many bio-systems that make life possible. In living organisms, these are strongly integrated and interconnected, otherwise I would not be writing this article. It is the connections between the trillions of cells and neurons in my brain that make my functionality possible. When such connections fail or are damaged by disease, then disruption occurs, often with disastrous consequences. The human body is the ultimate example of an active integrated system. As yet, we have not been able to manufacture anything that comes close to its complexity.

The convergence of nanotechnology and medical imaging has already spawned a revolution in molecular imaging that enables identification of a single molecule or single cell in a complex environment and thus detection of the early onset of cancer. This area of nanomedicine is considered a high priority for research by the European Technology Platform (ETP) for Nanomedicine².

Miniaturisation technologies such as microfluidics have enabled integrated multi-biosensor arrays to be incorporated into lab-on-a-chip devices so that thousands of samples can be analysed simultaneously. This large amount of data provides practitioners with more reliable

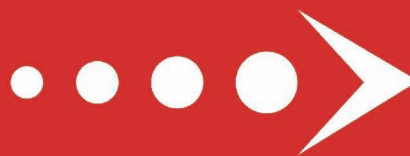
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diagnostics. These integrated systems are the basis of point-of-care devices now becoming more widely available in medical centres.

Another example of the convergence of disciplines, and one of personal interest since I was involved in early discussions on the instrumentation for accelerators, is the development and realisation of proton beam cancer therapy³. After many years, this form of radiotherapy has now become established as more centres are built in the UK and around the world. It was the closer cooperation and understanding between nuclear physicists, electrical and mechanical engineers, and medical practitioners that eventually made this a practical reality.

Like the Internet, the convergence of ICTs and biotech is opening the door to new horizons for advancing medicine and healthcare. By embracing other technologies, new industries and business practices can be created. For those interested in such possibilities, there is an extensive volume of material published on the Internet that predicts a range of possible future outcomes, etc.

ICTs with manufacturing

The greatest challenge facing microsystem engineers in the late 1990s was how to integrate and package micro electrical mechanical components into functional MEMS in order to facilitate the manufacture of useful end-products. It was the convergence of mechanical microsystems and microelectronics that made this possible. Functional products such as domestic appliances and vehicles had integrated microchips embedded in their structures. Crash impact sensors that trigger airbags in cars is one such example.

The technical issues associated with microsystems integration are described in my article Systems integration, published in the October 2017 issue of CMM⁴. In the past, all manufactured end-products, particularly those comprising microparts, have required the integration of many different process technologies for their realisation.

During the last decade, advances in computer-integrated manufacture (CIM), ICTs that provide faster data storage, retrieval and handling, more sensitive sensing, and the availability of algorithms to unite all of these with management systems have raised manufacturing efficiency to high levels and laid the foundation for fully automated manufacturing or smart manufacturing.

The automotive industry was the prime driver and was one of the first to establish programmable robotic machines for car assembly. With the integration of AI into the manufacturing infrastructure, huge efficiencies in production, quality and throughput are now obtainable.

These changes have only been made possible by the convergence of ICTs and operational technologies (OTs). This has necessitated the development of new machine learning software. The demands of the global market will place even greater emphasis on these technologies to help industry deliver competitive quality products.

Multifunctional materials

The emergence of materials with unique properties was the basis of nanotechnology derived from the acquisition of knowledge of structures at the nanoscale (10⁻⁹). However, it required the convergence of nanotechnology with micro- and macro-technologies before useful end-products could be manufactured and packaged. Ultra-fine inkjet printers and coatings applied to textiles to make them stain-resistant or flame-retardant are just a couple of many nanomanufactured products that have ongoing commercial applications.

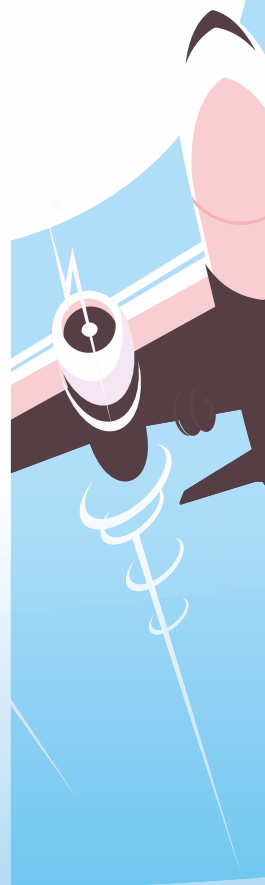
Combining two or more materials with different properties as coatings or composites can enhance the structural performance of a product. Some materials can be made multifunctional, thus reducing weight and lowering cost. Take, for example, the need for extended electrical storage to make electric cars more viable. If electrical energy could

be stored in the material of the car's body instead of just the battery, it would reduce weight, lower cost and extend drive time. This principle could be applied to all electrically driven vehicles, possibly including, in future, electrically powered aircraft. Airbus is already working on electric and hybrid-electric propulsion for aircraft with government support as part of the programme to reduce future CO₂ emissions and noise level reduction⁵. This work is being carried out with partners Rolls-Royce and Siemens. Airbus is focusing on the integration of electric motors into the overall design, and Rolls-Royce and Siemens on the use of lightweight composite materials for body parts.

Functional carbon-based nanomaterials have become important due to their unique combinations of chemical and physical properties, and extensive research efforts are being made to utilise these materials for various industrial and medical applications. There are ongoing European and national research programmes on the properties and synthesis of multifunctional nanocomposites made from nanomaterials such as graphene and nanotubes in applications for the construction of solar cells and battery electrolytes⁶.



► The LHC particle accelerator at CERN. ►





The Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN)

In contrast to scale but similar in complexity to the Airbus aircraft is the LHC at CERN. It is the world's largest and most powerful technologically advanced particle accelerator, comprising a 27 km ring of superconducting electromagnets.

The LHC is not only the best example of the convergence and integration of almost every scientific, engineering and technology discipline but also the most impressive in terms of bringing together over 10,000 researchers sharing a common interest from across the globe. It also has the world's largest network, with 170 computer centres spread out in 44 countries⁷.

Further details of the LHC's construction and the scientific programme can be found on the CERN website. It was the need for automated information-sharing between and distribution of data to CERN researchers that was the basis of the formulation of the World Wide Web by Tim Berners-Lee in 1989 and later generated the Internet⁸.

The way ahead

The aforementioned examples highlight how convergence and integration of technologies bring about the realisation of new manufacturing methodologies, products and systems. There is little doubt that irrespective of the political hubris of Brexit and political turmoil that currently afflicts the world, science and technology continues to provide solutions to many of the world's practical problems.

We live in a connected world but also in a very non-integrated one. These two aspects seem to defy rationality. Why is this when, as a species, we have been very successful in advancing our civilisation by adapting and surviving in a harsh environment? We have acquired knowledge to grow food, to manufacture products and to combat many diseases that prolong life but, unfortunately, too often diversity produces disharmony. In societies, the instinctive desire to protect old customs and tribal cultures is often a barrier to integration. Generally, however, when such barriers are broken down and integration occurs, significant benefits accrue.

The outcomes of the Human Genome Project continue to provide large volumes of genomic data, which are proving invaluable to medical research and practical medicine. The continuing merging and integration of ICTs and biotech in the healthcare industry have already resulted in paradigm shifts in how it provides services to the public. This is an area that will have the greatest societal impact in the future. ●

David Tolfree, physicist and independent technology consultant

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