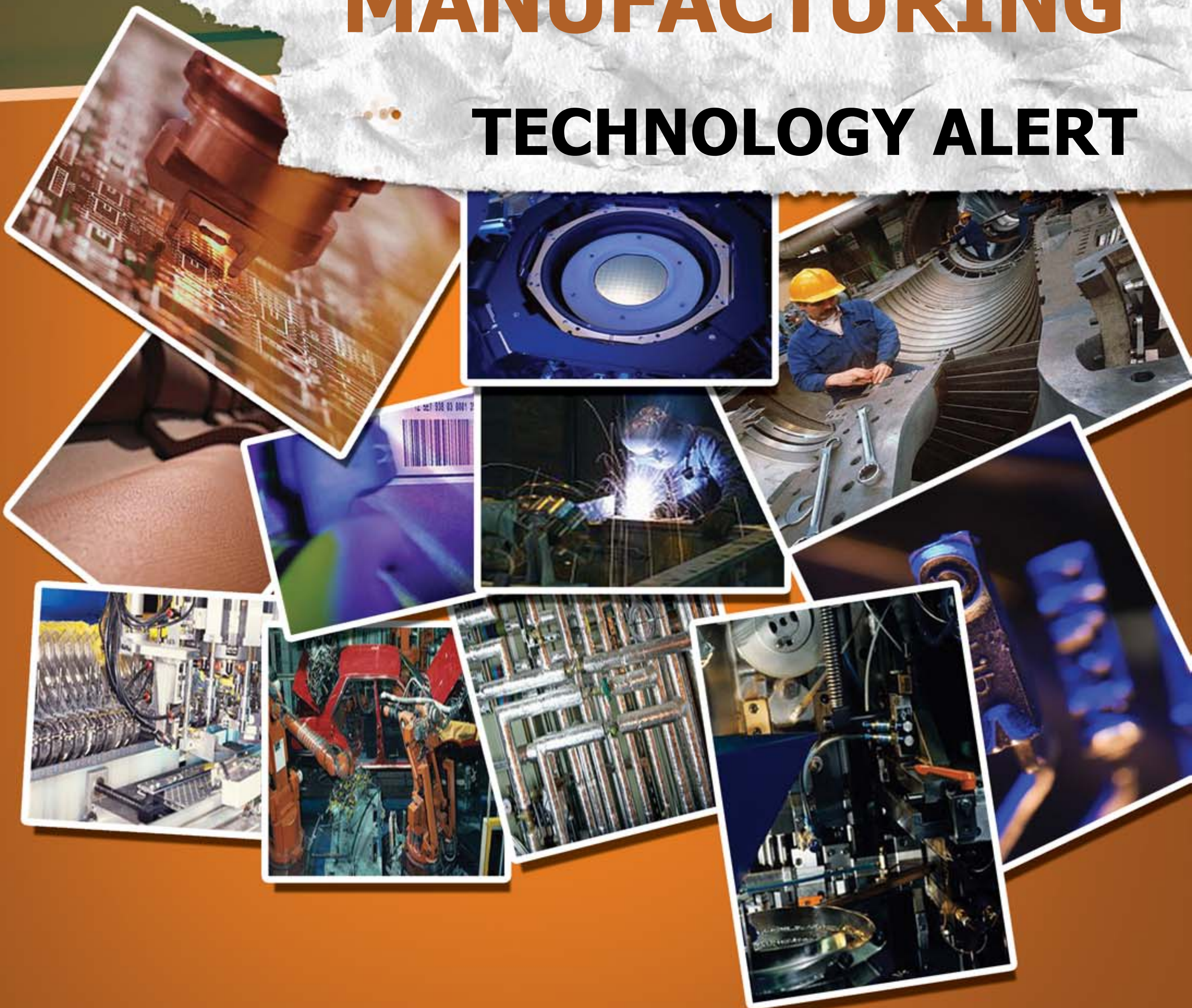
# TECHNICAL INSIGHTS

## ADVANCED MANUFACTURING

### TECHNOLOGY ALERT



24th July 2015

## 1. BENEFITS OF 3D PRINTING TO THE AIRCRAFT INDUSTRY

The benefits of three-dimensional (3D) printing are being extended to different manufacturing industries and applications.. Key industries that use 3D printing largely for prototyping parts in include automotive, aerospace, consumer goods, oil and gas, and so on. In the aero industry, 3D printing is increasingly being used or investigated for production parts.

