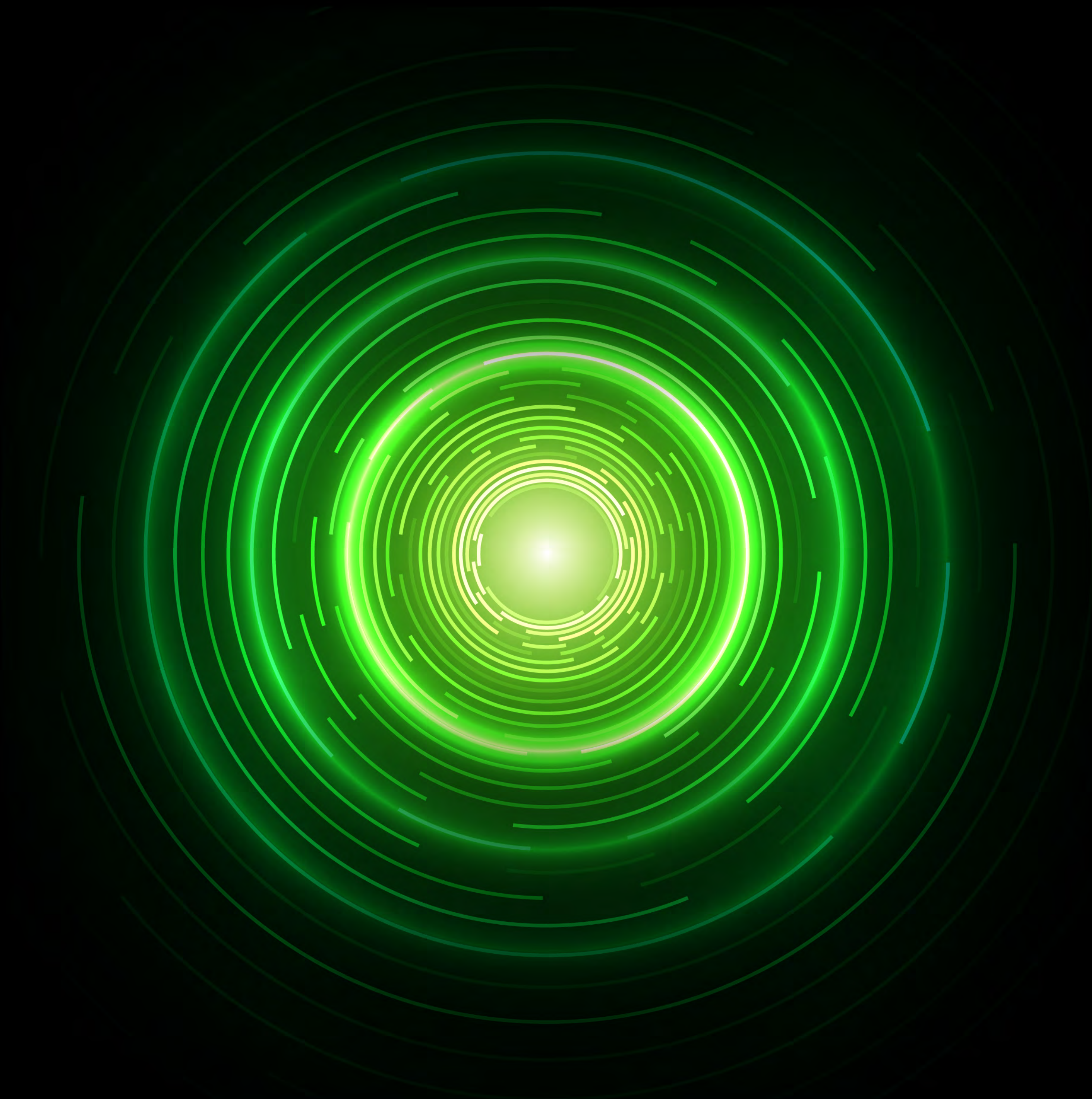
Deloitte.



Navigating the transition to a model-based enterprise

Today's manufacturers face intense pressure to dramatically reduce product cost and development time, all while their products are becoming exponentially more complex. Meanwhile, disruptors are introducing significant innovation in industries that have seen minimal innovation over the past several decades, making it extremely difficult for incumbents to compete.

How can manufacturers respond to this pressure and level the playing field with their competitors?

