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LEVERAGING THE CLOSED-LOOP DIGITAL TWIN

Of the powerful capabilities made possible by the industrial Internet of Things (IoT), smarter maintenance and closed-loop digital twins are two that yield the most significant and immediate benefits.

To gain a competitive advantage, manufacturers must continue to push the boundaries of technology and advance their processes.

As the power of the industrial IoT becomes increasingly apparent — to address operational issues and drive competitive advantage— forward-thinking organizations are pioneering new ways to leverage it. Driven by fierce competition, thin product margins, aging fleets of factory assets and fast-changing customer choices, manufacturers are turning to digitalization to optimize products and processes—and, ultimately, to increase profitability and stay ahead of the innovation curve.

Most manufacturers understand the value of using digital twins to establish a permanent connection between the physical asset and its virtual counterpart, as well as integrate with product lifecycle management (PLM) systems to continuously optimize production digitally.

Fewer are familiar with the benefits of extending digital twins across the production cycle to products in the field. Using MindSphere, Siemens' industrial IoT as a service solution, manufacturers can now build digital twins of performance. The product, production and performance twins connect to create a closed feedback loop, ensuring that performance data from products in the field and from production environments feed into the product and production.

The Closed-Loop Digital Twin

Implementing condition monitoring is widely considered to be among the best use cases for companies just beginning their digitalization journey. Manufacturers can conduct a pilot on a single, critical machine and gain a return on investment (ROI) within months. From there, they can extend it to other machines, entire lines and value chains, and even to customer equipment in the field.

Deploying the closed-loop digital twin often occurs further along the digitalization journey–especially if the digital twin mirrors the entire, fully connected product lifecycle. Manufacturers commonly begin implementing the digital twin in new product R&D and planning cycles, with a focus on virtually simulating new designs. More advanced companies also have digital twins of their production processes to confirm manufacturability and streamline new product engineering.

The most progressive organizations are pushing the boundaries toward using the digital twin to monitor the live performance of products and the production line. A digital twin that enables changes based on live data is called the closed-loop digital twin. With this advanced approach, production line machines are evaluated to determine if the line works as intended. Also, a product's performance is tracked after it leaves the production line. The product is monitored to analyze its expected use and performance against its actual use and performance. This data can then feed back into the design as well as the production line, allowing real-time adjustments and quick simulation updates.

The Benefits of a Comprehensive Closed-Loop Digital Twin

When a manufacturer's strategy includes a closed-loop digital twin, smarter maintenance can be extended into every area of production using the newest form of the digital twin, the digital twin of performance:

Digital Twin of the Product. In the early stages of design, manufacturers use the digital twin to virtually simulate and validate properties, rather than build and test physical prototypes. Virtual prototyping allows you to better understand how a product design will perform under various conditions while reducing development time, improving product quality and enabling faster iterations.

The closed-loop digital twin introduces live performance data to this process. Once the product leaves the production line, the digital twin of the product continues to collect real-time data about its performance. Manufacturers use this live performance information to make changes to the current design in production or to improve future design iterations by making updates to simulations. As an example, if a part is found to be defective in the field, it can be changed out in the live production line.

Furthermore, with this constant flow of performance information, manufacturers can adopt new business models, such as maintenance as a service. Manufacturers can offer their customers remote condition

