

AutomationWorld Design World TACTICAL BRIEF

Robots & Machines in Motion

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Motion: How to Decide When to Distribute Control

Although automation vendors tend to urge users to consider decentralizing drives and distributing as much intelligence as possible throughout their machinery, most readily admit that it's not for every application. The centralized approach is still valid for many applications.

By James R. Koelsch, Automation World Contributing Writer

The natural question to ask is, how does one go about making a decision? Here is some advice from Tom Jensen, technology evangelist at Lenze Americas Corp.

- **Start with a white sheet of paper.** “Don’t copy and paste code and concepts for new mechatronic machines,” advises Jensen. “Copying old concepts locks you into old hardware concepts.”
- **Think functionality.** Ask, what does the machine need to do? In general, complex motion tends to benefit the most from centralized control. “If the machine can be simplified, gains might be realized with remote motor-mounted frequency drives,” notes Jensen.
- **Consider the machine’s footprint.** Small machines with short cable runs normally have a cabinet.
- **Count the motors.** “A low motor count works against decentralized drives,” says Jensen. “Generally, decentralized motion control is great for a single axis, but syncing multiple axes requires programming and wiring between controllers that can be done easily in a centralized controller.”

An example of an application that can benefit from distributed drives is the machinery used in warehouses and distribution centers. These facilities can have more than 12,000 motors and drives actuating various palletizing and wrapping machines, conveyors, automated storage-and-retrieval units, and robots.

“A traditional motor would have a cabinet-mounted motor control device, such as soft start, breaker or drive,” says Jensen. “Such solutions would prove to be more costly and hard to maintain because of the motor structure.”

For this reason, he and his colleagues work with manufacturers of warehouse equipment to reduce the size of motor-control centers by installing motor-mounted induction drives. Driving many motors with one three-phase power supply can greatly reducing the branch protection needed to support a line, according to Jensen. Distributing drives and daisy chaining motors also can reduce the need for cabinet and cable by as much as 80 percent, he says.



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Bionics and Industrial Automation

Festo continues its research into biomechatronics to influence efficiency, construction, integration, and operation of its industrial automation and engineering products.

By David Greenfield, Director of Content/Editor-in-Chief

Two years ago at Hannover Fair in Germany I caught my first glimpse of Festo's ventures into biomechatronics. At the event, Festo introduced its automated herring gull (a seagull to those of here in the U.S.), which it referred to as the SmartBird. Essentially, the SmartBird is a light (less than 16 oz.) flying robot with a wingspan of more than 6 feet that can autonomously take off, fly, and land. Behind Festo's development of the SmartBird is the company's belief that learning more about efficiencies in natural motion can help deliver efficiencies in its automation technologies.

At this year's SPS/IPC/Drives show in Nuremberg, Germany (held the last

week of November 2013), I saw Festo's newest venture in biomechatronics—the BionicOpter. Inspired by the flight of the dragonfly, the BionicOpter can fly in all directions, hover in mid-air, and glide without beating its wings. According to Festo, the BionicOpter features thirteen degrees of freedom through control of the shared flapping frequency and twisting of individual wings in addition to an amplitude controller on each of the four wings. Amplitude control allows the intensity of the thrust to be regulated. When combined with the tilt of the wings to affect the direction of thrust, the remote-controlled dragonfly can reportedly assume almost any position in space.



Continued Bionics and Industrial Automation

Inside the BionicOpter, components such as sensors, actuators and open- and closed-loop control systems are integrated to operate with the remote control for wireless real-time communication. This integration of systems is ultimately the main point of Festo's BionicOpter—to demonstrate wireless real-time communication and the ability to combine different sensor evaluations to identify complex events and critical states.

R&D of this type underscores Festo's concept of integrated automation based on its CPX automation platform. Dr. Ansgar Kriwet, a Festo

management board member, noted at the SPS/IPC/Drives event that CPX is helping position Festo to take advantage of the Internet of Things as it develops because the CPX platform can integrate field device bus systems as well as industrial Ethernet. CPX is "well-equipped for the future ... [where automation] installations will adapt automatically to product modifications," he said. The CPX automation platform enables integration of Festo's motion control, pneumatic components, measurement and control technology, and safety to all of its field devices for process and factory automation.

