

DIGITAL INDUSTRIES SOFTWARE

Transforming the manufacturing value chain

Using personalized and adaptable MES to tailor the power of MOM for high tech industries

Executive summary

As the high tech electronics value chain continues to optimize manufacturing to get better, faster and cheaper, there is a paradigm shift emerging. Adopting new technology in the quest for efficiency gains must not be burdensome or constraining for the production team, but rather should adapt to the unique environment, workflows and cross-functional collaboration that fosters speed and creativity. A manufacturing execution system (MES) that has broad and deep functionality yet provides a flexible user experience promises to bring an entirely new level of agility and productivity to the shop floor. The enabling technology for this shift is a low-code, multi-experience development environment that augments the core MES.

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Introduction

Low-code development lets team members personalize their user experiences (and, in many cases, make new connections to data they need) without waiting on highly skilled frontend developers to perform complex software development. With this human-centric approach, manufacturers can leverage the ingenuity and collective know-how of their entire workforce, empowering them to take ownership and drive innovation in their areas of responsibility. At the same time, the core, mission-critical enterprise manufacturing system remains intact, lowering the cost and complexity of maintenance and upgrades.

Siemens Digital Industries Software is championing this adaptable MES approach with the Mendix™ Low-code platform, which is integrated with our manufacturing software portfolio, Opcenter™ software. This integrated solution creates a flexible, configurable, role-based user experience (UX) that makes it easy for customers to use and deploy.

Adding Mendix to the core MES solution enables easier upgrades by decoupling metadata-driven business logic from the UX while lowering the total cost of ownership (TCO). It also provides built-in connectors to shop floor automation, as well as a marketplace of re-usable apps, templates, connectors and components to easily extend the value of core systems. Mendix is a market leader in the enterprise application development market space. This combined solution enables customers to realize their vision of single-pane UX/composite apps for manufacturing.

This white paper discusses how the approach is being leveraged throughout the high tech electronics value chain to create new levels of collaboration, productivity and efficiency. Mendix and Opcenter are part of the Siemens Xcelerator business platform of software, hardware and services.

Maximize the value of your MES

If your manufacturing operations are going to help your company keep or gain more of a competitive edge, your shop floor must quickly and efficiently accommodate each new product introduction (NPI), each new variant of an existing product and each new process or procedure. This goal is not new but accomplishing it during today's unprecedented pace of change is a formidable challenge.

As an example, consider the plant of a mid-size electronics manufacturer, which may have up to 200 different operator terminals. The advanced power

and functionality of a modern MES will provide this company with visibility and control over product quality and production efficiencies across its manufacturing enterprise. At the same time, it will provide operators at their respective stations with all guided tasks, visual instructions, behind-the-scenes track-and-trace activities, error-proofing and more. The functionality of such an MES has been tailored to the specific needs of an electronics manufacturer, giving the company capabilities that best fit their needs at the time of implementation.

That's the good news. But as managers at the company look out across the plant floor, they see 200 workstations and operator terminals providing 200 UXs – some of which are standard out-of-the-box (OOTB) implementations of the MES product and some of which are tailored to certain processes and tasks that happen at particular stations. The latter has typically required a moderate to high degree of implementation effort involving information technology (IT) and software specialists. Now imagine a change in products or procedures or introducing new machines or equipment. Suddenly, a large portion of the 200 operator terminals requires a UX update for the enhanced operations. Such updates achieve improved productivity by providing intuitive human interactions with the new process or machine.

For an MES solution to be as beneficial as possible for this electronics manufacturer, the challenge is to keep each UX personalized so the set of tasks at each workstation can be performed effectively and efficiently, even as the task set evolves. Indeed, for any manufacturing company that has semi-automated or highly automated manufacturing processes, such as semiconductors, electronics, medical devices and battery manufacturers, the MES solution must be able to reflect the specificity of the supported production system.

These manufacturers require maximum flexibility to adapt to changing demands that necessitate changes to processes and visibility into updated information for users in their respective areas of work. They also must provide visibility into the change and trace-ability and accountability for the change. Achieving this flexibility means personalizing the MES solution to evolving details of each company's production processes and machine systems.