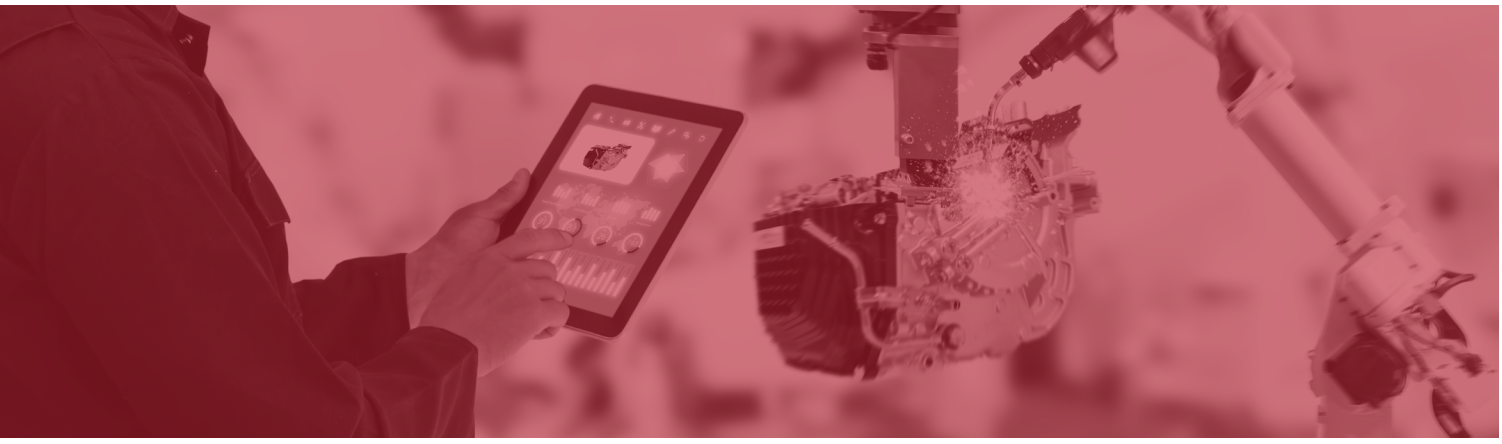
monitoring through the end of the product's lifecycle. They can also lease machines to customers and charge based on actual usage.

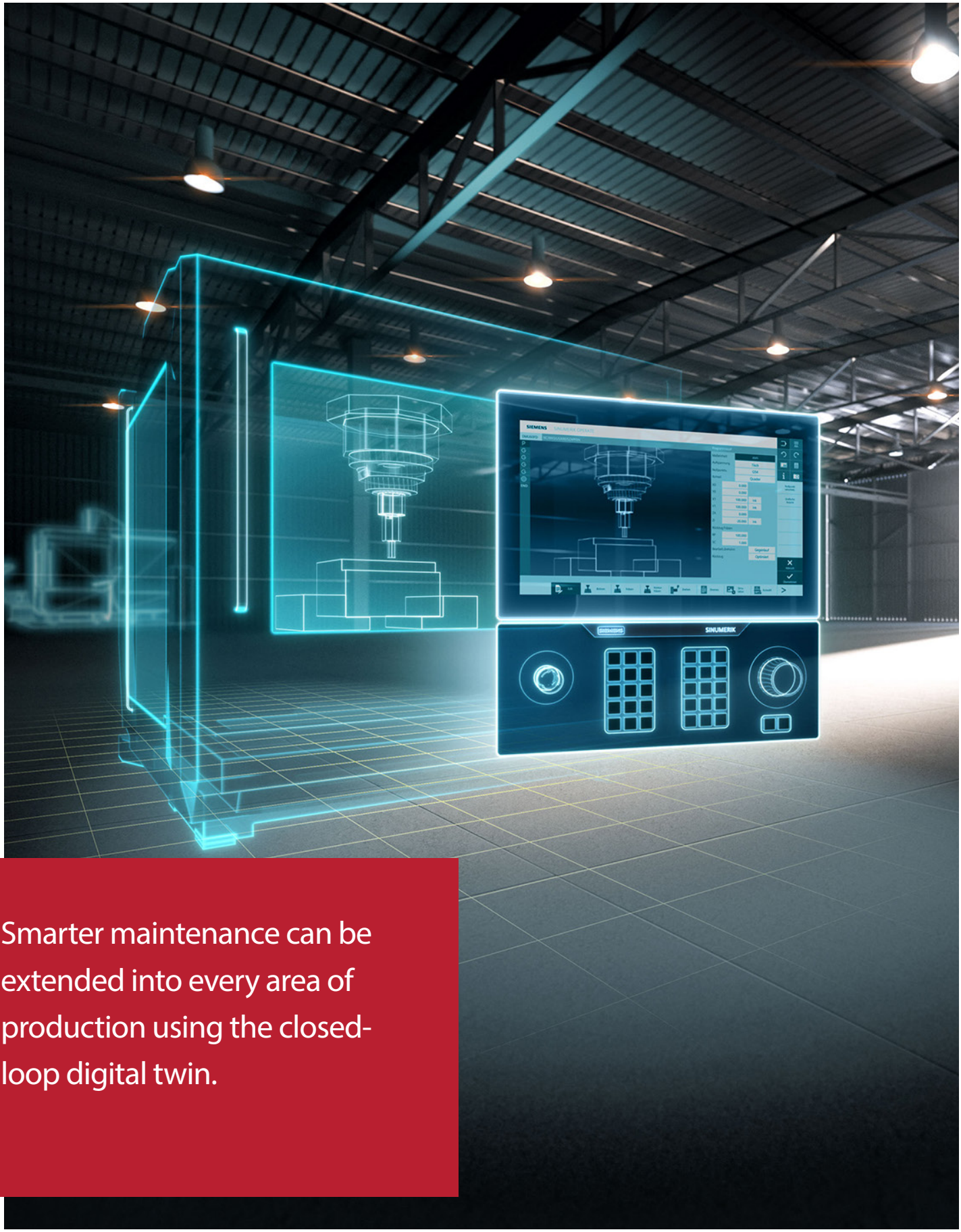
Digital Twin of Production. A typical production twin validates critical aspects of the production line through virtual simulations, ranging from plant assets to controllers. This capability enables industrial organizations to identify sources of error or failure in a production line before implementing the line.