Mechatronic Motion Solutions



Mechatronic Motion Solutions from Festo is a unique system of components, modules, and software. It integrates all types of pneumatic, servopneumatic and (electro) mechanical automation motion and combines them according to your task. Irrespective of the control system environment you use, Mechatronic Motion Solutions always provides the appropriate interfaces.



What's Next for Machine Controllers

By Steve Meyer

In the world of Industrial Controls, the traditional platform has been the PLC. This control was initially the by-product of decades of hard wired automation based on relay logic. The rules were fairly simple, everything got broken down to “on” and “off” contacts, but with the creation of an electronic platform that solved the logic at higher speed and with greater complexity, you could create lots of sophisticated systems from some fairly simple building blocks. The real motivation here is to use a common language to communicate how things work that maintenance people can be comfortable with. Since plant floor electrical maintenance people were generally familiar with relay logic, the programming language of the PLC was pretty much decided.

Not that other ideas weren't tried. I remember Boolean programming and some other variants that were attempted due to the variety of solutions being offered by competing vendors. Some of the early PLC's involved some very exotic variants such as programs that executed software in strict line-by-line form as part of the control system strategy to insure precise, repeatable execution. Larger systems with 1000's of I/O points simply relied on centralized execution and the controllers focused on increasing speed to manage system behavior. The common metric was so many thousands of lines of code per millisecond of execution time.

Where does all this go when the cost has fallen to a \$.50 chip of FPGA logic and an OEM editor that you can license for \$5 a copy

from one of the major suppliers of ladder editors? As a marketing proposition, it's hard to differentiate a highly technical production like a controller when there are 20 or 30 brand of mature products to choose from. This is made more difficult when the system pricing varies from \$300 to \$3000 for what could be argued is the same thing. If the assumptions about the commodity level product are correct, then where is all this headed.

When evaluating controls, the dominant cost is generally not the processor, it's the I/O system. There certain applications where there are specific I/O considerations such as platinum RTDs or specific alloy thermocouples which cannot be avoided. In these cases, the supplier with the best product wins, pricing may be a secondary consideration. With regard to general purpose I/O products, ac and dc discrete inputs and outputs, lowest cost combined with highest density will be the most effective. So if the system requirement is relatively simple, direct hardware cost will be a significant drive to best overall cost. Where more complex I/O are required, careful examination of the specialty components will be the key differentiator.

Given the tendency of the market to gravitate to the lowest cost, the technology curve for machine control suggests that there are some very large bumps in the road ahead. Let's hope the “unseen hand” of the free market prevails and some really cool new control solutions break out into the real world.



Meeting the Emerging Challenges in Manufacturing: The Practical Applications of Lightweight Robotics

This white paper examines the advances in mechanics and controls that are enabling the practical and economical application of lightweight robotics for manufacturing on an increasingly broad scale. It is an important development in today's "new manufacturing."

Today's global marketplace has changed and continues to change the dynamics of manufacturing. The speed of business is accelerating, competition has increased dramatically, and competitors are as likely to emerge from across the globe as around the corner. Consumer expectations for product consistency and quality have reached unprecedented levels. No quarter is given for where and how goods are manufactured; quality is today's de facto universal standard, regardless of place of product origin or consumption.

For those manufacturers who have moved facilities abroad to leverage lower labor costs, the realization is rapidly dawning that maintaining high quality products using manual production methods is not a sustainable, long-term strategy. Further, the need for high levels of productivity is escalating as greater opportunities and surprising demand emerge from new markets, while the volatility of demand across all markets makes it difficult to predict and plan for. Labor itself is problematic, less from a cost perspective than from demographics and capability. Indeed, increasingly sophisticated manufacturing processes need a skilled workforce that simply doesn't exist in the numbers employers need to fill new positions, particularly as older skilled workers retire.

Add to this mix the powerful movement towards mass customiza-

tion. The once prevalent high volume, low mix model of manufacturing is rapidly giving way to lower volumes and higher product mix. Companies involved in the production of specialized components and products for industrial customers are challenged with producing small lot sizes efficiently and meeting high quality standards consistently while being cost competitive.

To operate effectively in this environment, manufacturing agility is key. The large, centralized production plant is becoming a dinosaur. The factory of the future will be small, flexible, movable, and local. (One of the ironies of rampant globalization is that it ultimately leads to a return of local production.)