They can start by focusing on breaking down organizational silos and removing the large pockets of waste at the handoffs between their functions. In a model-based enterprise (MBE), organizations integrate their functions under a common set of digital models. Products are developed virtually and concurrently with requirements from all functions, collapsing organizational silos and dramatically improving collaboration, product cost, quality, and time to market.

Disruptors already know the benefits of MBE capabilities. They're unconstrained by legacy thinking, processes, and systems and have adopted a fully model-based approach. Meanwhile, incumbents are working to quickly transform their enterprises as well; our research indicates that more than 85% of enterprises across industries are undertaking initiatives in one or more of the following core MBE capabilities:

- Model-based systems engineering
- Model-based definition
- Model-based (virtual) verification/validation
- Model-based manufacturing
- Model-based service (sustainment, aftermarket, etc.)

The challenge for legacy manufacturers is the integration of these individual initiatives at scale to achieve the full value of being model based. To do so, functional stakeholders must align their objectives and initiatives and shift away from disjointed "random acts of digital" and toward a cohesive vision for a full MBE transformation.

While aligning the entire organization can be a daunting proposition for some, it is entirely achievable by leveraging experiences of others who have paved the way to transformation. By taking a methodical approach, organizations can define and execute a realistic road map and realize the full business value of MBE.

A vision for the model-based enterprise

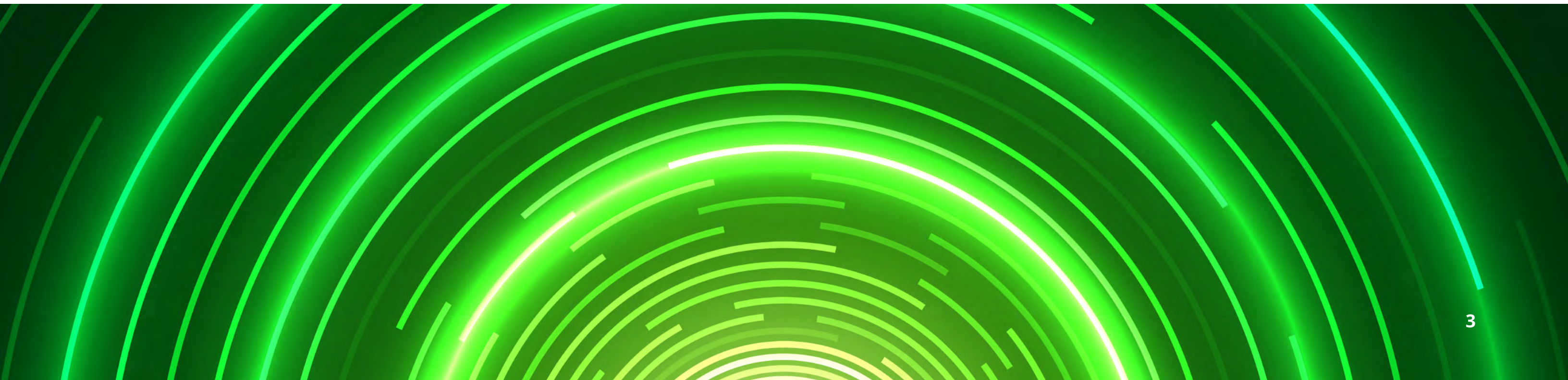
Today, leading organizations (and in some cases, specific teams within legacy organizations) have a clear vision for their future product delivery and maintenance. This vision calls for the enterprise to consume and rely on real-time data contained in live models, connected via integrated processes, and enabled by systems spanning the entire product life cycle.

This is the digital thread that enables MBE.

Consider some of the future MBE capabilities:

- Cross-functional teams are engaged at the beginning of the development phase to assist in program scoping and develop holistic sets of requirements and plans.
- Program and product development plans shift toward an iterative and cross-functional design process, formalizing feedback from all business functions and digital simulations before a design is finalized to achieve “first time right.”
- Digital verification (e.g., simulation) allows designs and processes to be tested digitally, enabling rapid iteration.
- Functions, teams, and individuals are measured against overall program success, aligning incentives.
- Organizational operating models are realigned around product platforms that focus on commonality and reuse across products and programs.
- Organizations collaborate seamlessly and focus on forming partnerships with strategic suppliers to leverage supplier best practices and their internally developed capabilities.
- The manufacturing organization is engaged early in the design process to ensure all product manufacturing information (PMI) is fully captured in the design models, eliminating manually generated, static artifacts and enabling automated quality checks at the end of line.
- From product inception, aftermarket input is weighted to the impact it has on the overall program life cycle costs and becomes a strategic differentiator to define ways to exceed customer expectations.
- Field performance information is provided in a real-time feedback loop enabling predictive maintenance, accelerated product improvement, and new feature development (e.g., identifying ways to provide “data as an asset” value to the customer and automated over-the-air delivery of customer-specific product upgrades-driven customer insight data).