In a recent study, a research team from the Northwestern University has outlined the immense benefits 3D printing could bring to the aircraft industry. Their study indicates that incorporating 3D printing for making several parts of the aircraft could reduce the weight of the aircraft by 4% to 7%. The study highlights that 3D printing of aircraft parts will not only save a lot of money to the aircraft industry, but will also make the aircraft industry more environment friendly. Apart from these benefits, 3D printing could also bring in benefits such as significant reduction in consumption of fuel, raw materials, and other resources.

The research study included data published by the aircraft industry on the environmental effects of using 3D printed parts in aircraft. This data was crucial to the study and helped the researchers establish the fact that 'printing' aircraft parts that are light and parts that deliver high performance, could significantly reduce the aircraft's weight and generate less manufacturing waste.

This study was funded by the US Department of Energy's Advanced Manufacturing Office. The research also included a couple of scientists from Argonne National Laboratory. The study explains that the aircraft industry is one of the earliest adopters of 3D printing technology mainly because of its weight reduction potential. Other way of reducing weight of aircraft is to use specialized lightweight metal alloys, which involves very expensive processes and materials.

In comparison with traditional manufacturing techniques, 3D printing requires raw materials in less quantity. For instance, the study illustrates that for producing an airplane bracket weighing 1 kilogram, up to 10 kilograms of raw materials would be required. This not only produces waste of around 9 kilograms, but the bracket produced may often weigh more than 1 kilogram. In comparison, in the study, it was found that 3D printing reduced the weight of an aircraft bracket from 1.09 kilogram to 0.38 kilograms while the other properties of the bracket remained the same.

The researchers claim that 3D printing has great potential to be used to manufacture less critical aircraft parts such as brackets, hinges, seat buckles, and furnishings. Each of these components will have less weight when produced using a 3D printer. Individually, the weight reduction seems less, but since several parts are used in an aircraft, when added up, the aggregate weight reduction contributes 4% to 7% of the aircraft's weight, and this is a significant weight reduction in aircraft industry.

Currently, the researchers do not see 3D printing as a replacement of traditional manufacturing for manufacturing critical aircraft parts such as engines, propellers, and wings. However, there are consistent research activities that are carried out to extend 3D printing into those areas. (Moreover, GE Aircraft plans to use 3D printing to make fuel nozzles for the next-generation LEAP aero engine.) During the assessment of 3D printed parts in aircraft, the researchers ascertained that the fuel consumption of aircraft using 3D printed parts reduced by around 6%. Analysis of the lifecycle of 3D printed components on aircraft revealed that the energy used by 3D printing equipment is 30% to 65% lesser than conventional technology, which results in reducing the carbon footprint. Also, the industry could save tons of raw materials used such as aluminum, titanium, and nickel and reduce the amount of waste generated.

The benefits of 3D printing technology for the aircraft manufacturing industry are immense. But shortcomings in the printing process, scalability, mass production, issues with surface quality, and residual stress are limiting the adoption of 3D printing in the aircraft industry. More funding research in improving the 3D printing process will help to address these issues in the short term and pave way for the aircraft industry to reap the benefits of 3D printing in the near future.

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## 2. INNOVATIVE, HIGH-SPEED 3D PRINTING TECHNOLOGY

Three-dimensional (3D) printing is making its way into the manufacturing industry as a replacement for complement to convention manufacturing processes. In what can be called the beginning of a new era in manufacturing, 3D printing technologies are being investigated and embraced for their enormous benefits for the future of manufacturing. Although 3D printing is expected to significantly impact the manufacturing industry, it is anticipated that it will take time (perhaps 5 years or so) until 3D printing can be used for more widespread mass production in certain industries such as aerospace At present, most of the 3D printers are used for making prototypes, with different structures, geometries, and materials.