In this competitive landscape, manufacturing equipment must meet certain essential requirements:

- Easy to set up and implement into production operations (ideally portable)
- Flexible
- Cost effective
- Highly reliable
- Fast
- Compact and lightweight as possible



Continued

Meeting the Emerging Challenges in Manufacturing: The Practical Applications of Lightweight Robotics

Pursuit of these requirements has helped drive the development of the lightweight robotics and desktop automaton solutions increasingly prevalent in today's manufacturing automation. By providing scalable and modular functionality in increasingly agile and compact packages, these solutions are dramatically changing manufacturing by enabling automation on a smaller and more flexible scale, and helping achieve the responsiveness necessary to compete in today's rapidly-changing global markets. Among the tasks and processes, lightweight robotics are now employed for in many manufacturing sectors:

- Feeding, screwing, and mounting small components
- Setting adhesive points
- Electronic testing: approach to contact points, resistance tests
- Flexible positioning of workpieces and components
- Logistics and storing operations

- Sample preparation, dispensing, transport, and distribution (medical diagnostics)

What Is a Lightweight Robot?

Lightweight robots are particularly designed for transportability – portable and easily moved around - interaction with a priori unknown environments and humans. Robot mobility combines the requirements of a lightweight design with high load-to-weight ratio (close to the 1:1 ratio) and high motion velocity (tip velocity of 6m/s). Moreover, collaborative robots that interact with humans and in unknown environments require sensing and control capabilities to enable skillful, compliant interaction.

Structural and Control Considerations

Lightweight metals or composite materials are used for the robot links. In fact, the design of the entire system is optimized for weight reduction in order to enable the mobile application of the robotic system.

Fast and Precise Positioning from Festo



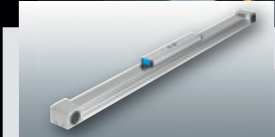
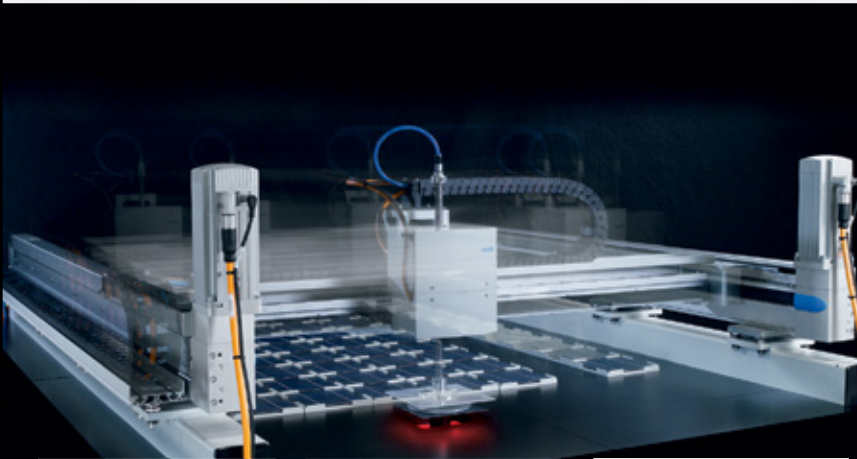
The H-gantry EXCM provides precise and fast positioning in cramped installation conditions. This ready-to-install system allows fast positioning, making the compact H-gantry suited to applications in electronics production and small parts assembly.





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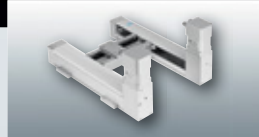
Under control and in motion



Toothed belt axis ELGA-RF



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Continued Meeting the Emerging Challenges in Manufacturing: The Practical Applications of Lightweight Robotics

In order to increase performance and/or safety of the arms, additional and sometimes variable mechanical compliance is introduced into the joints of some lightweight collaborative robots.

Within the lightweight robot concept, a strong emphasis is set on robust performance as well as active safety for the human and the robot during their interaction.

Compared to standard industrial robot control, the following aspects are of particular importance:

- Extensive use of sensor feedback from the environment, including vision, force-torque sensing at the end-effector and in the joints, tactile sensing, and distance and proximity sensors.
- The control implementation is not limited to position control, but also includes the interaction forces in the constrained directions us-

ing methods such as impedance control. In this way, instead of prescribing a position or a force, the dynamic relation between the two is prescribed, while the actual force and position resulting during interaction also depend on the environmental properties.