Because processes, machines and products are changing so fast, personalization and the ability to

extend to dependent processes is an ongoing need – one that cannot be met sustainably by customizing the core MES. Each personalized application is designed to meet a unique, unrepeated set of requirements to produce a particular user experience at a particular operator terminal – possibly for a limited amount of time until the next manufacturing change arises.

Two difficult options

Until recently, manufacturers in the high-tech electronics value chain have been limited to two problematic options as they seek to maximize the contribution of their MES to operational excellence. The first is to enlist the expert services of front-end software developers, possibly on staff but more likely from a software vendor or a certified third-party integrator. We have heard growing frustration from many of our customers regarding this option; first, because it fails to give the manufacturing company visibility into the total cost of ownership of their MES. When each adaptation requires outside software coding, it is difficult for a company to produce a realistic estimate of annual expenses associated with such personalization, much less build a business case to determine if the expense is justified by productivity or quality gains. Of course, it is costly to hire expert software developers to conduct it, but it is also becoming more costly in terms of development time. When companies seek to leverage the tribal knowledge of employees who interact with production systems and processes every day, taking a lengthy time before implementation poses a considerable impediment.

The second problematic option, which may be deliberately chosen or may be the de facto circumstance because of software development delays, is to have the production team adapt to the non-personalized UX. This option requires companies to allocate a substantial budget to change management.



A better option emerges

With the advent of low code, multi-experience development solutions, a third option has been pioneered – one that alleviates the pain accompanying the other approaches while also enabling manufacturers to maximize the quality and productivity benefits of a modern, powerful and flexible MES. A functionally rich MES, tailored to your industry and embedded with low-code capabilities, provides your entire team with an adaptive solution that achieves new levels of agility and flexibility.

This adaptable MES, recently launched by Siemens, combines Opcenter Execution with the Mendix low-code, multi-experience environment. We collaborated with numerous MES customers from semiconductors, electronics, medical devices and battery manufacturing industries to develop this solution. These customers conveyed their growing need to accelerate customization of user experiences and workflows while maintaining the core mission-critical MES.

An Opcenter Execution system embedded with low-code Mendix technology uniquely places ownership of UX personalization in your hands, empowering you to follow new business leads and requirements in a simple and timely way. It equips your team members to personalize the solution to their specific requirements, while also deriving maximum value from the core MES. This capability has the added potential to expand to the rest of your organization's process value chain for increased connectivity with disparate systems and enriched, connected digital experiences.

This white paper describes the capabilities of our adaptable MES and addresses the implications specific to various parts of the electronics value chain. Our goal is to prompt innovative thinking about your specific operations. Your manufacturing initiatives, powered by and implemented on our low-code embedded adaptable MES solution, promise to spark new business vitality both today and into the future.

Defining personalized and adaptable MES and low-code personalization

A modern MES, with its powerful functionality tailored to the specific requirements of your industry, already drives your business a long way toward operational excellence. The next wave of MES benefits arises from the system's wealth of capabilities and flexibility that can be tapped with personalization, making your user experiences custom-fitted to your distinct operations and personnel. Achieving these gains quickly and cost-effectively requires the right digital tools.

Using Opcenter Execution equips your team members with less software development skills and know-how to personalize in-house the solution to their individual requirements without calling on IT specialists to code each personalized UX or requiring the end user to adapt to the OOTB user experience. Key to this new approach is a shift from OOTB *user experiences* to OOTB *UX templates*. As templates, the UXs provide solutions to end-to-end use cases and can be used as they are out-of-the-box. Many such templates are offered as OOTB features of the core MES system, and they can also evolve into a company-built library of best practices and institutional learnings.

For a personalized UX, each template presents a prepackaged baseline application that serves as a starting point. The template can be customized to address a user's needs with a few simple visual steps using low-code assembly tools:

- **Snippets and widgets** are tools that simplify and speed up screen creation starting from a set of re-usable building blocks. The UX created in Opcenter Execution are graphical components and modular pieces
- **App services** provide domain-specific sets of capabilities. For example, a 3D viewer app enables the user to view computer-aided design (CAD)

drawings much like one would within the CAD program – rotating, zooming in, etc.

- **Connectors** enable users to extend a workflow or experience beyond a normal MES scope

Screens are personalized by pulling the desired information or snippets into the UX template with simple drag-and-drop actions. App services are then employed to bring in specific functionality. The resulting UX supports everyone's runtime interaction with all relevant information, which remains up to date because the UX interacts directly with the MES backend thanks to standard OData protocol and REST application programming interfaces (APIs).