Typically, additive manufacturing or 3D printing technologies, which deposit layers of materials to create a 3D object of a desired shape, tend to be relatively slow, due to the multi-layer deposition process. This raises serious questions about using such technologies for large volume production.

A California-based 3D printing start-up company, Carbon3D, has created a novel 3D printing process that works at high speeds and delivers 3D objects with precise geometries. Moreover, this 3D printing process is more suitable for mass production. The novel technology developed by Carbon3D is called Continuous Liquid Interface Production (CLIP) technology.

The CLIP technology, in contrary to the traditional layer-by-layer approach, prints 3D objects more like injection molding. In the CLIP process, liquid resin is contained is a special container. The resin is UV (ultraviolet) curable and solidifies when UV light hits it in presence of oxygen due to a phenomenon known as ‘UV photopolymerisation.' The bottom of the container is made of materials that are selectively permeable; in this case the materials are permeable only to oxygen.

The oxygen at the bottom of the container facilitates solidification of the resin. The oxygen creates a layer at the bottom called ‘dead zone’ between the container and liquid resin, which has thickness of few tens of micrometers. The UV light is projected in accordance to the design of the 3D object desired through the bottom of the container. When the UV hits the resin layer, it solidifies at the exposed region just above the dead zone. This dead zone is a unique feature of CLIP technology and allows the solidification of the resin right above this layer. Thus, the 3D object formed by solidification of the resin can be pulled up continuously. Thus, by cautiously balancing the oxygen supply and light (UV) interaction, 3D objects can be printed continuously from a pool of resin.

 

The innovative CLIP technology approach for 3D printing reduces the printing time of a 3D object from a few hours to a few minutes. Further, the new technology has the potential to incorporate a broad range of materials that are used in real-time manufacturing environments. One such example is the use of elastomers, a class of polymers with very high elasticity that are used in making automobile parts and shoes of athletes.

Crabon3D has received funding of $10 million from Autodesk in April 2015. Carbon3D is expecting to commercialize the 3D printer featuring CLIP technology during the end of 2015.

CLIP technology can be a disruptive technology in the manufacturing industry, which is generally keenly interested in 3D printing. While other 3D printing technologies raise queries about deployment in high-volume production environments, CLIP technology is promising for adoption in mass production environments.

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## 3. METHOD TO USE METALS IN 3D PRINTING

The popularity and wider acceptance of 3D printing as the next disruptive manufacturing technology has spurred immense interest among universities, research organizations, and industries to explore and experiment with 3D printing. The intense research activity in 3D printing is pushing the capabilities of 3D printing year after year. Today, 3D printing can print objects in less time than in the recent past (for example, 3 years ago). The number of materials that can be used to print 3D objects has increased exponentially in the past 5 years or so.

One research endeavour to extend the 3D printing capabilities was undertaken by a research team at the University of Twente. The researchers were able to successfully print 3D structures out of copper and gold. In this work, 3D printing was successfully achieved using metals. The researchers believe that their discovery would create opportunities for creating new microelectronic components such as small cooling elements or connections between stacked chips in smartphones.

Since metals have a very high melting point, controlled deposition of melted metal droplets on substrates is a challenging task. Moreover, nozzles that are thermally robust are required to transfer melted metals, but such nozzles hardly exist. Hence, the research team used an alternative technique to tackle the problem of melting the metals and transferring them to the substrate. In their approach, the researchers used laser light to melt copper and gold. The researchers used a very powerful pulsed laser that melted the metals into a micrometer-sized droplet and then transferred it onto a substrate. This process was repeated and droplets were sequentially placed on top of the previously deposited droplets to make a 3D structure. The team stacked thousands of droplets to form structures that resembled micro-pillars. They were able to achieve a structure of with 2 millimeters height and 5 micrometers width. They were also able to successfully print copper lines on circuits and vertical electrodes in a cavity.

