

EBOOK

THE CONNECTED FACTORY: MAKING CLOSED-LOOP MANUFACTURING WORK

Your Roadmap to Seamless Integration of ERP, PLM & MES
for Smart Production



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RETHINKING MANUFACTURING FOR TOMORROW: THE POWER OF CLOSED-LOOP SYSTEMS



Manufacturing has never been more challenging. Market volatility keeps leaders awake at night. Customer demands evolve at lightning speed. Sustainability is no longer optional—it's essential for business success. Within these market dynamics, how can manufacturers stay ahead?

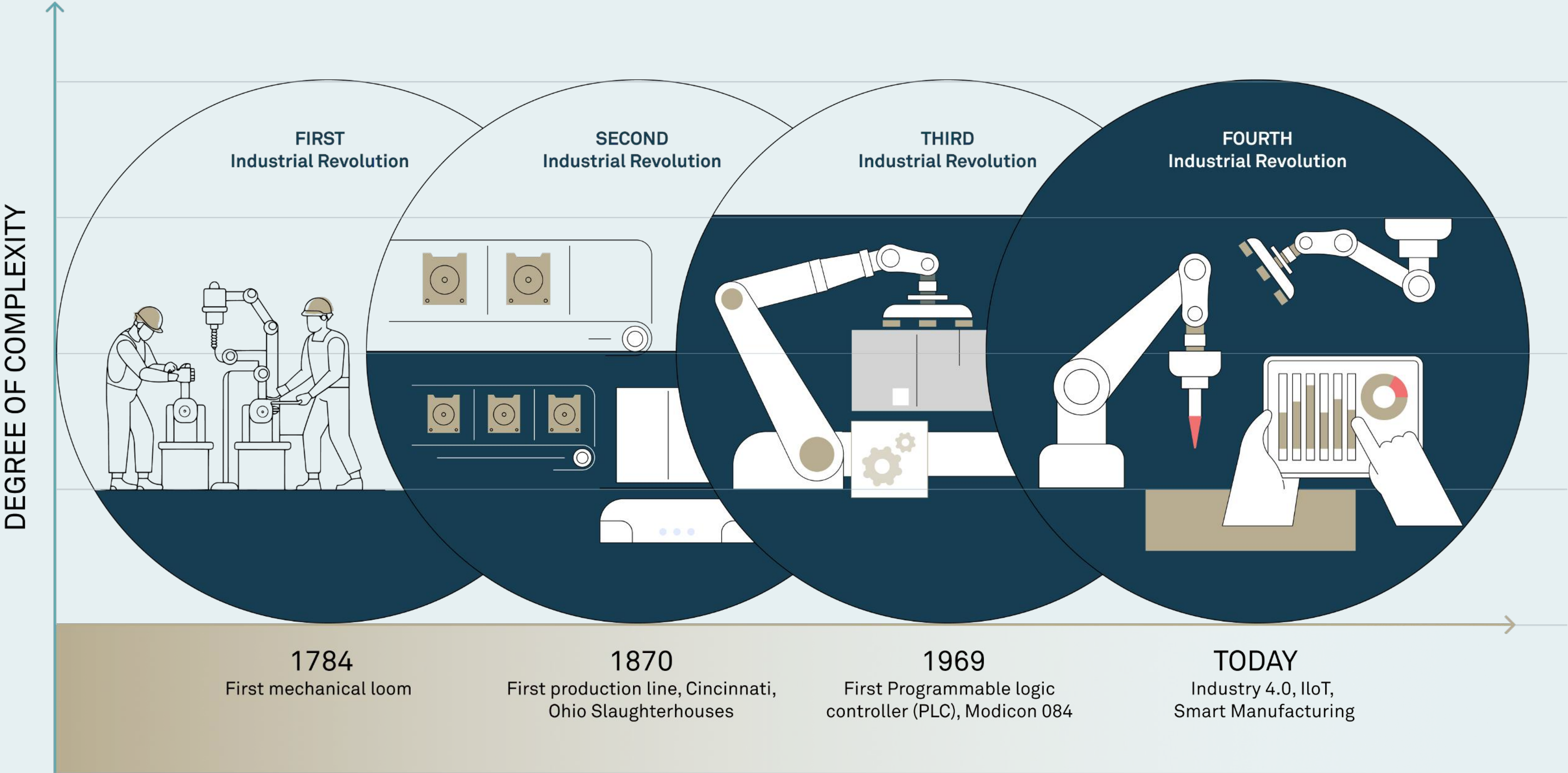
The answer lies in connecting the dots. Closed-Loop Manufacturing (CLM) reimagines how we think about production by creating a continuous flow of insights across the entire product journey. Think of it as your manufacturing ecosystem's nervous system, where every piece of information—from initial design sketches to real-world performance data—feeds back into a cycle of constant improvement.

At its heart, CLM bridges three critical states of your product's life: **how you plan it, how you build it, and how customers use it.** When these three elements work in harmony, something remarkable happens. Production becomes more flexible. Quality reaches new heights. Time-to-market decreases. And perhaps most importantly, you gain the ability to adapt quickly when market conditions shift.

But that's just the beginning. When you pair CLM with Closed-Loop Quality (CLQ), you create a powerful framework for excellence. Together, they don't just help you make products—they help you make better products, more efficiently, with less waste and greater precision.



CHAPTER 1: THE CONNECTED FACTORY VISION

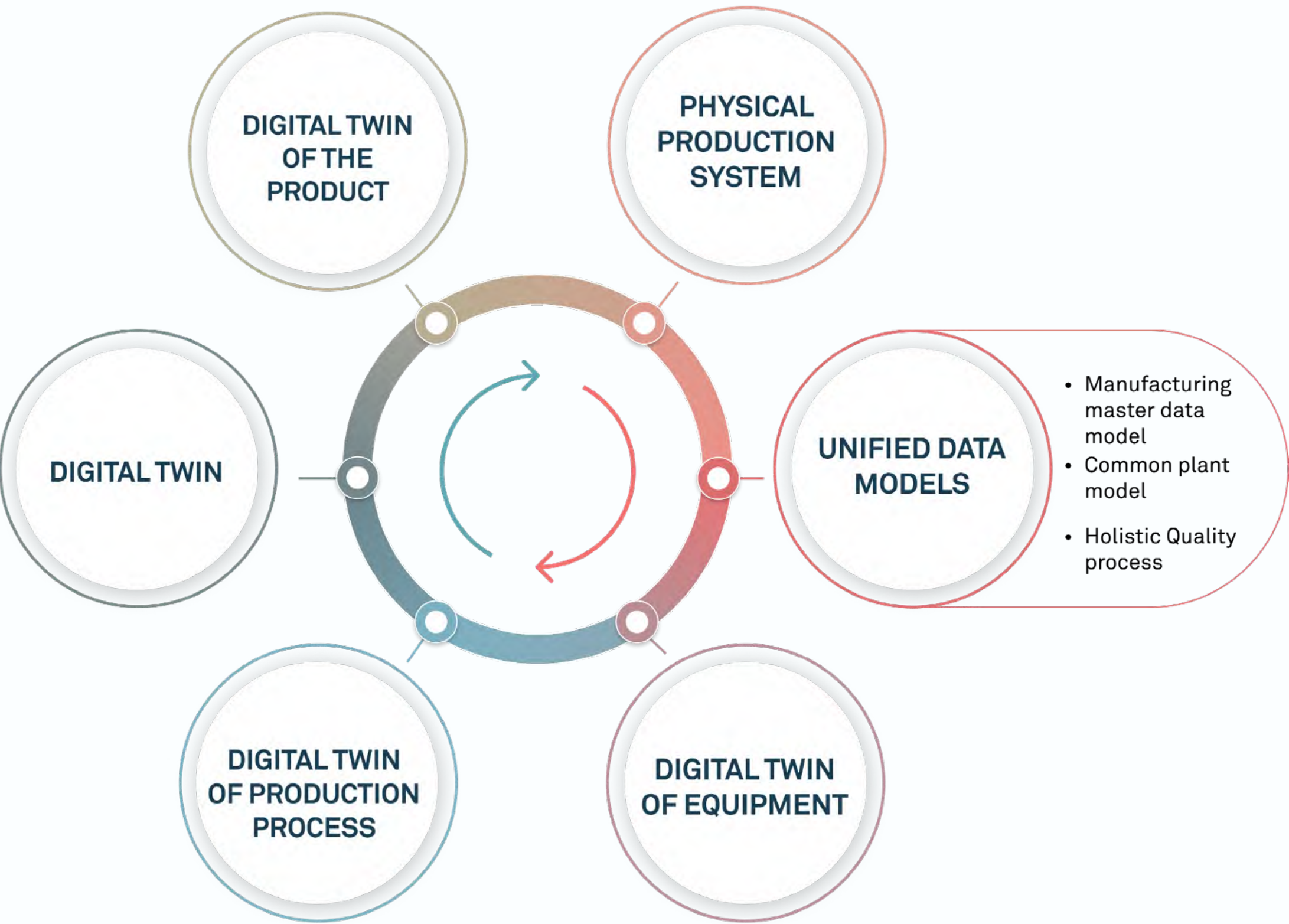


Manufacturing has entered an era of unprecedented change. What started with steam power and evolved through mass production and automation has brought us to a defining milestone: the age of connected manufacturing.