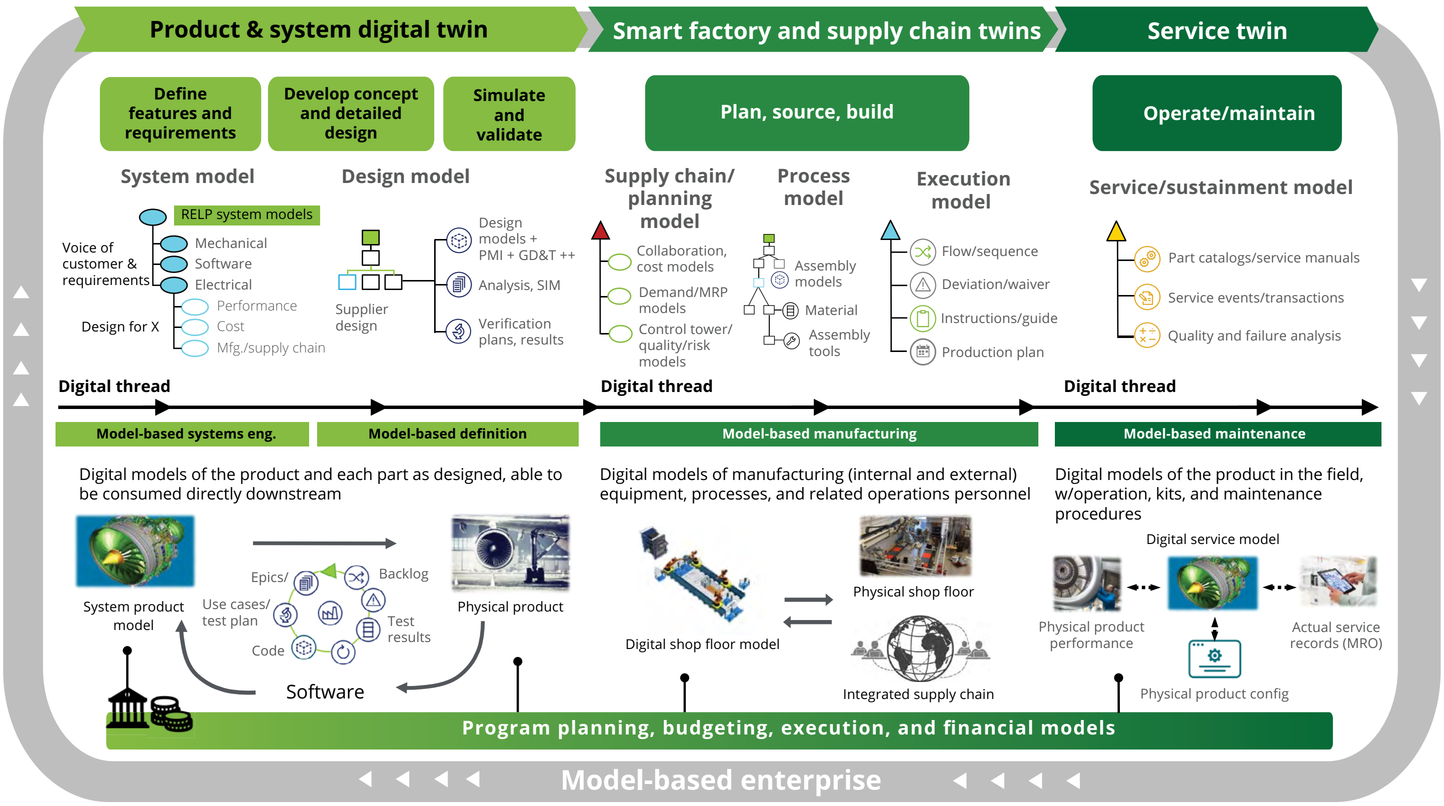
For a comprehensive list of future MBE capabilities and the traditional challenges that they solve, see page 12 in the appendix.