- Position control has to compensate for the effects of the inherent robot elasticity (e.g., vibrations or the steady state position error) to ensure the performance of positioning and trajectory tracking. This problem also exists for industrial robots moving at high velocities, albeit to a lesser degree.
- The robot needs control strategies that allow detection of unexpected collisions with the environment and with humans and to be able to react in a safe manner. In some lightweight robots, torque sensors in each joint



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Meeting the Emerging Challenges in Manufacturing: The Practical Applications of Lightweight Robotics

play a key role for so-called soft robotics control (i.e., impedance and force/torque control). These sensors allow implementing most of the aspects described above with high accuracy and performance.

Today, two principal types of lightweight robots are being produced: those with compliance and those without. Originally, manufacturing robots were caged: for humans to interact with them, parts were fed from outside the cage. Today's compliant lightweight robots have no need for such barriers. Humans can be side-by-side with them because of built-in sensors that detect human presence and ensure safety, so workers can interact with them even when the robot is active. Other robots have lightweight structures but without the sophisticated sensing capabilities of compliant robots; workers cannot directly interact with them while the robot is active.

Good examples of lightweight robotics commercially available today include the Barrett WAM™ arm, the Mitsubishi PA10 arm, the KUKA LBR iiwa, the DLR MIRO robot, and the Festo EXCM planar surface gantry.

The Barrett WAM arm is a cable-driven, lightweight arm that has actuators placed at the base of the manipulator to reduce the total moved weight. The joints are back-drivable due to its low reduction ratio.

The Mitsubishi PA10 arm is a lightweight redundant arm that weighs 38kg with a payload of 10kg. The PA10 is ideal for precise manipulation

tasks because of its back drivability, precise positioning capabilities, and zero backlash afforded by its harmonic drive transmission (HDT).

The Kuka LBR iiwa is a trailblazer for totally new forms of cooperation between humans and machines. The robotic innovation with sensory capabilities for safety, fast teaching, and simple operator control opens new areas of application in the vicinity of humans that were previously off-limits for robots.

The DLR MIRO is the second generation of versatile robot arms for surgical applications. With its low weight of 10 kg and dimensions similar to those of the human arm, the MIRO robot can assist the surgeon directly at the operating table where space is sparse.

The Festo EXCM is a compact planar surface gantry that can approach any position within its working space. The robot's recirculating toothed belt moves the slide within a two-dimensional area (X and Y axes). Fixed motors are connected to the slide; moving masses remain low because of the parallel-kinematic drive principle.

The ready-to-install system allows fast positioning at speeds of up to 500 mm/s and repetition accuracies on the order of ± 0.05 mm. This makes the compact solution suited to applications such as sample handling in medical and research laboratories, small parts assembly, , and emerging technologies such as printed electronics production, and 3D printing.



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Meeting the Emerging Challenges in Manufacturing: The Practical Applications of Lightweight Robotics

Challenges in Manufacturing

Operations are generally categorized in two production models: high volume, low mix (i.e., long runs with relatively few part changes) and low volume, high mix (i.e., short runs with frequent part changes). Originally, it was only high-volume operations that were automated; however, as noted above, the momentum in manufacturing is going towards mass customization, which means lower volume and higher mix. Therefore, successful manufacturing operations need to be leaner, more agile, and operate at higher efficiencies than ever before. This is doubly true as the speed of product introductions accelerates. Furthermore, the medical research, laboratory, and other industries are increasing working with ever smaller parts and precise processes. Automation must be able to work on these small scales.

That being the case, significant challenges in automating manufacturing processes remain:

- Part presentation. Parts are often presented in bulk and need to be channeled so that individ-

ual components can be consistently presented and handled in the assembly process. Manual methods significantly affect throughput and therefore some type of automatic feeding method or robotic handling is required.

- Machine access. Access to the machine tool for setup and tool changes is critical. Automating the machine tool adjustment reduces downtime and eliminates any safety and product consistency issues that could arise when making adjustments manually. In simple systems, automatic adjustments are accomplished with the use of an integrated motor; in more complex arrangements, flexible robotic handling systems are used.
- Process rates. In all machining operations, shorter load/unload time is important; in fact, in smaller part, shorter cycle operations, it is critical.
- Space and layout considerations. Most production equipment is positioned for manual operations and to maximize machine den-

Advanced Handling Systems



The new generation of handling systems represents a giant step forward. It is not intended as a replacement for the many conventional handling systems which are available but as a useful complement to these. And one which offers a big increase in productivity. See for yourself!