THE JOURNEY TO CONNECTED MANUFACTURING



Think of today’s factory floor as a living ecosystem where every machine, product, and process has a story to tell. These stories, told through data, are transforming how we manufacture. Just as the smartphone connects us to world of information, the connected factory links every aspect of production into one harmonious system.



At the heart of this transformation are two powerful concepts:

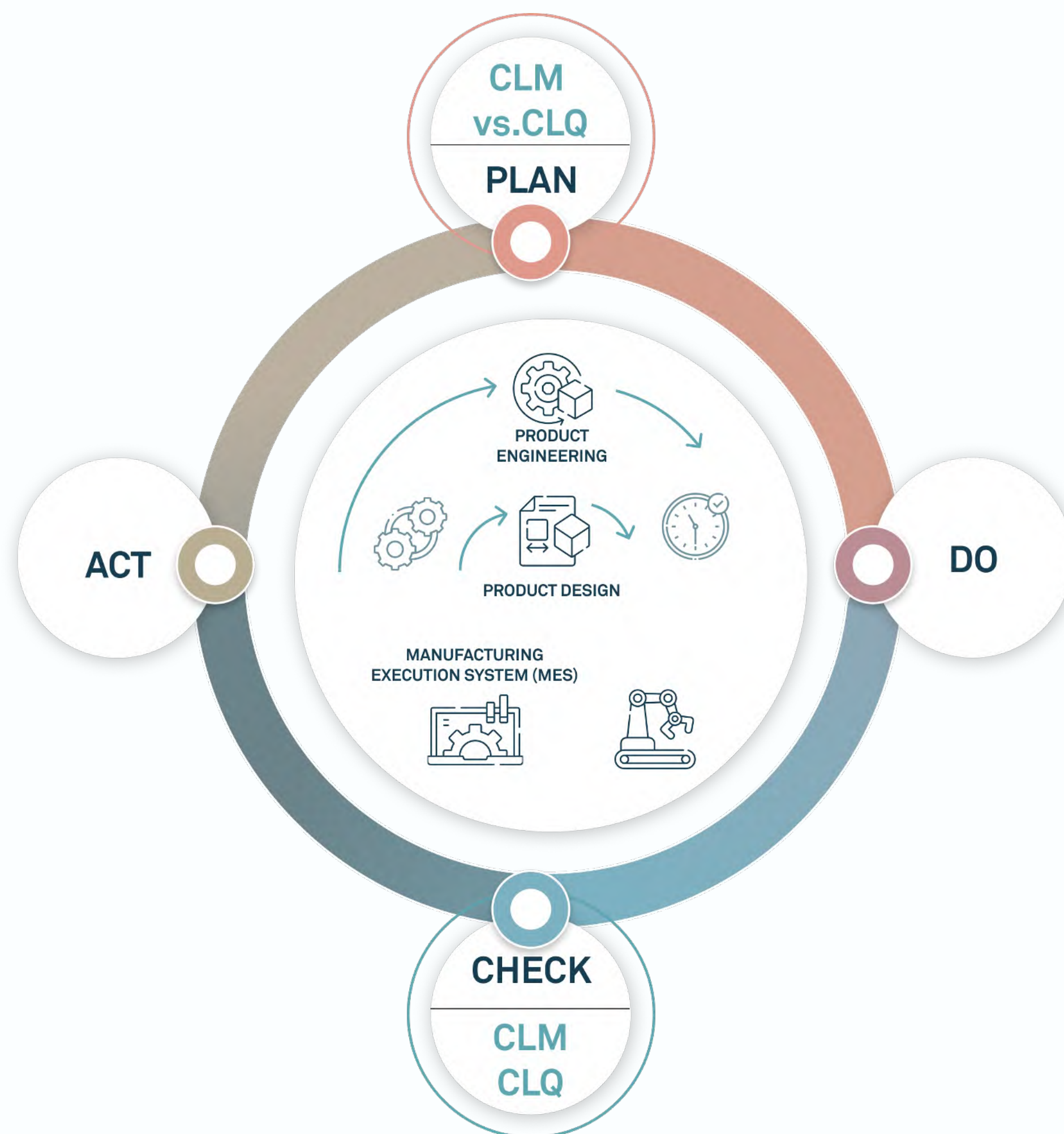
The Digital Thread:

This acts as your product’s digital lifeline, connecting every piece of information from initial design through real-world use. It ensures continuity of data and insights across the entire manufacturing process, enabling better decision-making at every stage. Working alongside it is the Digital Twin.

The Digital Twin:

This is a virtual mirror of your physical products and processes. This sophisticated digital replica enables you to test, predict, and optimize before making real-world changes, reducing risk and accelerating innovation.

BUILDING BLOCKS OF THE CONNECTED FACTORY



The connected factory stands on three fundamental pillars that work together to create a robust manufacturing ecosystem.

First, **seamless integration forms** the foundation of connected manufacturing. This means breaking down traditional barriers between design, production, and delivery departments that have historically operated in isolation. By creating a continuous flow of information across systems, manufacturers can enable real-time decision making at every level of operations. This integration ensures that insights gained in one area can immediately benefit all others.

Intelligent automation represents the next level of manufacturing sophistication. Moving beyond simple automation of repetitive tasks, smart and adaptive systems can now use data to predict and prevent issues before they occur. These systems continuously optimize processes in real time based on actual performance data, leading to improved efficiency and reduced waste.

Quality-driven production completes the foundation by embedding quality assurance throughout the entire manufacturing process. Rather than treating quality as a final checkpoint, this approach creates a continuous learning cycle. Every product made provides valuable data that feeds back into the system to improve future production. This creates a true closed loop between design intent and actual results, ensuring consistent quality improvement over time.

THE IMPACT ON YOUR BUSINESS

The transformation to connected manufacturing delivers tangible benefits across multiple dimensions of business performance. By connecting design directly to production, manufacturers can significantly reduce development time and accelerate speed to market. This direct connection ensures that design innovations can be quickly implemented in production.

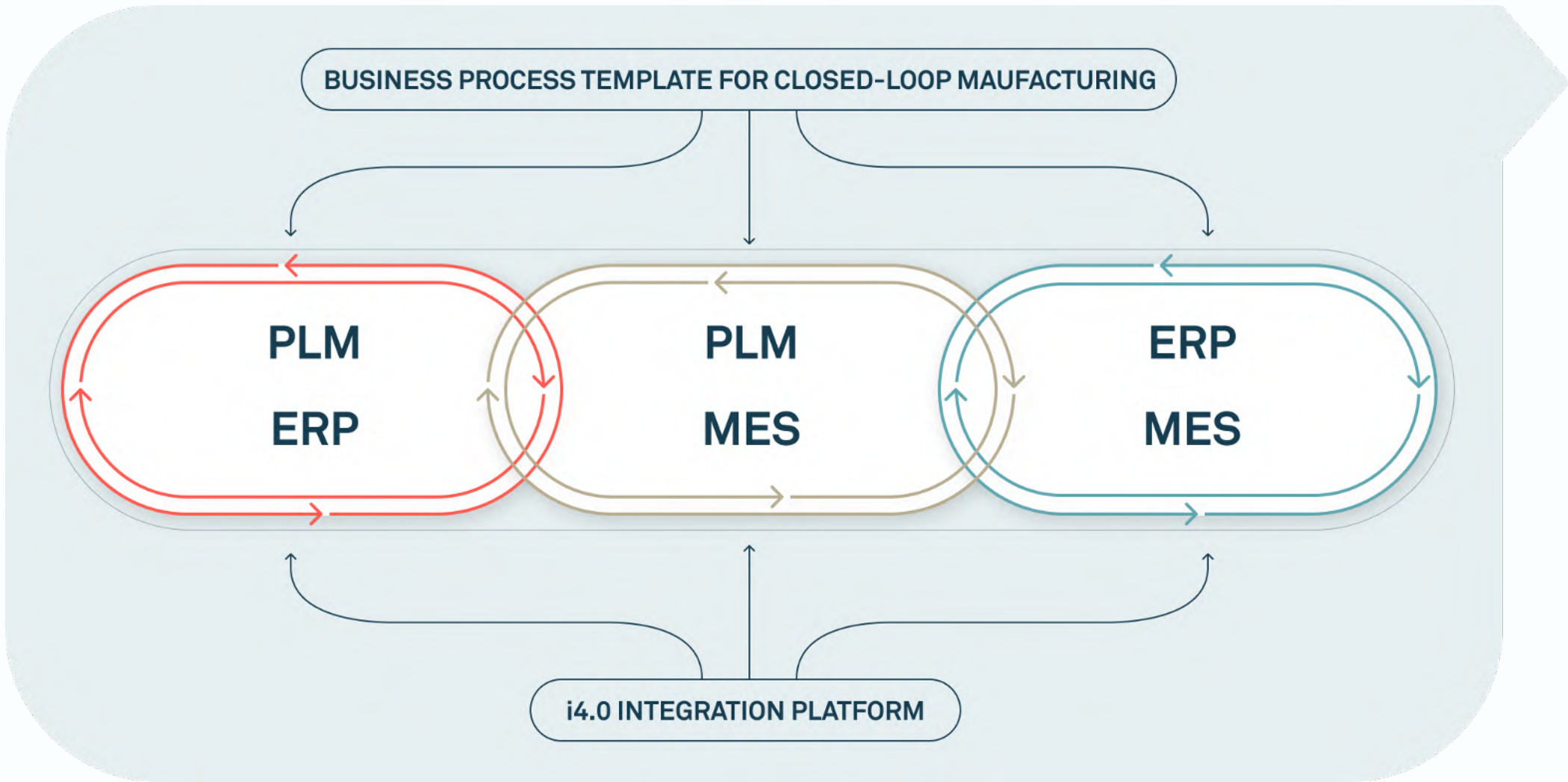
Agile manufacturing processes enable quick responses to market changes, providing the adaptability needed in today's volatile market conditions. When quality issues arise, early detection and consistent monitoring ensure they're caught and addressed before affecting the final product. Through intelligent monitoring, resource use can be optimized and waste reduced, supporting both sustainability goals and operational efficiency.

