

DIGITAL INDUSTRIES SOFTWARE

The digital future of **aerospace and defense** **manufacturing**

How closed-loop manufacturing accelerates data-driven
production excellence.

siemens.com/xcelerator





Table of contents

Executive summary	3	CLM facilitates collaboration between the shop floor and engineering	9
Closed-loop manufacturing and the future of aerospace and defense	4	CLM accelerates new product introductions and change orders	10
CLM builds continuity into A&D digitalization	5	CLM supports low-code personalization	11
What closed-loop manufacturing in A&D looks like	6	CLM and continuous improvement	12
CLM is built on a robust digital thread and comprehensive digital twin	7	Partnering with Siemens for your digital future	13
CLM digitally connects engineering production plans to the shop floor	8		

Executive summary

Closed-loop manufacturing (CLM) can and has achieved new levels of manufacturing productivity and excellence for those aerospace and defense (A&D) manufacturers that are implementing it. This includes companies across the globe, from startups to long-established OEMs with any level of existing digitalization as a starting point.

For many companies in today's challenging A&D climate, CLM is no longer a nice idea that offers competitive advantages; it is a business imperative. The good news is that you can attain closed-loop manufacturing step by step with payoffs all along the way, rather than waiting to complete a multi-year mega-project that pays off only at the end. The key is building an interconnected digital ecosystem on a foundation of robust digital tools, which bring cross-domain capabilities to bear on your operations.

This ebook is designed not just to describe CLM and talk about its successes, but also to prompt innovative thinking about your specific business goals and how you might leverage CLM to reach them.

Closed-loop manufacturing and the future of aerospace and defense

How long does it take the typical aerospace and defense (A&D) manufacturer to incorporate an engineering change into shop floor operations? What if you could decrease this time by an order of magnitude or more, taking less than a day to do something that previously took weeks to accomplish? Much more than a concept blue-skied at a conference, **closed-loop manufacturing (CLM)** is attaining results like this one, which a Siemens Digital Industries Software customer has achieved through its CLM implementation in its aircraft engine manufacturing operations.

Closed-loop manufacturing coordinates product design and production engineering with production planning and execution. It enables direct cross-domain feedback loops from upstream to downstream processes and vice versa, streamlining activities like change management and nonconformance tracking and correction. In other words, it offers much-needed speed and agility to an industry facing unprecedented market challenges.

The products of A&D manufacturers must operate under extreme conditions for decades of service life, making them perpetually some of the most complex and difficult to design, build and maintain. Today, these challenges are compounded by market trends that uniquely burden A&D manufacturers. Closed-loop manufacturing offers a welcome solution in this harsh business climate:

- CLM's interconnected digital ecosystem manages the **increased complexity and integration** of A&D products by **orchestrating cross-domain** development and engineering processes.
- As calls for greater **sustainability** lead to more and more materials and process (M&P) changes, CLM **accelerates innovation**, speeding new product introductions (NPIs) and time to delivery.

- To address **supply chain bottlenecks** that can quickly cascade into production delays and missed delivery dates, CLM gives procurement and planning teams **full visibility** and immediate access to all relevant data, enabling effective responses.
- With the **skilled workforce** on which the A&D industry has relied now retiring, CLM helps convert their tribal knowledge to **electronic work instructions (EWIs)**, augmented reality (AR) devices, automated processes and other means of accelerating accurate production.

With closed-loop manufacturing, your A&D company can do much more than survive these challenging times. You can transform and elevate your manufacturing enterprise to attain exceptional competitive advantages.



CLM builds continuity into A&D digitalization

The aerospace and defense industry has recognized the value of digital technology since it first came on the scene. Digital tools and systems have helped create complex A&D designs and ensure the exacting production needed to gain critical safety certifications.

But more is needed from digitalization. After all, the majority of A&D programs across the world are either over budget, late or both, and the current digital landscape at most A&D companies does not alleviate these time and cost pressures. It may even contribute to them. The chief culprit is discontinuity – something that came about because A&D companies were early adopters of digital systems.

- Before digitalization became available as a mature, standardized technology, companies created **homegrown solutions** that accelerated specific functions in specific ways for specific applications.
- Even as design and engineering domains transitioned to digital solutions, the low volumes of A&D production have made **paper-based** solutions the norm on the shop floor, right up to the present for many A&D enterprises.

- As product lines, production methods and volumes evolved, **point solutions** were adopted as they became available from digital technologies vendors. Accelerating and standardizing operations within a particular domain, these point solutions do not offer cross-domain functionality.
- The digital ecosystem at many A&D companies today consists of a patchwork of paper-based, homegrown and point solutions, perhaps linked by **integrated platforms** but limited in scalability due to the complexity of this integration.