The closed-loop digital twin introduces live performance data to production lines. Once a line is set up, data can be captured during test runs that allow manufacturers to optimize the production by checking machine performance and adjusting the timing between product runs.

After testing, live data is continually collected, which allows monitoring of the condition and performance of each machine in the production line. Using this data, manufacturers can go beyond identifying machines or parts that will soon fail. They can identify areas that are not running as expected and then simulate changes to the line before making adjustments. With the simulations, manufacturers can proactively change the line to boost productivity, reduce scrap and decrease manufacturing errors without affecting production.

Introducing the digital twin of performance augments the capabilities of the other twins. More importantly, it effectively creates the closed feedback loop that links the very design of the product to its implementation and then back to its design. The implications are powerful.





Smarter maintenance can be extended into every area of production using the closed-loop digital twin.

Real-time Data Means Real-time Improvements

Because the digital twin can be continuously updated with real-time data, it changes as the physical asset is changed. Digital twin-enabled maintenance allows scheduling according to real-world usage data and enables real-time virtual simulations, both a step-change improvement. With a real-time model of an asset, manufacturers can run virtual simulations to determine performance based on age, runtime or exposure to harsh conditions. The addition of the closed-loop digital twin enables manufacturers to peer into the future to determine maintenance needs.

With a permanent connection between a physical asset and a digital twin, manufacturers can continually optimize a product and its production digitally–including its maintenance requirements.

Once deployed, the digital twin-based solution delivers these enhanced benefits to the production process:

Downtime reduction. Using real-time data, manufacturers can identify and solve problems before they cause shutdowns, and schedule maintenance during times that would be least disruptive to operations.

Reduced maintenance costs. Enhanced with a digital twin, maintenance can be smarter to prevent it from being performed neither too early nor too late, both of which are costly. Maintenance can be planned and based on

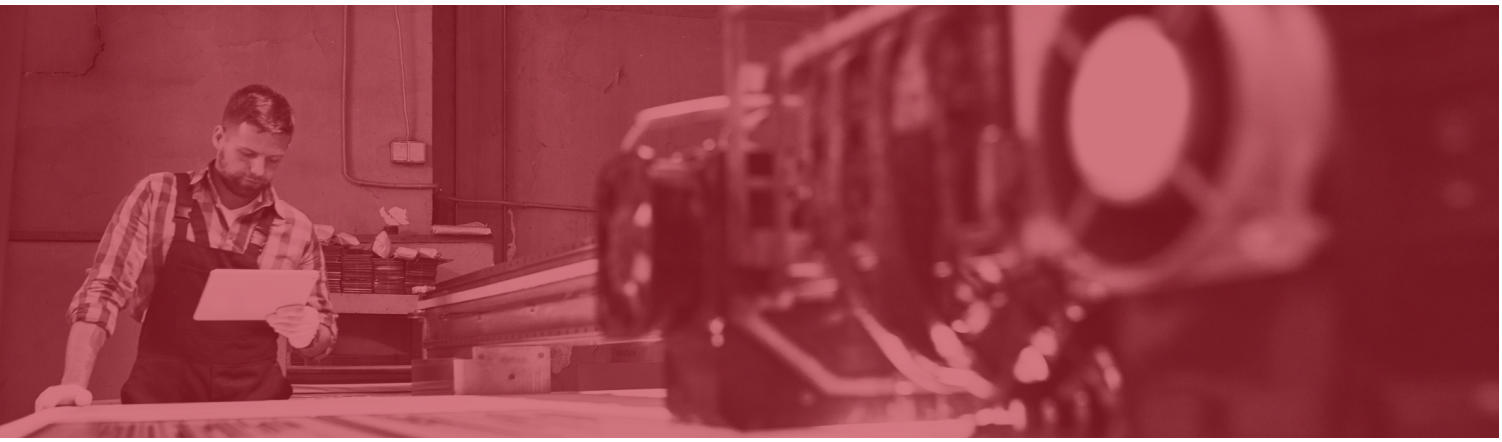
the actual condition of the equipment, so manufacturers can be sure the maintenance they perform is the most cost-effective.