Realizing these capabilities requires models not only of the product as designed by engineering and produced by manufacturing but also models of customer intent, manufacturing process performance, and field performance. These various digital models are often referred to as "digital twins."

What do we mean by "model-based enterprise"?

And what types of models are included?



Together, these MBE outcomes have a significant impact on how products are created, manufactured, and serviced. When executed correctly, and data created by one step in the process is used directly by the next, teams focus less on traditional day-to-day tasks (e.g., data entry and validation) and more on future-facing innovations (e.g., data analysis and insights). This creates an environment of higher employee satisfaction, given that employees are working on innovation and value-added activities versus the rework and manual activities that they do today. This also creates an environment in which processes are executed using platform engineering, model-based systems engineering, and simulation-based analysis in an integrated fashion that further enhances the innovative design and reduces the unnecessary workarounds.

The vision for the future is clear—what's needed is a plan to get there.

An approach to bridging the gap between today and the fully model-based enterprise

Transforming a traditional organization into an MBE takes collaboration; no single function or discrete technology investment can deliver the digital thread and MBE objective. The path forward requires a plan to bridge the gap between today's outdated processes and technologies and the value of tomorrow's model-based capabilities.

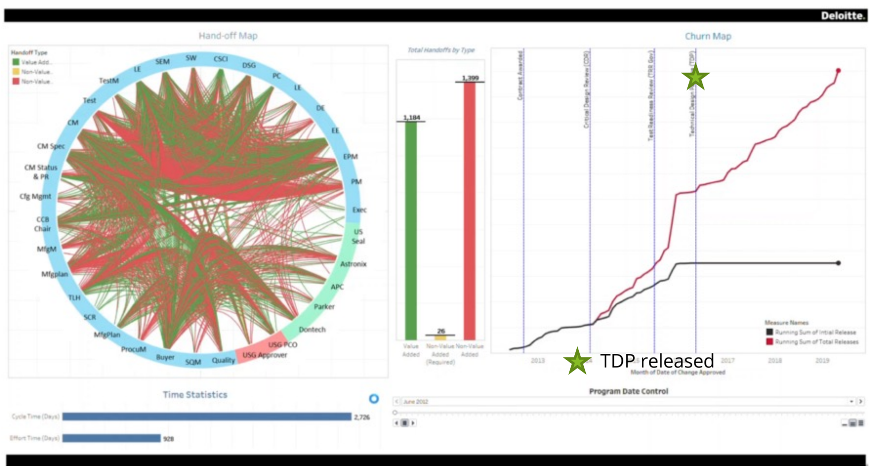
The approach we've successfully used with dozens of clients is multi-phased and supported by the key tenets listed on the following pages.

1. A relentless focus on value

Define what success looks like and the associated business case value to your organization. Take real examples from real programs (even those that were executed to "the best" of your current capabilities) to paint the picture of why change is needed. Use objective, value-oriented data to govern the scope and execution of your transformation.

Transition to MBE: Sample company handoffs, churn, and waste

Case example: 50%–57% of effort on a leading A&D program was non-value-added (NVA) work, each design is reworked 2.5–3.6 times