Perhaps most importantly, connected manufacturing enables innovation through virtual testing. New ideas can be thoroughly evaluated in the digital realm before committing physical resources, reducing risk and encouraging experimentation.

LOOKING AHEAD

The connected factory isn't just about technology—it's about creating a manufacturing environment that's ready for whatever the future brings. Whether it's changing customer demands, new sustainability requirements, or emerging market opportunities, connected manufacturing provides the flexibility and intelligence needed to succeed.

CHAPTER 2: BUILDING BLOCKS OF INTEGRATION - CONNECTING ERP, PLM & MES



Just as a symphony orchestra creates beautiful music through the coordinated efforts of different instrument sections, modern manufacturing excellence emerges from the harmonious interaction of three core systems. Each system brings unique capabilities, but their true power emerges when they perform in concert.

UNDERSTANDING THE CORE SYSTEMS

PRODUCT LIFECYCLE MANAGEMENT

Product Lifecycle Management (PLM) serves as the conductor of your product’s journey from initial concept to market reality. It maintains the single source of truth for all product-related information, ensuring that everyone from designers to production teams works with the latest product data. Through PLM, engineering changes are tracked, design data is maintained, and product specifications are managed with precision throughout the entire lifecycle.

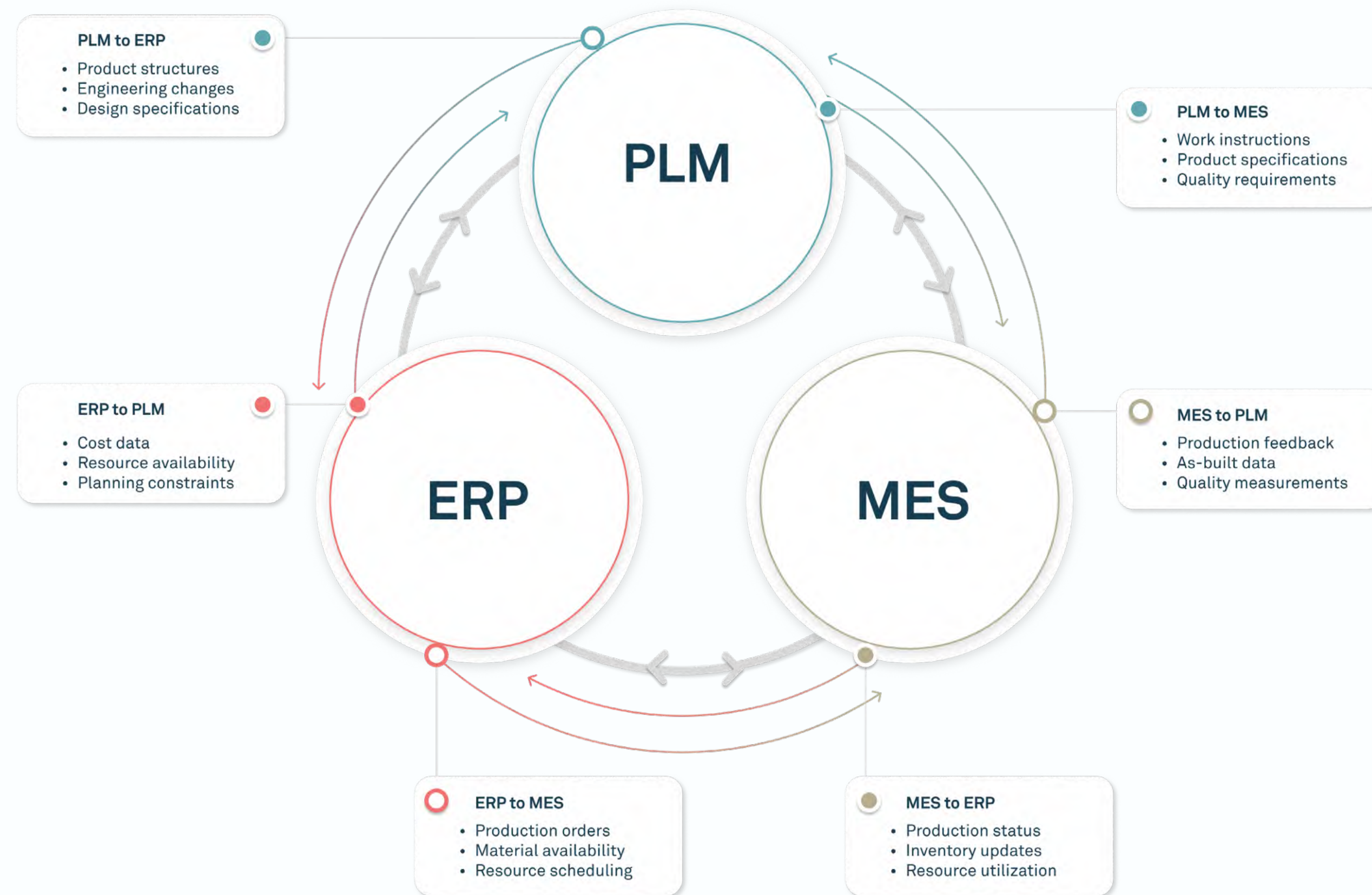
ENTERPRISE RESOURCE PLANNING

Enterprise Resource Planning (ERP) acts as your business’s central nervous system, coordinating the complex dance of resources, materials, and finances. It manages the critical business aspects of manufacturing, from purchase orders to inventory management, ensuring that your organization has the right resources at the right time. By handling the business side of manufacturing, ERP provides the foundation for informed decision-making and efficient resource utilization.

MANUFACTURING EXECUTION SYSTEMS

Manufacturing Execution Systems (MES) bring plans to life on the factory floor. Operating at the crucial intersection between planning and production, MES manages day-to-day manufacturing operations while collecting vital real-time data. This system bridges the gap between high-level planning and shop-floor reality, ensuring that production execution aligns with business goals while maintaining efficiency and quality.