Mendix and its partner community deliver a breadth of functionality to make the user experience as effortless and error-free as possible. Speech-to-text capabilities allow operators to dictate information instead of typing. Barcode scanning eliminates key-in time. Powerful workflow capabilities allow business processes to be supported naturally. An OPC UA connector provides seamless shop floor connectivity. Messages can be pushed to Microsoft Teams through the Microsoft connector. Automation and internet of things (IoT) connectors access the shop floor. The Mendix marketplace has a wealth of localized and public components and connectors that add to its rich native functionality.

Mendix is also a solution for creating composite apps that offer an end-to-end view of data across the enterprise. A single composite app can pull in order/demand information from enterprise resource planning (ERP), combine it with order fulfillment information from MES, quality information from quality management systems (QMS) and machine status from the shop floor. It simplifies the systems landscape that manufacturers require for a 360-degree view of their business.

With Opcenter Execution low-code personalization capabilities, low-code capabilities are embedded within the MES development toolset, enriching the development experience. As a user employs these tools, Mendix performs the data extraction and workflow generation processes for the UX behind the scenes, thus eliminating the need for high-level coding. Meantime, the MES continues to host and power data model definitions and business logic implementation.

This is a key point about personalized and adaptable MES versus simply employing technology from a pure low-code vendor. Mendix has been deliberately adapted to extend Siemens' stellar MES solution for the high tech electronics industry. The extensibility requirements are anticipated, and functionality is pre-built to accelerate the entire process.

Depending on the availability and skill sets of various team members, a manufacturer may assign certain personalization tasks to the IT department, which is now able to make changes much more quickly and without the assistance of the software vendor. This is good news given today's changing IT landscape. Gartner reports that business technologists – employees who report outside of IT departments and create technology or analytics capabilities for work – now make up 41 percent of digital technologists. Another 49 percent are technology end users, leaving only 10 percent inside the IT department.

Business technologists on a manufacturing team are tech-savvy, but they typically are not high-end software developers. A low-code environment makes it possible to give these employees the responsibility to build UXs for their production areas. In some cases, the person using the operator terminal possesses the requisite skills to personalize the UX with a low-code solution.

MES personalization ignites new quality and productivity gains

Personalized and adaptable MES enables manufacturers to accelerate the development of user- and process-specific applications. These personalized

user experiences enable operators to access MES capabilities more readily and leverage them to generate new efficiencies across your manufacturing operations. Moreover, because personalization occurs in the low-code layer of the solution, you will leave the core MES system intact, which lowers the cost and complexity of MES maintenance and upgrades.

With personalized UXs built in-house with great efficiency, the total cost of ownership of your MES will not only be reduced but will also be visible and controllable. You will decrease IT demand and expenses. Application development will occur much faster – as fast as drag-and-drop operations compared to writing code. Your business technologists and floor operators will be able to put their creative, cost-saving ideas to work quickly. Product and process changes will take less time and money to implement. Additionally, because you control the personalization layer of the MES, you also control the timing and pace of personalization. You decide how and when you will innovate to meet specific needs on the manufacturing floor.

A personalized and adaptable MES with an embedded low-code environment addresses three specific demands of present and future operational excellence:

- **Adapting to change:** The unprecedented pace of change in manufacturing operations is fueled by supply chain disruptions, implementing new enabling technologies, adapting to more sustainable materials, new product introductions (NPIs), mergers and acquisitions and more. None of these factors show any signs of slowing. As the pace of your production operations accelerate, a personalized and adaptable MES can help you keep up.
- **Accelerating workflows:** A personalized and adaptable MES not only provides a wealth of information to manufacturing personnel, but it also enables each team member to choose the elements of that information most critical to their job performance. By constructing their personalized screens to make this data easily and quickly comprehensible, your manufacturing team can

make better and faster decisions that increase the efficiency of your production operations.