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sity. Creating operational space for a robot to load and unload parts can be difficult, especially if safety fencing is required.

Cost. In North America, robotic automation has primarily been justified based on labor reduction. This is typically coupled with a short-term view of return on investment.

How Lightweight Robotics Addresses These Challenges

Point by point, here is how lightweight robotics is fitting into the manufacturing process by addressing these challenges:

- Part presentation. While conventional vibratory solutions may work for some applications, they don't work for others. In those cases, fixed trays and/or conveyors can be used as a staging area for the robot. The integration of vision-based solutions with robotic systems is proving to be the most flexible, lowest cost solution. Parts can be loosely positioned onto a tray, belt conveyor, or vibratory belt where the vision system will determine the part location and orientation. The vision system then transfers the information to the robot, allowing it to pick up the part. The vision system eliminates the need for part locating details or precision transfer devices, reducing the cost of processing a new part.
- Machine access. With the large variation of robot configurations available, many alternative system layouts are possible. An over-

head robot can be a good solution for tending multiple machine tools. With proper guarding, it can allow manual access to each machine without shutting down the robot system. Many types of robot mounts, bases, and positioners can also be designed to allow temporary repositioning of the robot for machine access. Collaborative lightweight robots enable the operator and robot to work side-by-side without the need for guarding or disabling the robot.

- Process rates. Piece rate is only one measure of an automation system. A more important measure of capability is net throughput. Robotic machine-loading systems have proven to have a much higher percentage of uptime than comparable manual processes. This additional uptime creates more available hours of operation per shift than the manual process, so a robot system with a slower piece rate can still have a much higher net throughput.

Furthermore, robots continue to improve in terms of speed, reach, and payload capabilities. Today's robot may be more than 20 percent faster than a comparable model from five years ago.

- Space and layout considerations. As with the challenge of machine access, many space and system layout issues can be addressed with the variety of available robot configurations. One promising development: recent changes to robotics industry safety standards allow safety rated soft limits. Robots can now



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dynamically define operating space and restricted space based on the status of safety interlock signals. This allows tremendous flexibility in both system layout and access. In addition, robotic solutions are designed to be more compact and lighter for easy portability and reduced footprint.

- **Cost.** When justifying robotic automation, a range of factors must be considered, not just labor. A thorough return on investment evaluation must take into account all associated costs and savings, as well as changes in throughput. It can also be difficult to justify robotic automation because of the tendency to think “one-to-one”: one robot for one machine or one robot to replace one operator. Instead, manufacturers should look at multiple processes in a production area. In many cases, what appears to be a situation of one operator per one machine can turn into one operator per three or four machines when the bigger manufacturing picture is considered.

Additional Benefits of Employing Lightweight Robotics

The implementation of lightweight robotics offers many additional, tangible benefits for manufacturers:

- **Improved process control.** A properly designed automated process ensures that things happen when and how they are supposed to. For both regulated and non-regulated industries, this is essential to ensuring quality and meeting customer expectations.

Hard benefits include reduced scrap, higher throughput, and better responsiveness to volatile demand.

- **Improved machine utilization.** A machine that is not running generates no income for the manufacturer. Typical machine usage for a manual machining process is 65 percent. For a comparable automated process, this number is greater than 90 percent. Better machine tool usage results in a faster return on investment for the machine tool while simultaneously improving production capacity.
- **Better use of labor.** The most flexible and valuable resource in any company is its people. Good use of that resource is not necessarily for machine tending, but for machine setup and other operations that may not be suitable to automation.
- **Greater agility.** Today’s global marketplace is distinguished by accelerating change and volatile, hard-to-predict demand. Leveraging robotic technology improves a manufacturer’s ability to respond quickly and efficiently to these conditions, helping achieve the leaner, more agile operations essential to sustainable success.
- **Improved leverage to cope with macro-economic trends.** Certain developments are beyond an organization’s control, such as economic recessions and recoveries and the changing demographics of the workforce. Current consensus is that the economy is recovering, but the question is how fast is that recovery? This has implications on hiring practices, as does the growing shortage of





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skilled labor. Automation provides a hedge to allow increased production without precipitously adding to the labor force before the recovery is at a stage that warrants that, or before the workers you really desire are available.