MAKING THE CONNECTION

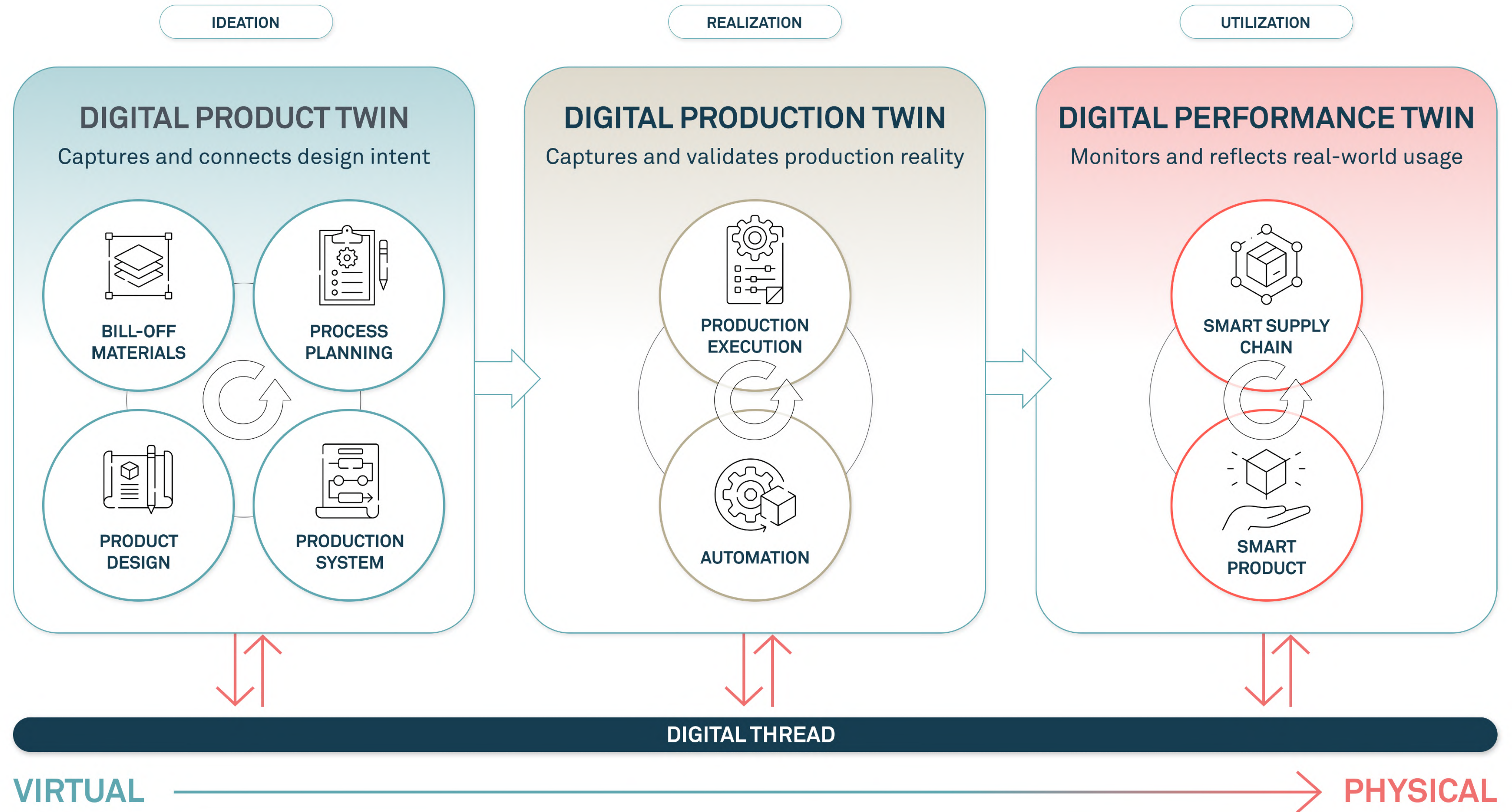


The true value of these systems emerges through their interactions. Each connection point creates opportunities for enhanced efficiency and intelligence. Here's how:

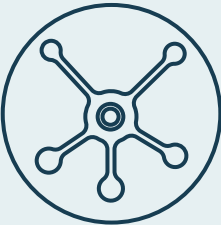
The **PLM-to-ERP connection** ensures that product innovations translate smoothly into production reality. When design changes occur, their cost implications are immediately understood, enabling informed decisions before changes are implemented. This connection ensures that product data drives accurate resource planning, preventing costly misalignments between design intent and production capabilities.

When **PLM connects with MES**, engineering specifications transform directly into practical shop floor instructions. This vital link ensures that production teams always work with the latest design information while providing crucial feedback from real production experiences back to engineering teams. Quality standards remain consistent throughout the process, creating a closed loop of continuous improvement.

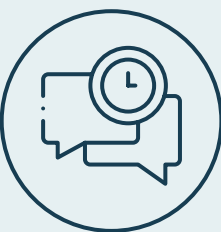
The **ERP-to-MES connection** creates seamless flow between business planning and production execution. Production orders move efficiently to the shop floor, while real-time inventory updates inform planning decisions. This dynamic interaction enables automated optimization of resource utilization, ensuring maximum operational efficiency.



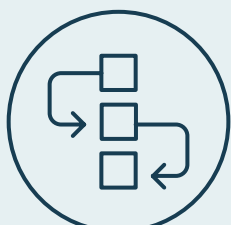
THE DATA FOUNDATION



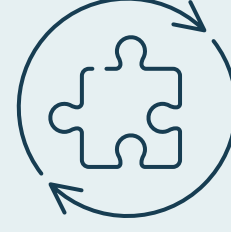
Unified Data Models ensure all systems speak the same language, preventing costly miscommunications and errors. This standardization enables seamless data flow across the organization, creating a single source of truth for all manufacturing operations.



Real-Time Communication capabilities ensure that critical updates reach their destination instantly, enabling immediate response to changing conditions. This immediate flow of information supports agile decision-making and rapid problem resolution.



Consistent Processes provide the framework for reliable operations. By standardizing workflows and procedures across systems, organizations can ensure reliable, repeatable results while maintaining flexibility for unique requirements.



Smart Integration goes beyond simple data exchange, creating intelligent connections that understand what information to share and when. This intelligence ensures that each system receives the right information at the right time, preventing information overload while maintaining operational efficiency.

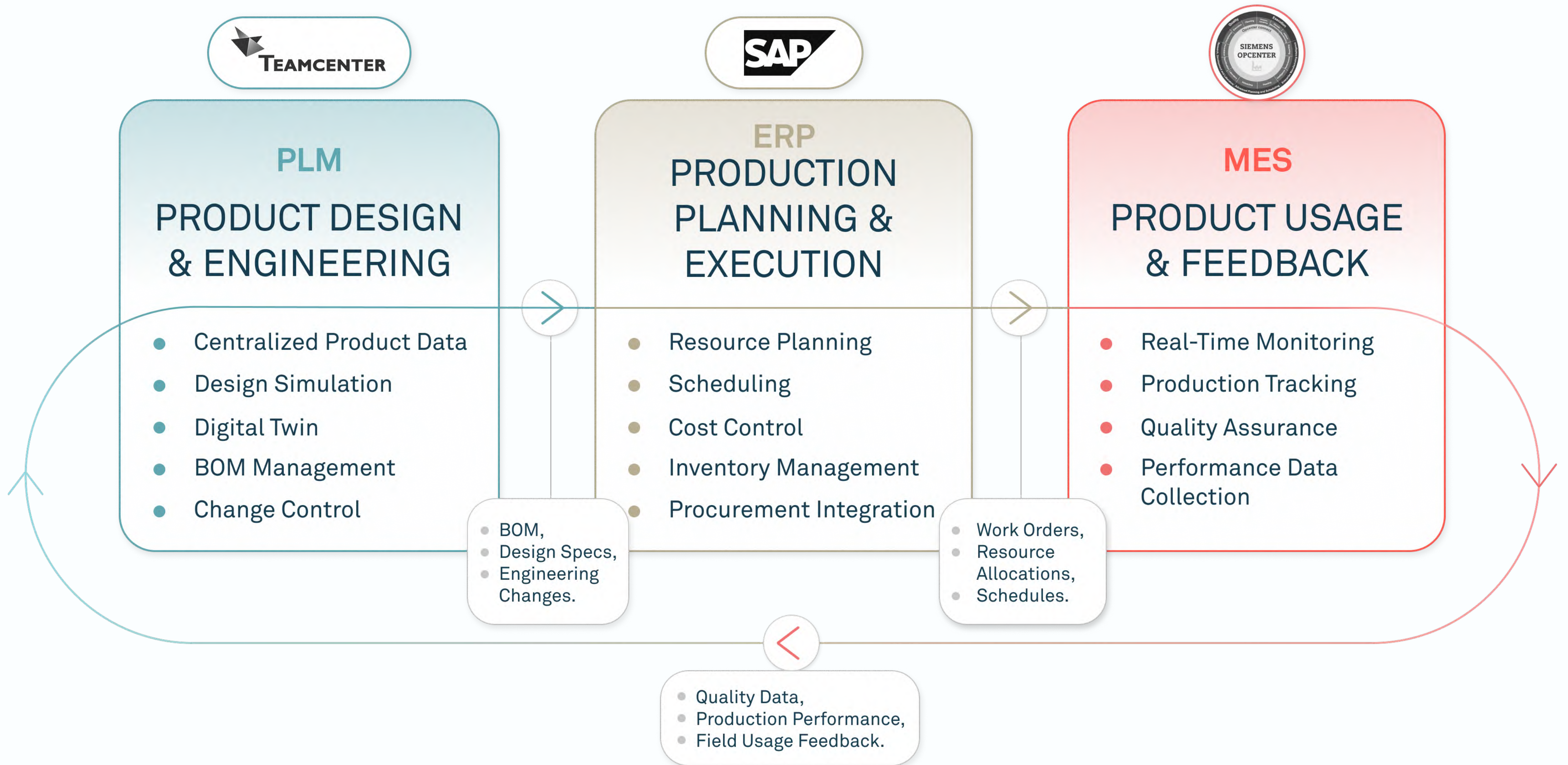
MAKING IT WORK FOR YOUR BUSINESS

Successful system integration requires a strategic approach tailored to your organization's specific needs. Begin by focusing on your most pressing challenges, building connections that deliver immediate value. This targeted approach allows you to demonstrate success quickly while laying the groundwork for broader integration.

Remember that technology is only part of the equation. People play a crucial role in successful integration. Invest in comprehensive training programs that help teams understand not just how to use connected systems, but why these

connections matter. Create clear processes for data handling and ensure everyone understands their role in maintaining the integrity of the connected factory.