While A&D digital systems have grown in sophistication and capabilities to address the needs of individual domains, manual handoffs of information from one domain to another and redundancies persist. Slow and error-prone, such discontinuities do not enable collaboration or enforce business processes.

The continuity provided by closed-loop manufacturing vastly accelerates accurate cross-domain communication, lowering costs and improving productivity, quality and competitiveness.

What **closed-loop manufacturing** in A&D looks like

Historically, digital systems for manufacturing enterprises have focused solely on one of three technological areas:

- Business systems such as **enterprise resource management (ERP)** solutions offer information processing and management
- **Product lifecycle management (PLM)** solutions enable product creation and process engineering
- **Manufacturing operations management (MOM)** solutions such as manufacturing execution systems (MES) monitor and control production operations

Demands for cross-domain data and processes have blurred these distinctions and created the need for CLM continuity.

By seamlessly integrating these three major domains – referred to as the “golden triangle” – CLM synchronizes and optimizes activities along the complete value chain, from product design through production engineering and planning to manufacturing execution and shop floor intelligence as well as consumer use in the field.

Closed-loop manufacturing thus provides an Industry 4.0 platform that supports all interactions within the golden triangle. The platform completely digitalizes and seamlessly integrates product and production lifecycles for flexible, scalable production processes. CLM accelerates product development and engineering and maximizes your responsiveness to real-time manufacturing events.

Information shared among PLM, MOM and ERP systems includes the following:

- PLM provides the product definition, master process, inspection definition, plant resources and workforce roles and skills to MOM.
- PLM provides the manufacturing bill of materials (mBOM), part definition and plant resources to ERP.
- ERP provides production orders and the order BOM to MOM, and MOM provides production reporting to ERP.
- MOM provides as-built records, order history and status and nonconformance/defect data to PLM.

CLM is built on a robust digital thread and comprehensive digital twin

Two key elements of closed-loop manufacturing are an end-to-end **digital thread** and a **comprehensive digital twin**.

The **digital thread** is the means by which CLM shares dialogue and activities across PLM, MOM and ERP systems – the golden triangle. Interconnecting these domains through a common digital backbone and single source of truth, the digital thread enables you to leverage complete lifecycle and change management to improve collaboration across your enterprise and along your value chain.

The **comprehensive digital twin**, a virtual representation that comprises all critical attributes and aspects of a product and its manufacturing processes, enables you to fully employ the virtual realm both before production ramp-up and while implementing product and process changes. Closed-loop manufacturing feeds performance data from the shop floor and, ultimately, from real-world application back to the digital twin to continuously refine and optimize product and production.

A robust digital thread and comprehensive digital twin are foundational elements of **Siemens Xcelerator**, our new, open digital business platform featuring a curated portfolio of hardware and software enabled by the internet of things (IoT) and a powerful ecosystem of partners. Siemens Xcelerator is designed to help our customers accelerate digital transformation. Businesses of all sizes rely on Siemens Xcelerator solutions to design, engineer, manufacture and optimize their products, from the chip level to entire systems, across a wide range of industries. At the center is our goal to make digital transformation easy, fast and at scale.



CLM digitally connects engineering production plans to the shop floor

Among all the cross-domain connections that closed-loop manufacturing offers, perhaps the most critical for A&D companies is the connection from manufacturing engineering to the production floor. Traditionally, once manufacturing engineers have created the bill of process (BOP) and operator work instructions for a particular aircraft or spacecraft configuration, documentation (often on paper) is delivered to the production supervisor and team members, who then have to read and understand the steps that involve them and what they have to do.

Connecting these two domains via the digital thread and providing a single, digital source of truth through the digital twin enables a company's PLM and MOM systems to interact transparently. Electronic work instructions (EWIs) are generated directly from the engineering-defined manufacturing process.

When new or modified processes are introduced, operators receive all the information they need to complete their assigned tasks. Digitally provided EWIs may include instructional videos, 3D visualizations, specifics about parameters to collect from machines or tools, and electronic buyoffs that replace paper travelers.

CLM is expected to **reduce development time (T2M) by 50% and recurring costs by 50%** for a leading supplier of civil and military launch solutions. Paperless manufacturing, streamlined operations and a direct link of PLM-generated process and work instructions to MES are critical outcomes achieved by the company. The integrated aerospace solution built on Siemens Teamcenter and Opcenter has enabled the company to establish a common digital product development and realization platform.