- **Leveraging tribal knowledge:** A personalized and adaptable MES enables you to harness the tribal knowledge found among employees who work closest to your production processes and machinery. The originator of an idea and his or her manager can tap a company-created set of templates and best-practice UXs as a starting point, and then assemble the application directly on the UX. Experimentation, iteration, implementation and refinement all are spearheaded not by IT specialists but by domain experts who

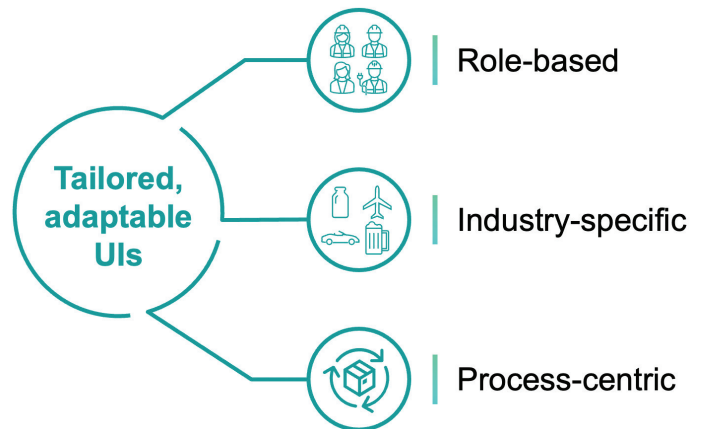
are motivated to complete each project quickly to make their jobs easier.

Multiplying the benefits of personalization across your shop floor

By moving UX development closer to your MES end users, you will unlock new opportunities to benefit from the creative innovation of your frontline manufacturing team. Here are some ways in which adaptable MES owners can leverage their unique knowledge about real needs on their production floors.

Opcenter Execution is feature rich and has organically grown to meet your diverse business needs with industry-leading, out-of-the-box capabilities.

Now we are bringing the power of these rich features and coupling them with intuitive data flows and a role-based user interface approach.



Applying a personalized and adaptable MES to the electronics value chain

Now that we understand the dynamics and potential of personalized and adaptable MES, let's take a closer look at the implications for specific segments of the electronics value chain – semiconductors, electronics, battery and medical devices manufacturing.

A personalized and adaptable MES for semiconductors manufacturing

One of the main objectives in a semiconductors fab is to improve process yield. Engineers continually investigate past process performance data and modify/override process parameters for each lot.

The Opcenter Semiconductor suite with its experiment management capability enables this process. By adding Mendix low-code capabilities, comprehensive information about the process spec, workflow and bill of equipment can all be brought together in a single screen, enabling users to modify/override parameters quickly and easily as needed. This out-of-the-box adaptability helps improve efficiency in managing experiments.

If we look to clean rooms in semiconductors fabs, we see the lighting is specific and operators and



technicians use gloves and are gowned up. Using Opcenter with Mendix provides personalized UI/UX capabilities to easily cater to the needs of clean room environments in a configurable way. A personalized and adaptable MES for semiconductors also enables users to optimize UI/UX on mobile devices and other handheld devices so they can easily and efficiently access information and complete their activities.

Semiconductors manufacturers want to know what is happening in their fab in real time, with the ability to act on information easily and quickly. With its resource-centric app, Mendix provides a graphical, single-pane view with real-time information on materials and equipment either in a plant or a work area. Operators and engineers can access material and equipment status in real time and complete all their activities like creating a repair ticket, placing material on hold and tracking materials into or out of a resource that is available. They can collect all data from a single screen.

These are just a few applications that are emerging with personalized and adaptable MES in the semiconductors industry.

A personalized and adaptable MES for electronics manufacturing

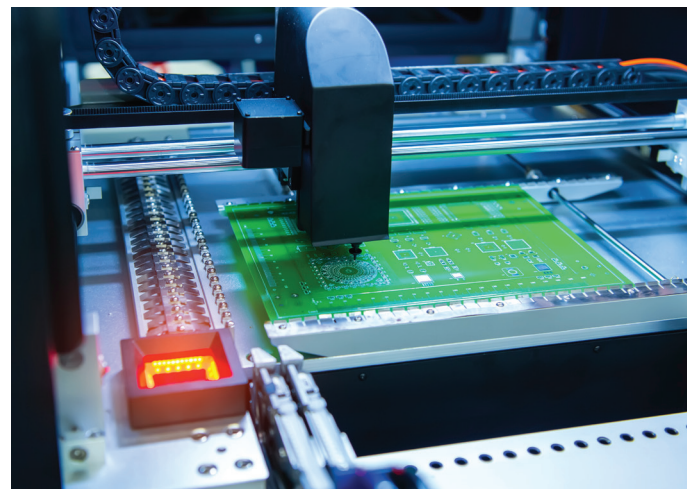
As we move farther into the value chain, the electronics industry's process varies from highly

automated, equipment-centric, surface-mount-technology (SMT)/printed circuit board assembly (PCBA) to semi-automated final assembly and test. Continual product and process improvement is a hallmark in this industry.