Initially, the researchers used a low energy laser for the experiment, but this method did not render metal droplets with the impact velocity required for transferring onto a substrate. But, using low impact velocity of the droplets made the droplets to solidify in a spherical form. Then, the team used a high energy pulsed laser to gather enough impact velocity for the metal droplets. This velocity helps the droplet to settle on the substrate in a disc shape and solidify in the same shape. However, the metal droplets obtained by melting through high-energy lasers often miss the desired location and land in places around it. The research team is currently working to address this issue. They are also investigating on methods to use the new technique to print with other materials such as other metals, gels, pastas, and very thick fluids.

This novel technique of 3D printing metals can be seen as another proof of the emergence of 3D printing as a strong force that could impact or disrupt manufacturing technologies in the future. Research and development activities to further improve the metal 3D printing process and scaling up for mass production will enable opportunities for development of many new products in the microelectronics space.

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## 4. PATENT ANALYSIS OF SPOT WELDING PROCESS

In the welding world, spot welding is one of the old processes used in various industries. In particular, spot welding is used in automotive assemblies for assembly of sheet steel vehicle bodies. Spot welding is a type of resistance welding used prominently in welding sheets or parts up to 3 mm in thickness. In this process, welds are made on overlapping sheets of metal at regular intervals.

The spot weld diameters usually range from 3 mm to 12.5 mm, and the strength of the joint produced by using spot welding depends on the number of welds done and the size of the welds performed. Spot welding process uses copper electrodes to perform welds. Copper is preferred for its high-thermal conductivity and low resistance, which are desired parameters for generating a very strong weld.

Patent analysis of the patents filed for spot welding in the last 5 years reveals that the number of patents filed has been consistent over these years. Since spot welding is prominently used in the automotive industry, in the last 5 years the highest number of patents have been filed by automotive companies such as Hyundai Motor Company, Nissan Motor Co. Ltd., and Mazda Motor Corp.

An interesting patent (WO/2015/081594) pertaining to an electric resistance spot welder for micro welding was filed by Guangzhou Micro Welding Equipment Co. Ltd. Another patent (US 20150174690), pertaining to a spot welding process for high strength steel, was filed by Nippon Steel & Sumitomo Metal Corporation.

| Title | Publication Date/Publication Number | Assignee | Inventor | Abstract |
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| **Spot welding system and operation method for the same** | July 2, 2015/ US 20150183050 | Hyundai Motor Company | Hyunwoo Lee | A spot welding system is disclosed. In particular, the spot welding system includes an upper moving unit provided with an upper electrode and a lower moving unit mounted separately from the upper moving unit and provided with a lower electrode corresponding to the upper electrode. Together, the upper moving unit and the lower moving unit separately vary a position of the lower electrode to allow for reduced size restrictions of objects to be spot welded therein. |
| **Spot welding apparatus** | July 2, 2015/ US 20150183049 | So Young Lee | So Young Lee | A spot welding apparatus is provided that includes a fixation panel mounted on an arm of a robot. An upper welding gun is vertically installed on a front of the fixation panel, reciprocatesvertically through a pressing unit and moves horizontally toward the fixation panel. A left and right moving unitis installed between the fixation panel and the pressing unit to move the upper welding gun horizontally. Further, two or more lower welding guns are horizontally disposed to correspond to the upper welding gun, and an upper and lower moving unit are installed on the fixation panel to reciprocate the lower welding gun vertically. |