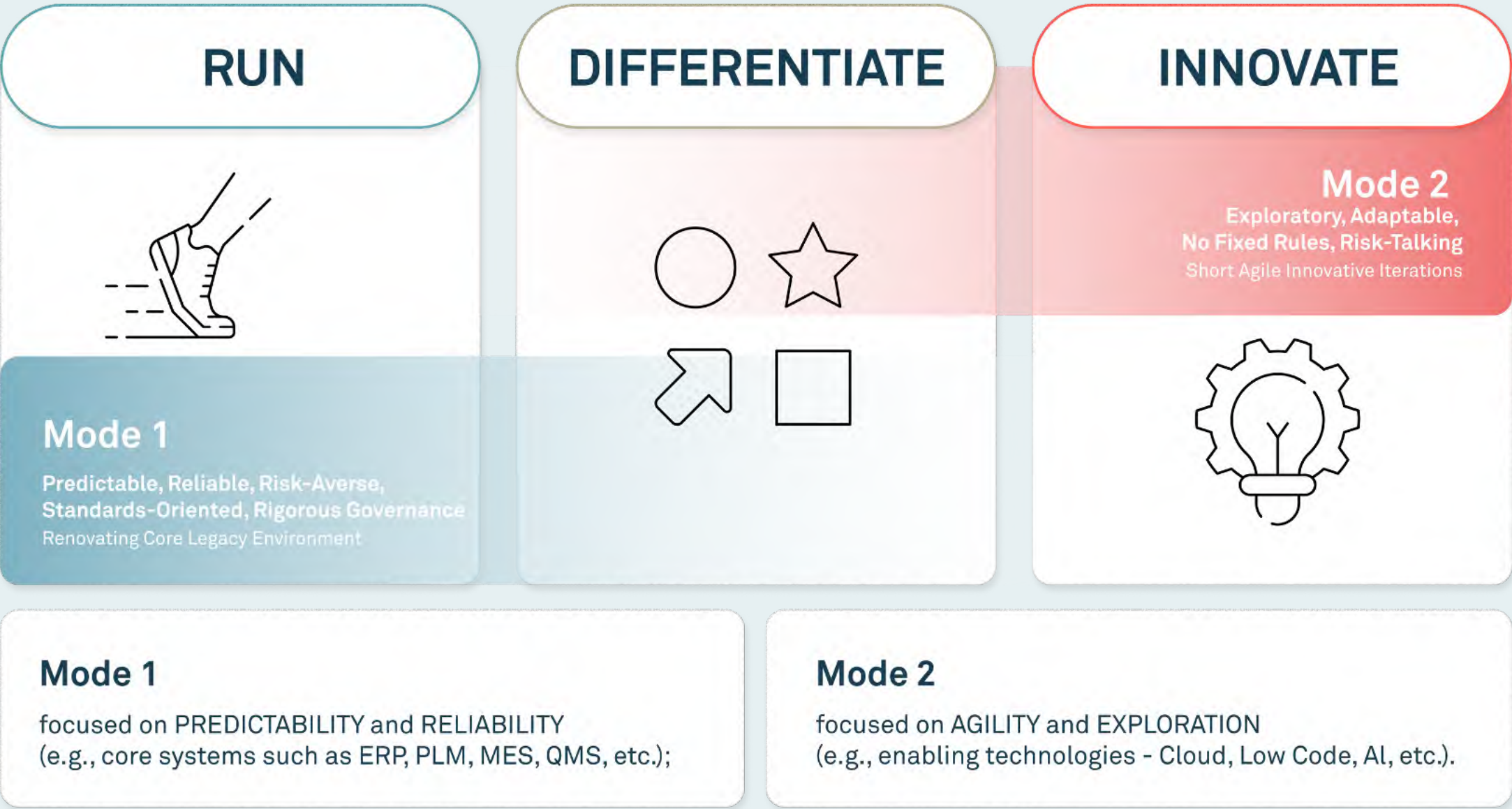
Finally, plan for growth from the start. Build flexible connections that can evolve with your business needs. When making integration decisions, consider not just today's requirements but tomorrow's possibilities. Choose standards-based approaches that will support future expansion while maintaining current operational efficiency.



CHAPTER 3: THE PATH TO SEAMLESS CONNECTION - MAKING INTEGRATION WORK



BUILDING YOUR DIGITAL FOUNDATION



Manufacturing excellence isn't built overnight. Like constructing a high-performance factory, digital transformation requires both a solid foundation and a clear vision. This transformation follows a bimodal approach that balances stability with innovation.

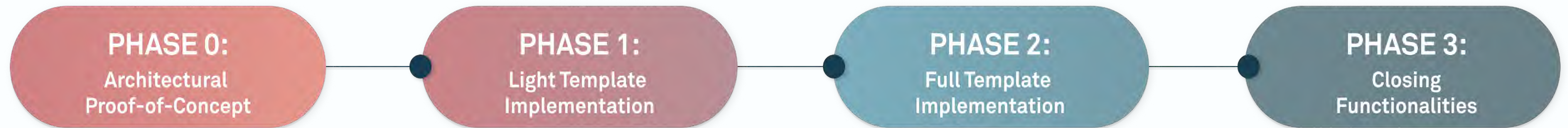
➔ **MODE 1**
Mode 1 focuses on strengthening your core operations. This foundational work involves establishing reliable system connections that can withstand the demands of daily manufacturing operations. It requires standardizing critical processes to ensure consistency across operations, while building consistent data models that enable seamless information flow throughout your organization.

➔ **MODE 2**
Mode 2 drives innovation forward. Once your foundation is solid, you can begin exploring new technologies that enhance your manufacturing capabilities. This involves testing innovative approaches in controlled environments and then scaling successful initiatives across your organization. The key is maintaining the balance between stable operations and continuous innovation.

THE FOUR-PHASE JOURNEY



The path to connected manufacturing unfolds in four distinct phases, each building upon the previous one's success.



PHASE 0

Phase 0 begins with proof of concept. Starting small but thinking big, you select a focused area where you can test key integration points without disrupting broader operations. This controlled environment allows you to validate business benefits and quickly learn from experience, adjusting your approach before wider implementation.

PHASE 1

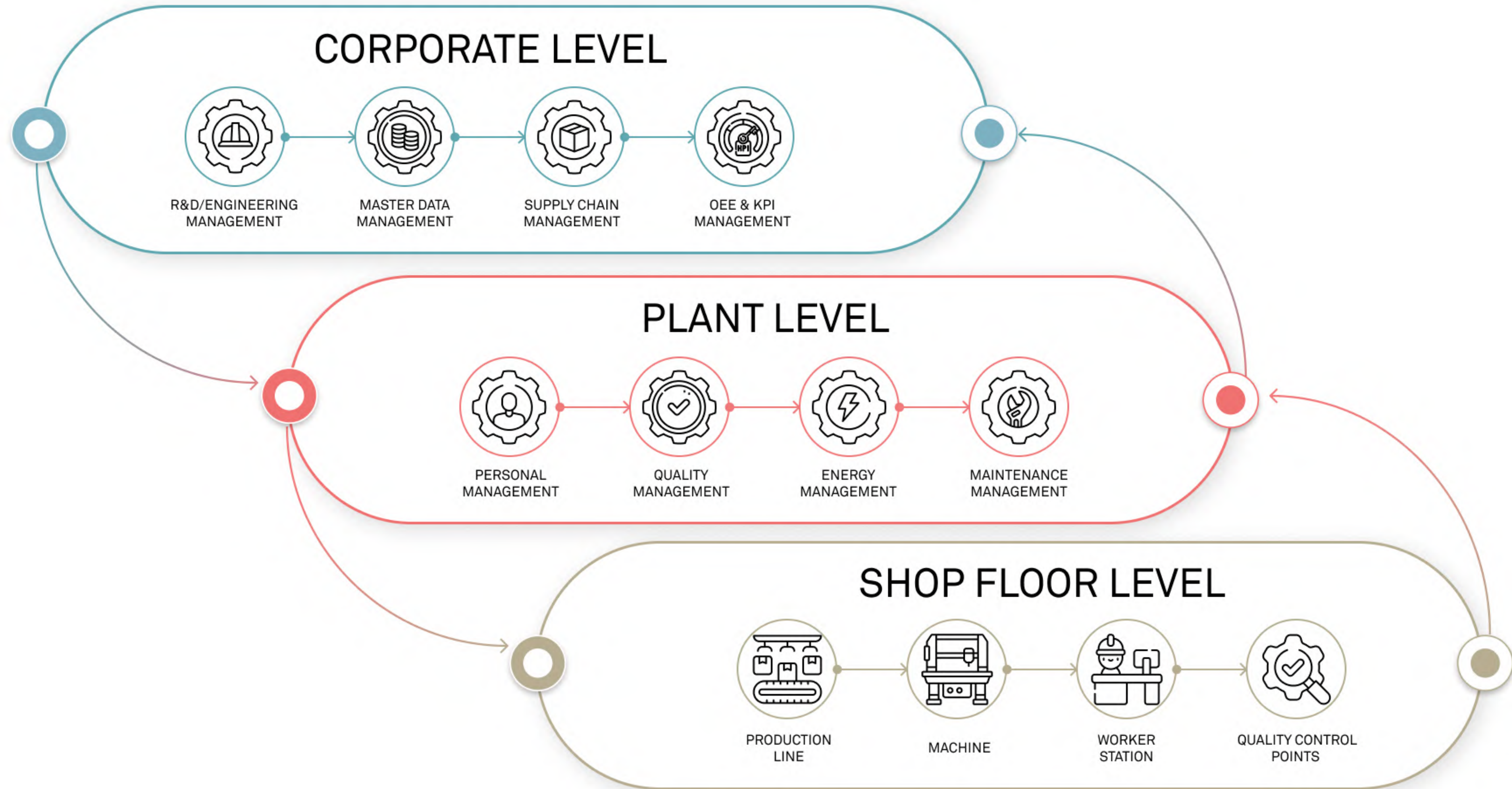
In Phase 1, initial implementation expands your early successes. Core functions are rolled out systematically, primary systems are connected with care, and essential data flows are established. This phase lays the groundwork for broader integration while delivering immediate value.