Generally, PCBA/SMT processes require a UI/UX that is optimized for that style. Manual assembly and testing require a more guided assembly-based UI/UX, while highly automated assembly and testing require an efficient UI/UX. Using Mendix provides out-of-the-box, process-centric UI/UX that is designed, developed and tested for a specific process. As Mendix provides unprecedented configurability, customers can further personalize out-of-the-box capabilities to easily meet their specific requirements.

Using Mendix provides role-based UI/UX configurations, bringing all relevant information required for a specific role into one screen. A specific user role can manage all their activities in one place, saving time and avoiding errors. Other real-time information can be integrated from the shop floor automation layer via connectivity configurators that Mendix provides as standard capabilities.

Most large/enterprise electronics manufacturers have numerous disparate software solutions that are used on the shop floor, resulting in inefficiencies for the operator, engineers and plant managers.

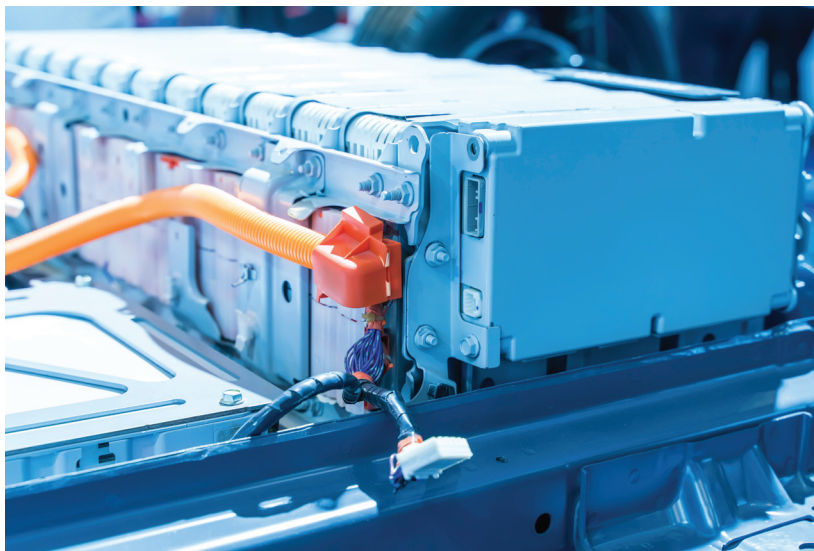


Some operators must log into 10 to 15 different applications to do their job. Mendix enables business users to build composite apps or single-pane UIs. Mendix seamlessly connects with many enterprise software applications, connecting them with the entire Siemens suite of solutions. Manufacturers can easily configure composite apps to bring together information from these multiple systems into a single screen in a secure way.

Let's turn to another part of this value chain, the battery manufacturing industry.

A personalized and adaptable MES for battery manufacturing

The battery industry is a relatively immature manufacturing segment compared to its semiconductors and electronics counterparts. It is challenged with rapidly evolving technology and complex production, which is a mix of process and discrete manufacturing steps. The market is highly competitive, with battery prices dropping while material costs and labor costs are increasing. The industry has limited experience scaling from pilot lines to gigafactories, and new standards and regulations are continually being introduced. Amid this challenging environment, the demand for batteries has never been higher. Manufacturing optimization is an existential requirement, as well as a tremendous opportunity for manufacturers able to achieve it.



A personalized and adaptable MES for battery manufacturing is empowering battery manufacturers to rapidly scale up with confidence, reducing time-to-market while maintaining control over quality costs and meeting regulatory and sustainability targets. By connecting IT/operational technology (OT) systems and harmonizing machine interactions, battery manufacturers can increase automation and reduce manpower.

Mendix is helping to achieve higher yields by executing proactive and predictive digital quality controls. Continual improvement is accelerated by enabling a closed-loop quality process as well as automatic backward and forward traceability. Agility and responsiveness are improved. With granular enterprise visibility into battery production key performance indicators (KPIs), agility and responsiveness are improved. Predictive quality and predictive factory performance enable manufacturers to meet production quality targets and achieve sustainability goals by reducing carbon footprint, energy usage and scrap while maximizing yield.