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| **Friction stir spot welding apparatus, friction stir spot welding method, and device for detecting perpendicularity to surface for friction stir spot welding** | July 2, 2015/ WO/2015/097727 | Kawasaki Jukogyo Kabushiki Kaisha | Okada, Hideki | This friction stir spot welding apparatus is provided with a rotating tool (10A) and a perpendicularity detection unit (20A) for detecting whether or not the position of the rotating tool (10A) is perpendicular to the surface of the welding site of the object being welded (50). The perpendicularity detection unit (20A) measures the distance to at least three measurement positions set around the welding site with, for example, position sensors (21). Said measurement positions are set on a reference plane, which has the forward-reverse direction of the rotating tool (10A) as the direction of the normal vector, so as to be located at the vertices of a polygon. The perpendicularity detection unit (20A) determines that the rotating tool is in a perpendicular state when the distances to all of the measurement positions are equal. |
| **Resistance spot welding method** | July 2, 2015/ WO/2015/099192 | JFE steel corporation | Sawanishi, Chikaumi | The objective of the invention is to provide a resistance spot welding method with which a nugget having a suitable diameter can be obtained even under special welding conditions, without increasing the energization time and without the generation of expulsions. The invention is a resistance spot welding method in which an energization pattern is divided into multi-stage steps having two or more stages, and in which test welding and main welding are performed. In the test welding, the energization is performed using a constant current that has a different current value for each step, and the time variation of the instantaneous amount of heat generated per unit volume, and the accumulated amount of heat generated per unit volume are stored as target values. In the main welding, if the amount of time variation of the instantaneous amount of heat generated per unit volume deviates from the results of the test welding during any step, the amount of energization is controlled in such a way that the difference is compensated for during the remaining energization time in said step. The configuration is such that in the test welding, if the energization current in a first step is Ia and the energization current in second and subsequent steps is Ix, the relationship $0.3 \times Ix \leq Ia < Ix$ is satisfied. |
| **Spot welding method of high-strength steel sheets excellent in joint strength** | June 25, 2015/ US 20150174690 | Nippon Steel & Sumitomo Metal Corporation | Seiji Furusako | When two high-strength steel sheets (1A, 1B) whose sheet thickness ratio={the sum of sheet thicknesses of the steel sheets}/{the sheet thickness of the thinner steel sheet (when they have the same thickness, the sheet thickness per one sheet)} is within a range of not less than 2 nor more than 5 and which both have tensile strength of not less than 780 MPa nor more than 1850 MPa are stacked to be subjected to resistance spot welding, a first welding step being pre-welding with a pressurizing force P1 kN and a welding current I1 kA and a second welding step being main welding with a pressurizing force P2 kN and a welding current I2 kA are performed, the pressurizing forces P1, P2 are set to a fixed pressurizing force P=P1=P2 all through the first welding step and the second welding step and are set within a range expressed by {$0.5 \leqq P \leqq 3.0t(1/3)$}, where t mm is an average sheet thickness of the steel sheets (1A, 1B), the welding current I1 is set within a range of not less than 30% nor more than 90% of the welding current I2, and the second welding step is started within 0.1 s after the first welding step is finished. |

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| **Spot welding method** | June 25, 2015 / US 20150174689 | Kabushiki Kaisha Kobe Seiko Sho (Kobe Steel, Ltd.) | Toshio Murakami | A spot welding method joins metal sheets by: clamping a stacked section of two or more stacked metal sheets with a pair of electrodes at a load of 100 N or more; applying pressure around the electrodes at a load, which is 5-1000% of the load due to the pair of electrodes, using a pressurizing member, which applies pressure on the stacked section in regions that are 20% or more of the total outer circumference of the electrode tips and for which the continuous regions of the entire outer circumference of the electrode tips that are not pressed are 30% or less (including 0%) of the entire outer circumference of the electrode tips; and passing welding current from the electrodes to the stacked section. |
| **Spot welding method for high strength steel sheet** | June 25, 2015 / US 20150174688 | Hyundai Motor Company | Ji Hong Yoo | A spot welding method for a high strength steel sheet is provided. The method includes a first pulse step for applying electric current of about 8 to 9 kA about 1 to 3 cy and a first cooling step for cooling for about 1 to 3 cy. In addition, the method includes a second pulse step for applying electric current less than the electric current applied in the first pulse step and a second cooling step for cooling for about 1 to 3 cy. A third pulse step includes applying electric current greater than the electric current applied in the second pulse step. |
| **Resistance spot welding method** | June 25, 2015 / WO/2015/093568 | Nippon Steel & Sumitomo Metal Corporation | Fujimoto, Hiroki | A plurality of steel plates including a high-tensile-strength steel plate are arranged in superposition; pulsed electrical energy is delivered using an inverter DC spot welding power source; the time over which the pulsed current is delivered, the electrical energy downtime; i.e., the intervals between the current pulses, and the welding current applied by the current pulses are variably controlled to yield optimal weld conditions; and, when hot-stamp steel plates are welded by resistance spot welding, the incidence of surface spattering and interior spattering is suppressed and a broad suitable current range is ensured, even with the use of an inverter DC power source, by performing the resistance spot welding in such a way that the minimum welding current during a second pulsation step is higher than the maximum welding current during a first pulsation step. |
| **Electric resistance micro-welding spot-welder** | June 11, 2015 / WO/2015/081594 | Guangzhou Micro Welding Equipment co. Ltd. | Yang, Shitong | Disclosed is an electric resistance micro-welding spot-welder comprising a spot welder machine head, a spot-welding power source (213) and a welding head holder (212), wherein a precise electrode force pressurizing system is provided on a machine head frame (201), the precise electrode force pressurizing system comprises an electromechanical welding applied force conduction apparatus, a precise electrode force pre-setting apparatus and a welding force breaker apparatus. Relevant structural collaborative action and mutual restriction enables the electrode force to be held within a pre-set range and relatively constant during the entire spot-welding time interval. Moreover, the spot-welder also has a plastic machine head frame structure, a stepped welding head holder structure, and a structure of a micro-welding optical apparatus mounted on a cantilever cross beam at the top end of a machine head frame, enabling the spot-welder to meet the basic requirements of electric resistance micro-welding. |