CLM facilitates collaboration between the shop floor and engineering

Comparing the as-built product to the as-designed and as-planned product is a critical value that closed-loop manufacturing provides. CLM aggregates and contextualizes the raw data generated on the shop floor, resulting in smart data that is shared upstream with designers and manufacturing engineers.

While smart data from the floor facilitates broader programs for continuous process improvement, more immediate impacts are also facilitated by CLM. In some cases, for example, production personnel must modify planned processes to make them compatible with the actual shop floor equipment and capabilities, or they may realize as they are performing an activity that something could be improved.

When this occurs, closed-loop manufacturing accelerates notification of designers and manufacturing engineers, enabling them to confirm that the as-built product meets customer requirements. Using shop floor insights, engineers are also able to adjust the as-planned BOP and EWIs quickly enough that benefits may be enjoyed by the floor team on the very next shift.

As we mentioned earlier, an aircraft engine company has used CLM to decrease the implementation time for engineering changes from weeks to less than a day. CLM enables the company to centralize engineering for different plants and streamline engineering resolution of shop-floor issues. This includes efficient shop floor quality checks and actionable insights.



CLM accelerates new product introductions and change orders

While integration of cutting-edge technologies into A&D products is part of the industry's DNA, the demand, speed and complexity of these integrations have reached unprecedented levels. A major factor is the industry's efforts toward sustainability. The use of composite materials in aircraft offers a great example. These lightweight, high-strength materials – one-tenth the weight of steel and half that of aluminum – markedly improve aircraft fuel efficiencies. Yet manufacturing technology for these materials is very different from metalworking. It is also evolving rapidly. Manufacturing engineering and execution for composite structures is an ever-changing endeavor.

With new product introductions (NPIs) as well as change orders, collaboration across a closed-loop manufacturing solution typically begins with product (or variant) information, which is defined and created by your design team and seamlessly communicated downstream to manufacturing engineers and quality personnel for production planning.

Tighter collaboration between design engineering and manufacturing engineering enables you to reduce the time required to get new products to market. Design engineers can consider multiple scenarios of how a product can be manufactured before committing to a particular design.

Manufacturing engineers may study designs early in the development cycle to ensure efficient manufacturability.

Contributing to this collaboration in a closed-loop manufacturing environment are simulation tools. Using the comprehensive digital twin, simulation enables you to verify that you are meeting requirements and addressing constraints – before any physical prototypes are produced. Simulation also allows you to model and simulate manufacturing and assembly processes in the virtual realm, resulting in safe, efficient facility operation and the ability to adapt quickly to the unanticipated. Robust 3D visualization capabilities, including virtual reality (VR), can be used to validate manufacturability.

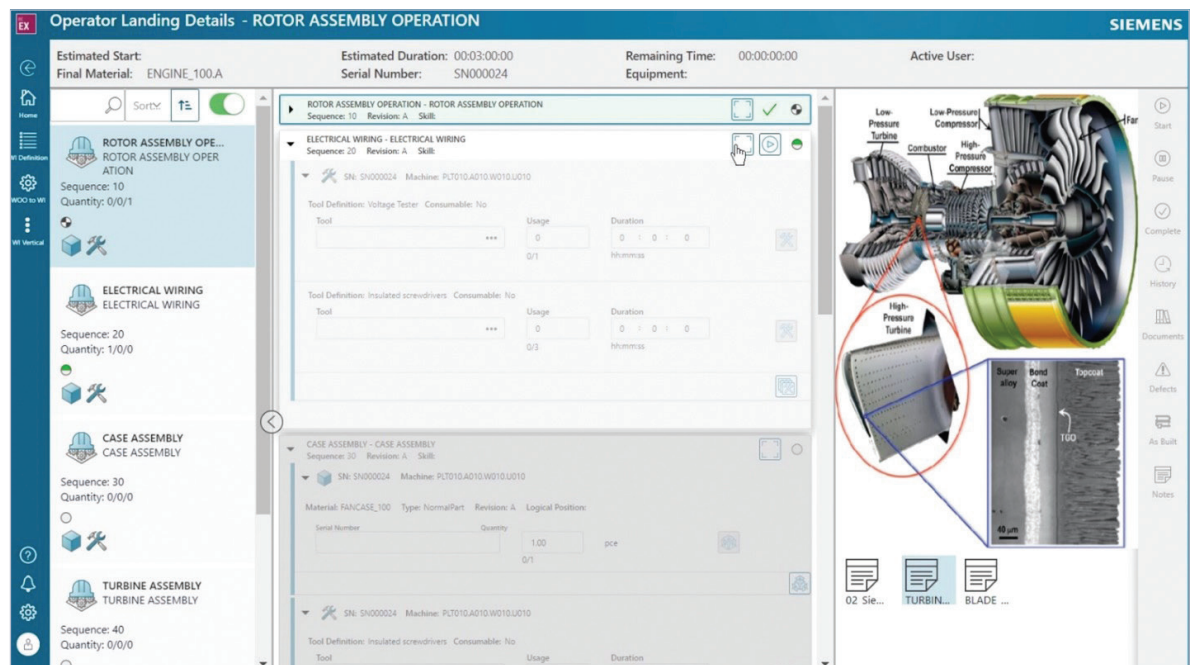
Rafael Advanced Defense Systems has implemented Siemens Teamcenter manufacturing engineering software to accelerate new product introduction, ensure first time right production quality and efficiently train workers in the manufacture of its military and defense technologies. The solution manages eBOM and mBOM, including eBOM-mBOM decoupling to allow for multiple mBOMs. The company is now running a successful production pilot that manages BOP, EWI and augmented reality (AR) instruction applications. Teamcenter supports quick engineering change cycles and validation including concurrent engineering from the early prototype stage, improved data quality and reliability, and shorter training of new shop-floor employees.