Improved equipment performance and reliability. Leveraging real-time asset performance data allows manufacturers to virtually adjust and test variables to determine how the changes affect equipment performance and reliability. By using those insights, manufacturers can make smart decisions about whether and when to make adjustments to the physical process. Additionally, they can see expected vs. actual performance, for example, to learn if unplanned variables are affecting performance, and then make adjustments based on the new knowledge.

Extended asset lifespan. With a simulated model, manufacturers will be better able to reduce emergency downtime and other unnecessary "wear and tear" to ensure they attain optimum performance from, and a maximum lifespan of, the asset.

Inventory management. When it can be predicted more accurately what maintenance needs to be completed and when, manufacturers can reduce internal service and spare parts inventory levels to more closely match the need. Maintaining safety stocks of parts and supplies, purchased and stored "just-in-case," is no longer necessary.

Fleet management. Whether monitoring hundreds of customer machines located throughout the world or multiple production lines replicated in several factories, the digital twin will gather all the data points from the



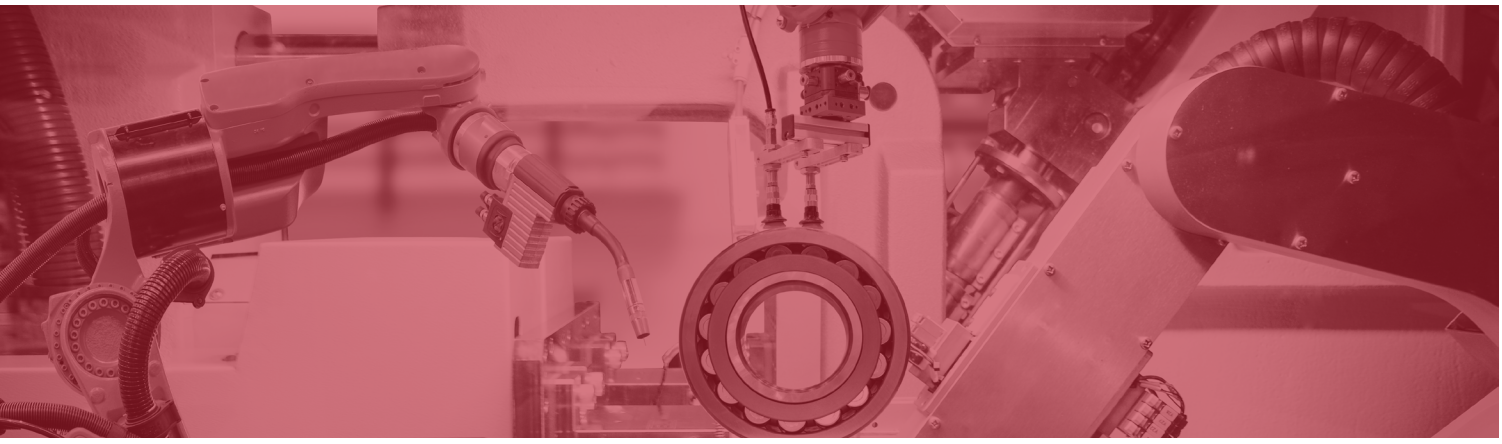
assets in near-real time. Manufacturers can establish benchmarks and thresholds that enable the digital twin to automatically highlight anomalies that may require action. Likewise, with IoT-enabled maintenance, updates to machines and production lines can more easily be replicated across a fleet of assets.