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| **Electrode for spot welding, and welding device and welding method employing** | June 11, 2015/ WO/2015/083835 | Nippon Steel & Sumitomo Metal Corporation | Watanabe, Fuminori | This donut-shaped electrode for spot welding has an electrode distal end portion (1) and an electrode-supporting portion (2). Because the electrode distal end portion (1) is in movable contact with the electrode supporting portion (2), the conformability of the donut-shaped electrode to a steel sheet is dramatically improved, and because the entire surfaces of donut-shaped contacting and conducting portions (14) can be brought into contact with the steel sheets (50), a high cross-tensile strength (CTS) of the spot-welded joint can be ensured, even if the steel sheets (50) are inclined. |

**Exhibit 1 depicts patents related to spot welding process.**

*Picture Credit: Frost & Sullivan*

## 5. TECHVISION 2015

The TechVision program is the premier offering of Technical Insights, the global technology innovation-, disruption-, and convergence-focused practice of Frost & Sullivan. TechVision embodies a very selective collection of emerging and disruptive technologies that will shape our world in the near future. This body of work is a culmination of thousands of hours of focused effort put in by over 60 global technology analysts based in six continents.

A unique feature of the TechVision program is an annual selection of 50 technologies that are driving visionary innovation and stimulating global growth. The selected technologies are spread across nine Technology Clusters that represent the bulk of R&D and innovation activity today. Each Cluster represents a unique group of game-changing and disruptive technologies that attract huge investments, demonstrate cutting-edge developments, and drive the creation of new products and services through convergence.

Our technology analysts regularly collect deep-dive intelligence on several emerging and disruptive technologies and innovations from around the globe. Interviews are conducted every day with innovators, technology developers, funders, and others who are a part of various technology ecosystems. The respondents are spread across public and private sectors, universities, research institutions, and government R&D agencies. Each technology is rated and compared across several parameters, such as global R&D footprint, year of impact, global IP patenting activity, private and public funding, current and emerging applications, potential adoption rate, market potential, and so on. This organic and continuous research effort spread across several technologies, regions, organizations, applications, and industries is used to generate an annual list of Top 50 technologies that have the maximum potential to spawn innovative products, services, and business models.

Furthermore, we analyse several possible convergence scenarios where two or more of the Top 50 technologies can potentially come together to disrupt, collapse, and transform the status quo. Driven by IP interactivity emanating from each of the top technologies, a whole range of innovative business models, products, and services will be launched at unprecedented speed in the future. We have come up with over 25 such unique convergence scenarios.

The Top 50 technologies we have selected for TechVision 2015 have the power to drive unique convergence and catalyse wide-scale industry disruptions. Frost and Sullivan's TechVision program empowers you with ideas and strategies to leverage the innovations and disruptive technologies that can drive the transformational growth of your organization.

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