Applications and Emerging Technologies

Laboratory Automation

Driven by the need for higher throughput and higher quality as well as to enable technically challenging or processes, many labs in drug discovery and In Vitro Diagnostics that were not previously adopters of laboratory automation are being drawn to the potential of simple, small-scale, benchtop automation enabled by lightweight robotics. During the past decade, many vendors emerged that specialize in delivering complex automated solutions

for large research labs, in some cases using hundreds of small robots that can perform the same task, the same way every time for millions of cycles.

However, for each of these core labs there are hundreds of others potentially interested in more efficient ways to carry out routine tasks at a smaller scale.

Most of these potential automation opportunities do not require high throughput or involve processing thousands of assays per day. Nor does the average lab have the budget or the space to accommodate “big automation.” For this group, lightweight robotics has been a revelation.

The types of benchtop automation most deployed to date are standalone automated pipettors or manually fed dispensers. In the future, we will see more automated workstations made up of multiple processing stations linked together by a plate mover/gripper. The Festo EXCM integrates well into benchtop



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liquid handling workstations such as dispensers facilitating fast and accurate filling. In fact, it is well suited to move microplates through a series of instruments such as dispensers and pipettors in a complex workcell.

Consumer Electronics and Small-Scale Assembly

Other industries are also experiencing a marked increase in the bench-top application of lightweight robotic systems. In the consumer electronics industry, tasks such as electronic printed circuit board (PCB) testing are ideal. A solution such as the Festo EXCM could be employed in a stacked configuration so that machine throughput could be significantly increased as seen in the PCB test station below. The electrical values are verified using test probes as part of the product quality test process.

This solution can also be used in the tactile examination of touch displays and switches and to verify the presence of installed components on a PCB. With the continuing miniaturization of products, positioning and aligning small screws prior to insertion can significantly affect productivity. Automation of such intricate tasks can result in a significant increase in throughput.

Other automated desktop automation tasks include dispensing in bonding, sealing, and gasketing; coating applications for dispensing adhesives, sealants, and lubricants; and filling electronic casings with resin. Such solutions can also easily integrate into machinery for hand feeding components, transferring workpieces, and position-

ing small parts. Additionally, they can be employed in contactless inspection systems to move a camera or laser probe consistently and smoothly over the material being checked.

Printed Electronics

Today, semi-automatic or automatic screen printing machines are used for printing on mobile phone panels, membrane switches, LCD display boards, etc. Such automated solutions provide the improved repeatability and speed required for high-volume production of miniature products. Other examples of printed electronics applications that use automated screen printing mainly involve the production of printed circuit boards, where a mask is applied to direct a metal (copper, silver, or other) circuit path on a bare board with attached components, or in applications that require thick layers of materials, such as batteries/PV technology, membranes/touch panels, sensors, and glucose test strips.

While screen printing has dominated most of the printed electronics applications to date, advanced industrial inkjet printers are emerging as an alternative technology, mainly in terms of cost, feature-size resolution, and digital architecture. Inkjet printing is a digital imaging technology that creates an image by jetting droplets of ink onto a substrate. Inkjet printers are the most commonly used type of consumer printer, along with laser printers. Inkjet printing is particularly good for depositing small amounts of materials that have



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specific electrical or structural functionalities onto well-defined locations on a substrate. The materials deposited can be soluble liquids, dispersions of small (nano-sized) particles, melts, or blends.

The main advantages of inkjet printing are the ability to change what is printed without making a new printing plate and the ability to print variable digital patterns. As a result, inkjet printing can achieve excellent resolution, uses a wide range of ink types (conductive, hot melted wax, solder, biomaterials), is receptive to on-the-fly error correction, uses small amounts of materials that involve little waste, can build up layers, and is a clean noncontact technology. The disadvantages include fairly slow throughput, sensitivity to substrate variations, problems with ink spreading, limited printing speeds, and print-head/solvent compatibility.

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Product Manager – Positioning

Further information is available on the web:

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3-D Printing

Three-dimensional printed parts are now used for a multitude of applications, from medical devices (custom medical implants) to airplanes (weight reduction of parts, resulting in billions of dollars in fuel savings), toys, and industrial manufacturing (metal 3-D printed injection molds). Typically, a 3-D printer starts with a few layers of disposable support material to provide a foundation. The extrusion head, which moves about an X-Y plane, lays down a ribbon of material. After each layer is complete, the Z axis lowers slightly to make way for the next layer. The Festo EXCM lightweight Cartesian solution delivers smooth, quiet operation for the critical linear movement and positioning functions in 3-D printers.