What-if simulation. Manufacturers can run simulations that will help them predict how an asset will respond to various changes, such as runtime or exposure to operating conditions. They also can perform test maintenance scenarios or specific repairs to see how they work digitally before applying them to the physical asset, reducing the risk and cost associated with making adjustments to machines and processes.

Improved safety. Unplanned events, and especially emergencies, create unsafe conditions. With a digital twin informing maintenance schedules, manufacturers can reduce–or even eliminate–the chance of an unexpected event or emergency.

Beyond production, additional benefits of the digital twin of performance emerge. With these new capabilities, manufacturers can:

Implement and develop a maintenance as a service business model. Manufacturers can provide customers with the option to outsource product



With digital twin informing maintenance schedules, manufacturers can reduce the chance of an unexpected event or emergency.

maintenance to them by offering service level agreements (SLAs) based on customer need. This provides a recurring revenue stream and also helps:

- Reduce support costs by minimizing asset failures, which reduces end-user downtime costs along with internal service and spare parts inventory costs.
- Increase customer satisfaction by increasing asset productivity.

Minimize warranty claims. By understanding exactly how end-users are using equipment, manufacturers can assess the validity of warranty claims.

Continually offer innovative products. By understanding how products behave in operation and at peak times, manufacturers can refine product development to drive quality and innovation.

Bringing the Closed-Loop Digital Twin to Life

While many manufacturers already use the digital twins of the product and production, they lack the ability to fully enable the digital twin of performance and create the feedback loop necessary for the closed-loop digital twin. It requires a cloud-based IoT solution that can not only remotely monitor assets, but also seamlessly integrate with the other technologies used in the digital twin of the product and the digital twin of production.

Siemens is leading the innovation–it is the only company able to fully provide the closed-loop digital twin (Figure 1). MindSphere, its industrial IoT as a service solution, adds the digital twin of performance to an already robust digital twin of the product and digital twin of production. The full digital thread is managed

with integrated CAD, CAM, CAE, PDM and IoT software, giving you operational transparency and a closed-loop digital twin that spans the enterprise and across the full product lifecycle. With all processes connected and updated in real time, you can leverage the closed-loop digital twin to power smarter maintenance across products, plants, systems and machines.

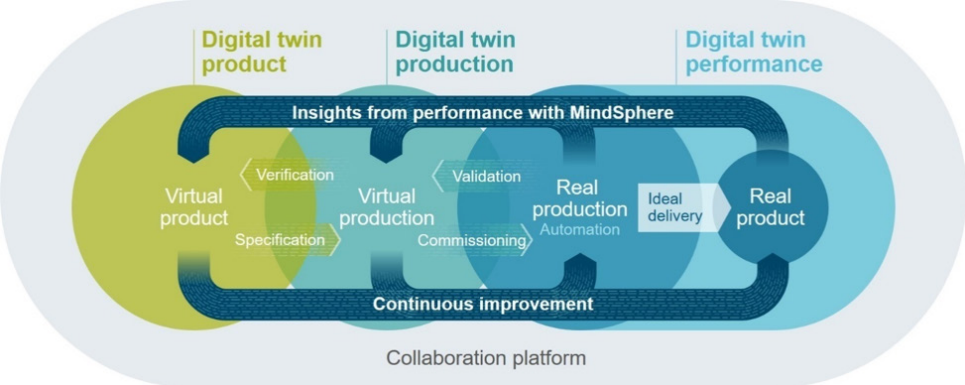


Figure 1: The Siemens closed-loop digital twin.

With the continuous collection and intelligent analysis of operating data from IoT-ready sensors, digitalization has opened up entirely new possibilities with advanced analytics and data collection from connected assets. By extending the digital twin out to machines and systems in the field, manufacturers have the opportunity to enable full-scale maintenance capabilities across the manufacturing enterprise and the full product lifecycle. With these capabilities, manufacturers will not only improve profitability but will establish a competitive advantage.

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