PHASE 2

Phase 2 brings full integration to life. Your connected factory vision takes shape as deployments extend across all planned areas. Advanced features are implemented thoughtfully, and processes are standardized across operations. This phase transforms isolated successes into a cohesive manufacturing ecosystem.

PHASE 3

Phase 3 focuses on continuous evolution. Regular system updates keep your infrastructure current, while ongoing process optimization ensures peak performance. New capabilities are added strategically, allowing your manufacturing operations to evolve with changing market demands.



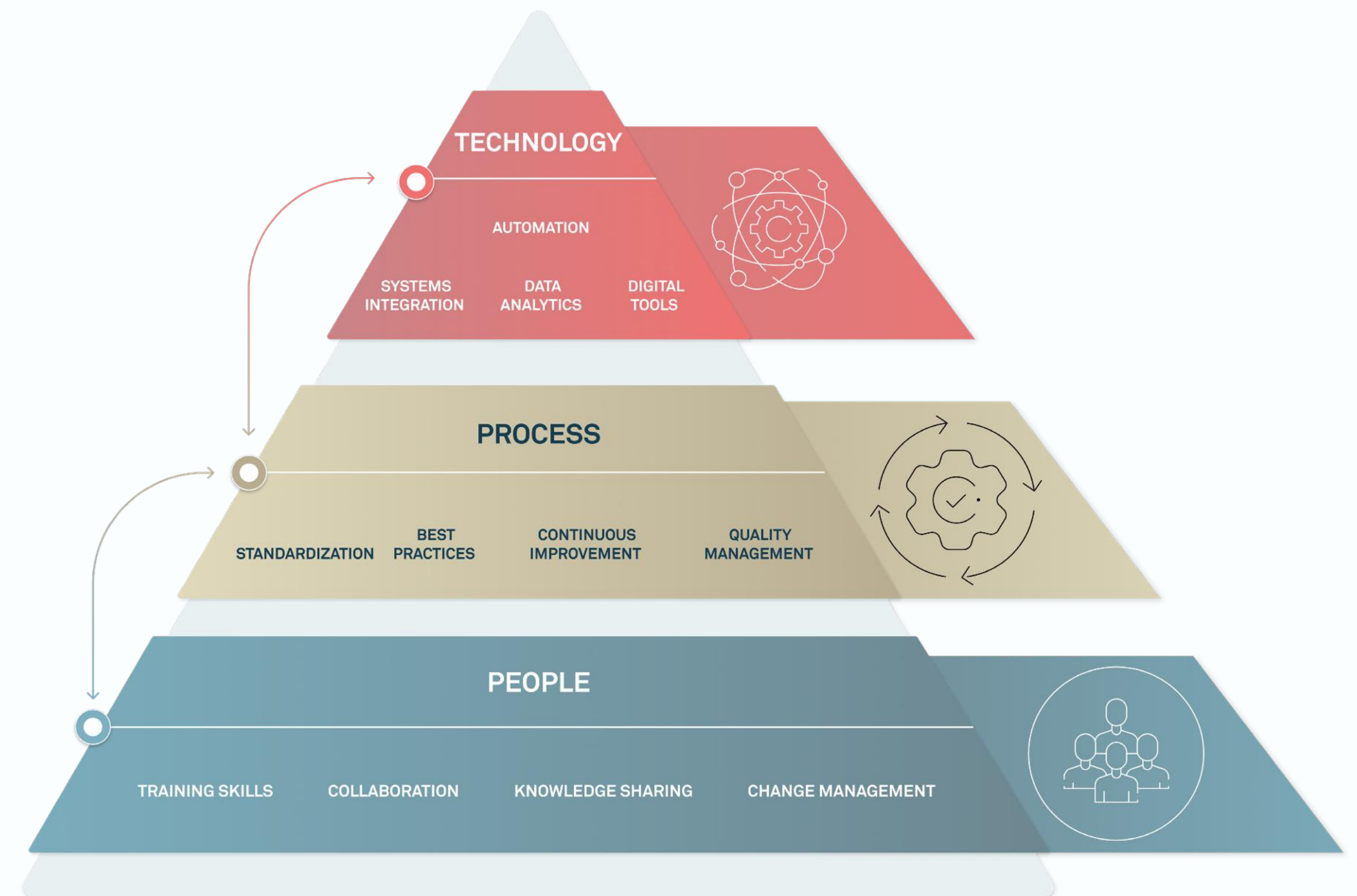
MAKING IT REAL

Success in manufacturing transformation depends on the harmonious integration of three key elements: people, process, and technology.

People form the foundation of any successful transformation. This means training teams effectively to use new systems and processes, building internal expertise that can support ongoing operations, and creating clear responsibilities that enable smooth execution. Your workforce must understand not just how to use new systems, but why these changes matter to your organization's success.

Processes provide the framework that guides operations. Well-documented workflows ensure consistency across operations, while established standards maintain quality throughout the manufacturing process. Clear success metrics enable objective evaluation of progress and guide continuous improvement efforts.

Technology enables and enhances these human efforts. System compatibility ensures smooth operations across your manufacturing environment, while scalability planning protects your investment as operations grow. Robust security measures protect your valuable manufacturing data and intellectual property.



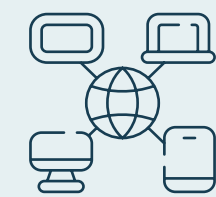


COMMON CHALLENGES AND SOLUTIONS

Every transformation journey encounters obstacles, but proper preparation can help overcome common challenges.



Data quality issues often emerge as organizations connect previously isolated systems. Address these by starting with thorough data cleanup efforts, implementing robust validation rules to maintain data integrity, and establishing clear standards for ongoing data management.



System integration challenges require careful handling. Use proven connectors to ensure reliable system communication, conduct thorough testing before deployment, and maintain contingency plans for handling exceptions.



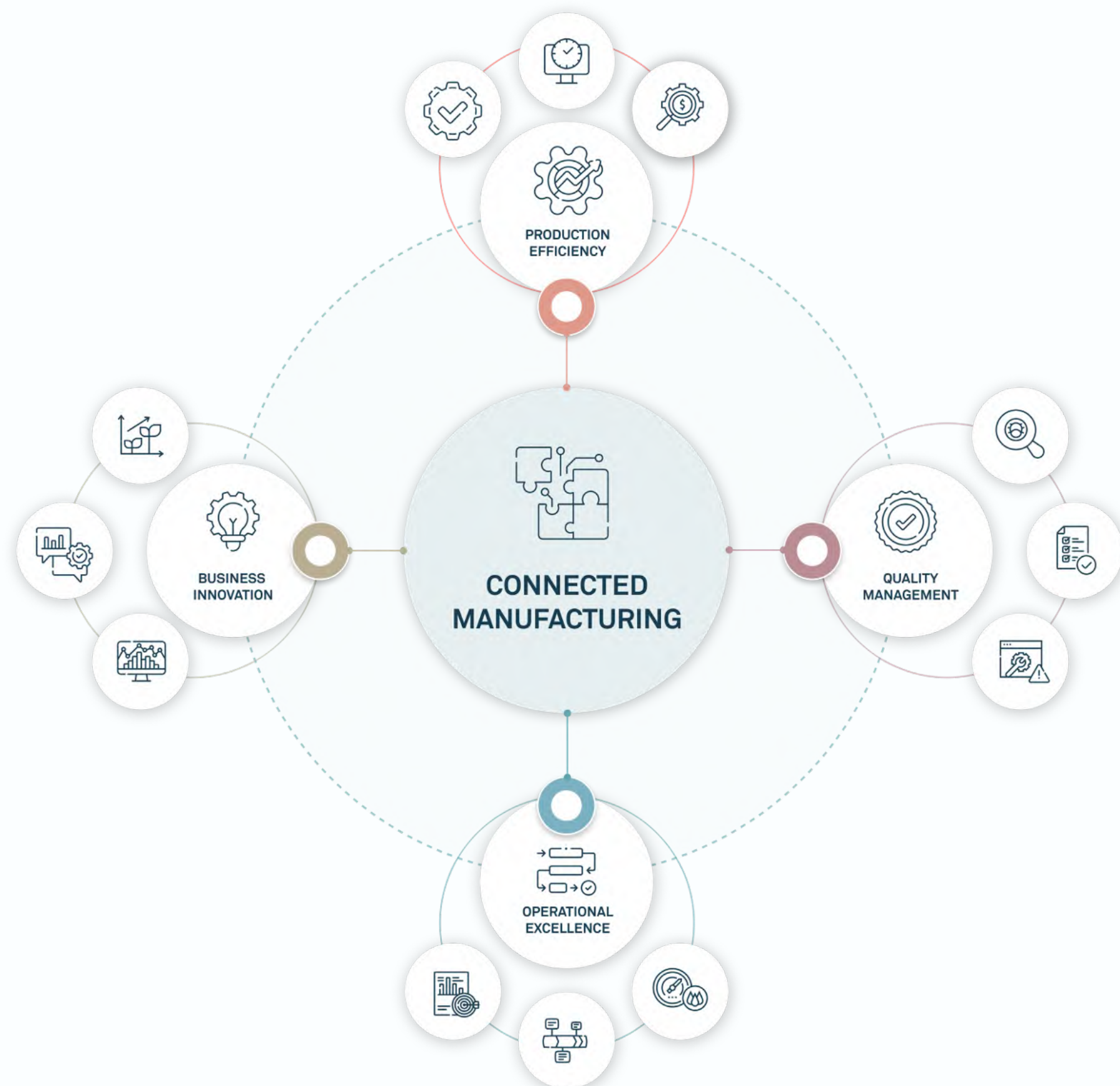
Change management remains crucial throughout the transformation. Clear communication helps teams understand and embrace new ways of working, while early wins demonstrate value and build momentum. Effective user support ensures teams can work confidently with new systems and processes.