Using Mendix accelerates solution deployment and adoption using modern user experience, pre-built solutions and interfaces designed and templated specifically for battery cell production. Battery manufacturers must focus on agile innovation, which requires constant research and development (R&D) to keep up. Using Mendix is making processes more efficient, connecting best-in-class tools to shorten the time from chemistry to production.

Battery manufacturers are quickly adopting a digital factory approach, with more automation, digital production execution and IoT enablement. The objective is transparency, flexibility, plant performance and knowledge re-use. This environment is where personalized and adaptable MES is required. The foundational systems are evolving rapidly, and processes are quickly being innovated. Using Mendix enables the manufacturer to keep up and accelerate the pace of innovation.

A personalized and adaptable MES for medical devices manufacturing

Medical devices manufacturing is characterized by a variety of process styles. From manual assembly to batch processing to extrusion, these processes often occur under the same roof to produce different products. To successfully manage this level of complexity, having a personalized and adaptable MES is especially important.

With Opcenter and Mendix, medical devices manufacturers can leverage embedded low-code capabilities to customize their MES to specific business needs. This enables process-centric and role-based user experiences, allowing operators, engineers and plant managers to easily access the level of information they need from a single screen. For any given process, they can view the real-time status of machines and work-in-process (WIP) while leveraging the seamless connectivity of diverse data sources.

Medical devices manufacturers often use several different software systems on the shop floor – including QMS, ERP, IoT and PLM – but accessing these various systems can be time-consuming and inefficient for manufacturing teams. With low-code, medical devices manufacturers can easily create composite applications to unify these separate data sources into one interface. Operators can then access the most critical information quickly and efficiently while reducing the number of system logins necessary to complete their tasks. When used at scale, this enables better, faster decision-making and ultimately improves collaboration and productivity across teams and processes.

For medical devices manufacturers in particular, maintaining cleanroom standards is also a high priority. It is quite common to have shop floor operations in cleanroom environments where operators, engineers and technicians are gowned, wear gloves and have less space for workstations. As a result, MES users need to work with devices of various form factors while completing their activities with the least amount of clicks possible.

Using Opcenter and Mendix help address these challenges by providing a seamless user experience that is optimized for devices with different form factors. This enables users to complete their manufacturing and quality tasks quickly and efficiently while maintaining high cleanroom standards.

Similarly, for medical devices manufacturers to remain compliant with regulations and requirements, maintaining batch and device history records is essential. As an industry-leading manufacturing software for electronic batch and device history records, Opcenter pairs well with Mendix – a market leader in enterprise application development – to enable efficient, error-free records and operations.

Conclusion

The types of personalization revealed in these industry cases support a human-centric approach to digitalization: adapting the UX to make the user's work easier, rather than having users accommodate the UX in its existing form. By listening to employees and co-developing solutions with them, we have found manufacturing companies experience much more positive uptake and feedback as production changes are made.

Outpacing the competition has never been as challenging as it is today. A modern MES like Opcenter Execution offers manufacturers a state-of-the-art solution to increase manufacturing efficiency and flexibility, and at the same time deliver consistently high quality. By supporting UX building with Mendix, a powerful MES becomes even more powerful, enabling your team to personalize their user experience efficiently and without the burden, expense and delay incurred when IT specialists must get involved.

Another important aspect of low-code UX building within your MES is that it represents a great entry point for low-code technology. Manufacturers today

are looking across their enterprises for ways that solutions may accelerate digitalization. A low-code UX initiative at your company may serve as a springboard to more widespread use of low-code technology, beginning with the efficiency and quality boosts you will realize by applying low code to MES-dependent processes. All in all, low-code technology represents a watershed opportunity to advance your agility, accelerate your innovation and maximize your productivity for greater business vitality.

The rich and mature MES functionalities of Opcenter Execution combined with embedded low-code capabilities of Mendix create the perfect landscape to support your entire team's individual information and functionality needs. A personalized and adaptable MES is making the electronics value chain more efficient, productive, connected and collaborative. It is allowing manufacturing systems to be used to innovate as fast as the products and technologies they support.

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