CLM supports low-code personalization

To optimize your team members' efficiency within the CLM interconnected digital ecosystem, each member needs instant visibility and access to the resources across the value chain related to their specific responsibilities – and only those resources. In other words, they need personalized user experiences (UXs), enabling them to easily access and comprehend only the information they need to perform their jobs with the utmost efficiency.

Providing such personalized UXs in the past has required complex and time-consuming software development activities by highly skilled front-end developers. But today, you can empower your team members to become “citizen developers” who tailor the applications they use to their individual needs without having to call upon IT specialists. The enabling technology for this transformational solution is the **Mendix low-code, multi-experience development platform**.

Low-code application development is a visual, model-driven way to build and deploy software applications. It employs a drag-and-drop interface with the ability to add more complex programming as needed. By abstracting the complexities of underlying technologies and data infrastructure, the low-code platform enables data connectivity and process automation with workflow simplicity. The Mendix platform's simple tools empower your workforce to quickly bring their ideas to realization.



CLM and continuous improvement

To improve both product designs and manufacturing and assembly processes on an ongoing basis, closed-loop manufacturing leverages your experiences of current and past manufacturing performance through closed-loop feedback. CLM enables your team to perform virtual analysis of recurring issues and to perform corrective actions and impact analysis to incorporate error-proof changes into production.

To achieve continuous improvement, CLM aggregates context-driven data intelligence from product, process, machine, people and business. It supports advanced data analytics, which lead to predictive and prescriptive manufacturing insights and a culture of effective data-driven decision making.

Shortening cycle time and reducing cost are two key CLM targets at Sierra Space Systems as the company designs, engineers, builds and tests the Dream Chaser, the world's only winged commercial space plane, using the Siemens Xcelerator portfolio. Sierra Space is using Siemens Xcelerator software in all phases of Dream Chaser development, including structural, thermal, mechanical, electrical and software design; vehicle manufacture and requirements verification; and complete lifecycle maintenance.

Partnering with Siemens for your digital future

A hard-earned conviction of ours at Siemens Digital Industries Software leads us to one last point about closed-loop manufacturing: choosing the right software partner is vital. After all, the digital tools you select today must be change agents that serve your strategic vision and manufacturing initiatives for the next decade or more. Your digital manufacturing partner must keep pace as you drive your business forward.

Siemens Xcelerator has built our closed-loop manufacturing solution by listening to and learning from our customers, then innovating and capturing best practices for every digital task. Your user experience

with our products is thus built on a rich and deep knowledge base and an extensive set of capabilities. We use this best practice to accelerate time to value of our software. Our robotics, assembly and machining simulation and plant design and optimization deliver a validated and optimized production process to the shop floor.

With Siemens as your software partner, your implementation of closed-loop manufacturing will bring about the manufacturing agility you need to thrive in the A&D marketplace, both today and into the future.

Siemens Digital Industries Software helps organizations of all sizes digitally transform using software, hardware and services from the Siemens Xcelerator business platform. Siemens' software and the comprehensive digital twin enable companies to optimize their design, engineering and manufacturing processes to turn today's ideas into the sustainable products of the future. From chips to entire systems, from product to process, across all industries, [Siemens Digital Industries Software](#) – Accelerating transformation.

Americas: 1 800 498 5351

EMEA: 00 800 70002222

Asia-Pacific: 001 800 03061910

For additional numbers, click [here](#).

© 2023 Siemens. A list of relevant Siemens trademarks can be found [here](#).

Other trademarks belong to their respective owners.

85310-D2 6/23 H