MEASURING SUCCESS

Effective transformation requires clear metrics to track progress and demonstrate value. Monitor system uptimes and response times to ensure reliable operations. Track process efficiency improvements to quantify operational gains. Quality metrics and defect reductions demonstrate improved manufacturing precision. User adoption rates indicate how well new systems are being embraced, while business value metrics connect transformation efforts to bottom-line results.



CHAPTER 4: REAL-WORLD IMPACT AND RESULTS - TRANSFORMING MANUFACTURING REALITY



THE PRACTICAL IMPACT OF CONNECTED MANUFACTURING

When manufacturers evolve from isolated systems to truly connected operations, the transformation touches every aspect of production. This shift represents more than just a technological upgrade—it fundamentally changes how manufacturing organizations operate, make decisions, and deliver value.

1. PRODUCTION EFFICIENCY TRANSFORMED

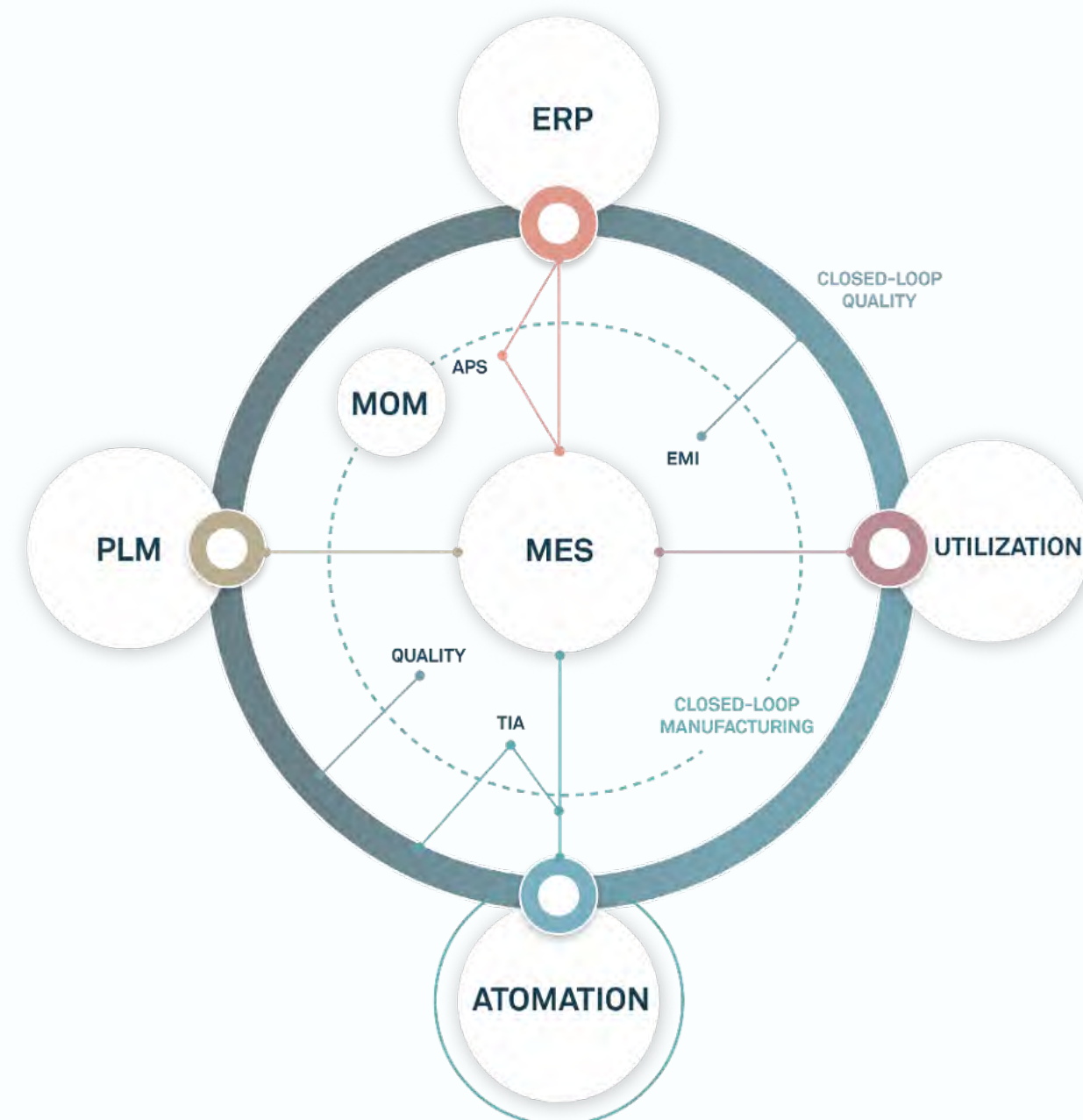
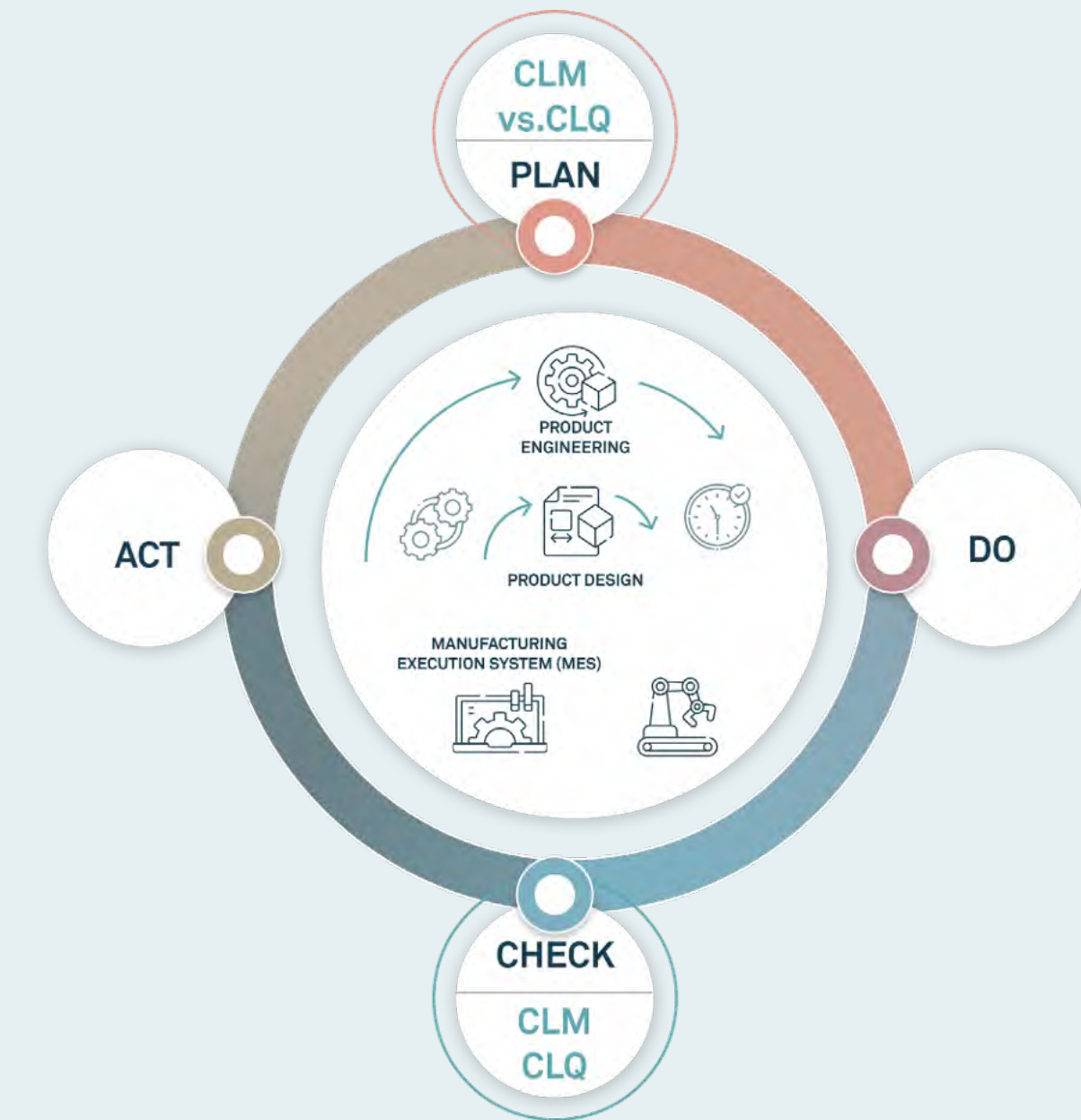
The conversion of manufacturing data into actionable insights creates new possibilities for operational excellence. Real-time monitoring and analysis enable manufacturers to identify and eliminate production bottlenecks as they occur, rather than discovering them through post-production analysis. Resource allocation becomes dynamic and responsive, with adjustments made based on actual demand patterns rather than historical estimates.

Predictive maintenance capabilities significantly reduce costly downtime by addressing potential issues before they cause disruptions. Throughout the production process, data-driven decision making replaces gut instinct with concrete insights, enabling more precise and effective operational choices.

2. QUALITY MANAGEMENT REDEFINED

Connected quality processes revolutionize how manufacturers ensure product excellence. Through early detection systems, potential quality issues are identified and addressed before they can impact finished products. This proactive approach is supported by consistent quality standards that span all production sites, ensuring uniform excellence across global operations.

Automated quality checks provide continuous verification without slowing production, while sophisticated feedback loops ensure that every quality insight contributes to ongoing improvement. This creates a self-reinforcing cycle of quality advancement that becomes more effective over time.



3. VALIDATED SUCCESS: THE SIEMENS AMBERG FACTORY

The Siemens Electronics Plant in Amberg demonstrates what's possible with closed-loop manufacturing. The facility has achieved a remarkable quality rate of 99.99885%, setting new standards for manufacturing excellence. This achievement is accompanied by significant reductions in energy consumption, demonstrating that quality improvement and sustainability can advance together.

The Amberg facility's success stems from its comprehensive integration of key technologies and processes. Real-time data monitoring provides continuous operational visibility, while advanced analytics transform this data into actionable insights. Automated quality management ensures consistent excellence, and optimized energy systems demonstrate the facility's commitment to sustainable operations.

4. MOVING FORWARD WITH CONFIDENCE



The path to manufacturing transformation follows a clear progression that organizations can navigate with confidence:

Begin with core integration by connecting fundamental systems that form the backbone of manufacturing operations. Establish robust data foundations that can support advanced capabilities, and build basic automated workflows that demonstrate immediate value.

Expand capabilities systematically by adding advanced analytics that provide deeper operational insights. Implement predictive features that enhance planning and maintenance, while strengthening automation capabilities across operations.

Finally, optimize and innovate by fine-tuning established processes to achieve peak performance. Explore new technologies that can further enhance operations, and scale successful solutions across the organization.



CHAPTER 5: INNOVATION THROUGH LOW CODE - CLOSING THE LOOP IN MODERN MANUFACTURING



THE LOW CODE ADVANTAGE

As manufacturing systems grow increasingly complex, the need for flexible integration becomes critical. Traditional development approaches often struggle to keep pace with rapidly changing manufacturing requirements. Low code development platforms have emerged as a key enabler for closed-loop manufacturing, fundamentally changing how manufacturers approach system integration and process innovation.

Low code platforms deliver this transformation through multiple capabilities. They enable rapid solution development, allowing teams to create and modify applications in a fraction of the traditional development time. Through intuitive interfaces, teams can create custom workflows that match their exact manufacturing processes, rather than adapting processes to fit rigid software constraints. Robust system integration capabilities ensure that both legacy and modern systems can communicate effectively, while user-friendly interfaces make complex manufacturing data accessible to all stakeholders.

BRIDGING SYSTEMS WITH LOW CODE

The Mendix platform plays a crucial role in connecting manufacturing ecosystems. In the realm of system integration, it excels at creating custom interfaces between existing systems, whether they're decades-old legacy applications or the latest cloud-based solutions. Modern front-ends can be rapidly built for legacy applications, breathing new life into valuable existing systems. Perhaps most importantly, Mendix enables seamless data flow between different platforms, creating the connected information environment that modern manufacturing demands.

Process innovation accelerates through low code development. Teams can quickly develop custom applications that address specific manufacturing challenges. Manual workflows that once consumed valuable time can be automated, freeing staff to focus on higher-value activities. Mobile solutions bring critical information directly to the shop floor, enabling real-time decision making where it matters most.



LOW CODE

VS



TRADITIONAL DEVELOPMENT

REAL-WORLD APPLICATIONS



Low code solutions are transforming manufacturing operations across multiple domains. On the shop floor, real-time production monitoring applications provide immediate visibility into operations. Quality inspection apps ensure consistent standards across all production lines, while maintenance management tools help prevent costly downtime.

Data visualization becomes more accessible and actionable through low code development. Custom dashboards present complex manufacturing data in easily

understood formats. Performance analytics provide insights that drive continuous improvement, while real-time reporting ensures that decision-makers always have current information.

Process automation reaches new levels of sophistication through low code platforms. Workflow applications streamline complex procedures, approval processes become more efficient, and document management systems ensure that critical information is always accessible to those who need it.





THE FUTURE IS FLEXIBLE

As manufacturing continues to evolve, low code platforms provide the adaptability needed to thrive in a changing environment. Organizations can quickly respond to new requirements without extensive development efforts. Solutions can be iteratively improved based on user feedback and changing needs, while scalable architectures ensure that successful applications can grow with the organization.

Innovation becomes more accessible through low code development. Rapid prototyping allows teams to quickly test new ideas, while easy testing environments reduce the risk of deployment. Quick deployment capabilities ensure that valuable innovations reach users faster, accelerating the pace of manufacturing improvement.

GETTING STARTED WITH LOW CODE

Success with low code development follows a clear path. Begin by identifying opportunities where low code solutions can deliver value. Look for manual processes that consume excessive time, integration gaps that slow operations, and reporting needs that current systems don't address.

Start small with carefully chosen pilot projects that can demonstrate quick wins. Build momentum through successful deployments that show clear value. As confidence grows, scale your success by expanding successful applications to new areas, training more developers in low code development, and building a library of reusable components that accelerate future development.



CHAPTER 6: START YOUR CONNECTED MANUFACTURING JOURNEY WITH CLEVR



POWER OF EXPERIENCE

The journey to connected manufacturing requires more than just technology—it demands a partner with deep expertise and proven success. As a Platinum Siemens Solution Partner with decades of experience, CLEVR brings comprehensive mastery across the entire manufacturing technology spectrum. Our expertise spans Siemens PLM solutions, Manufacturing Operations Management (MOM), Manufacturing Execution Systems (MES), and Mendix low code development platforms.

This unique combination of manufacturing process understanding and digital technology expertise enables us to deliver solutions that create tangible business value. We don't just implement systems—we help transform manufacturing operations.

WHY CLEVR?

Our strength lies in providing complete solution coverage for manufacturing organizations. Through end-to-end implementation capabilities, we ensure seamless integration across all aspects of your manufacturing operations. Our deep manufacturing industry knowledge means we understand not just the technology, but the real-world challenges you face daily. With proven integration expertise, we can connect disparate systems into a cohesive manufacturing ecosystem.

CLEVR's proven track record speaks for itself. Decades of experience implementing Siemens solutions has given us unparalleled insight into manufacturing excellence. Our successful implementations span the globe, demonstrating our ability to deliver results in diverse manufacturing environments. We build long-term client partnerships based on trust and consistent value delivery. Leading manufacturing companies like Kongsberg, Continental, Mondi, Sandvik, Kempower, Nexans, Bergen Engines are part of our client portfolio.

As innovation leaders, we continually push the boundaries of what's possible in manufacturing technology. Our pioneering work in low code development has helped manufacturers accelerate their digital transformation. Our manufacturing technology experts combine deep technical knowledge with practical industry experience to create forward-thinking implementations that drive real results.

YOUR PATH FORWARD

Working with CLEVR means embarking on a journey of continuous improvement and innovation. From day one, you'll benefit from expert guidance that helps navigate the complexities of manufacturing transformation. Our approach delivers tailored solutions that address your specific challenges and opportunities, not generic implementations.

We provide continuous support and optimization to ensure your systems evolve with your business needs. Most importantly, we help build future-ready manufacturing systems that can adapt to changing market demands and technological advances.

TAKE THE NEXT STEP

Transform your manufacturing operations with a partner who understands both where manufacturing has been and where it's going. CLEVR's comprehensive approach begins with a thorough assessment of your current state, helping identify opportunities for improvement and innovation. We can help you build your business case and together we'll define a digital roadmap that aligns with your business objectives and sets a clear path to success.

Let's Build Tomorrow Together Ready to start your journey to manufacturing excellence?

CONNECT WITH CLEVR TODAY:

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