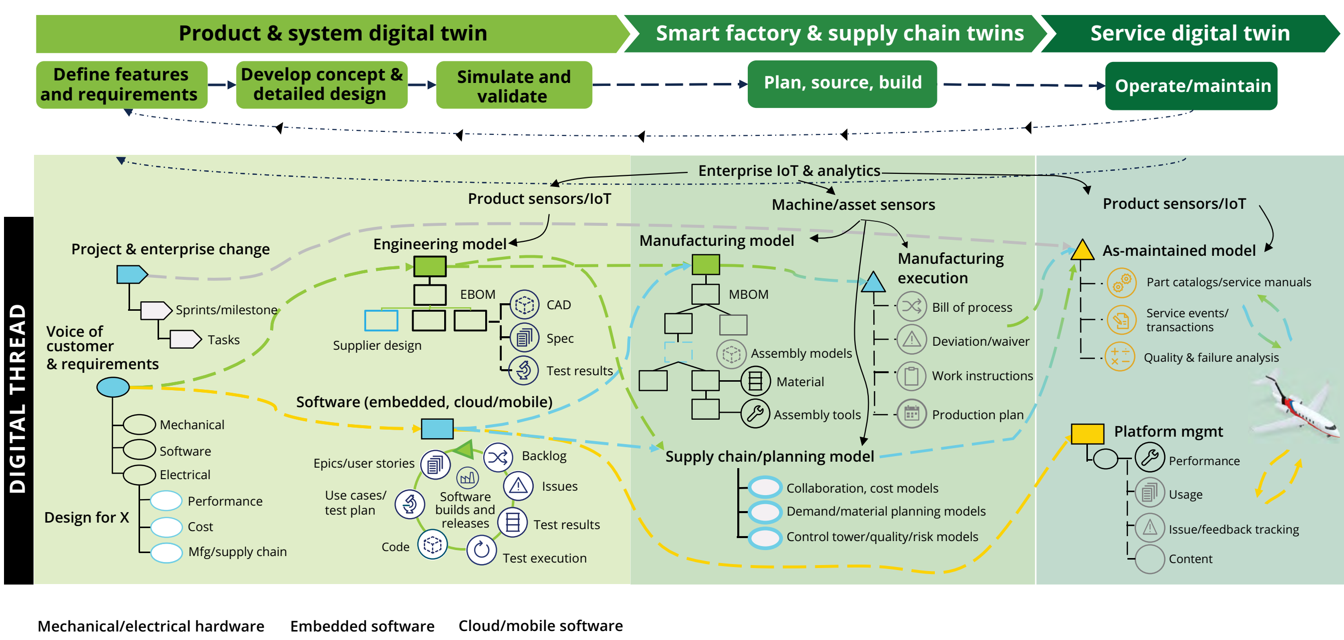


Statistics	As-is
Total effort	**935 days**
Value-added (VA)	422 days / **45%**
Non-value-added (NVA)	497 days / 53%
NVA required (NVAR)	16 days / 2%
Cycle time	**2,724 days**
Handoffs	**2,197**
# Initial releases	**1,851**
Post-initial release	**6,655**
Churn ratio	**3.6**

Root causes of inefficiency	NVA effort
Siloed processes and metrics • Qual conducted w/o TDP, on a shifting design, leading to major issues during FAT testing • Engineering claimed success prior to FAT • Manufacturing/SCM not involved early	230 days
Change mgmt process has **redundant activities** and often **limited to engineering/CM**	70 days
Manual data entry, management and auditing (e.g., EBoM/MBoM)	124 days
Disconnected requirements – Contract vs. technical vs. manufacturing/service requirements	74 days

SAMPLE OUTPUT

The digital thread drives the end-to-end product life cycle and includes all the process and system capabilities that enable digital twins



2. Defining and prioritizing business capabilities to achieve the vision

In our work across industries, we've defined 42 capabilities of MBE that span organizational functions. We work with each client to assess the maturity of these capabilities across their organization and align on which capabilities are most critical to accelerate and achieve their MBE vision and business case.

Key MBE capabilities by function

Breaking down MBE into underlying business capabilities and mapping to core functional areas

Design and development

Engineering

- Part and product info management
- Hardware (mech/elec) management
- Software management and integration
- Tooling (and externals) management
- Product platform management
- Enterprise change control
- Product compliance
- Digital development: Model-based systems engineering/requirements management and traceability (MBSE)
- Digital development: Model-based definition (MBD)
- Digital development: Model-based collaboration
- Digital development: Design simulation and optimization
- Digital development: Generative design
- Enabling capabilities: Product definition alignment
- Enabling capabilities: Product hierarchy and ontologies
- Enabling capabilities: Product/part rationalization and reuse

Production and supply chain planning

Manufacturing

- Product quality management
- Digital factory: Data collection and reporting
- Digital factory: Manufacturing process definition
- Digital factory: Production execution
- Digital factory: Tracking and traceability
- Digital factory: Production quality management
- Digital factory: Model-based consumption
- Digital factory: Model-based manufacturing
- Digital factory: Integration with systems of record and shop floor controls
- Digital factory: Production scheduling

Supply chain

- Smart operations: Operations command center
- Supply and demand analytics
- Intelligent supply: Supply analytics
- Intelligent supply: Supplier design collaboration
- Intelligent supply: Digital contract management

Program planning

- Product and portfolio performance management and metrics
- Program and project management
- Synchronized planning: Portfolio life cycle management
- Agile product development processes
- Product cost management

Sustainment and service

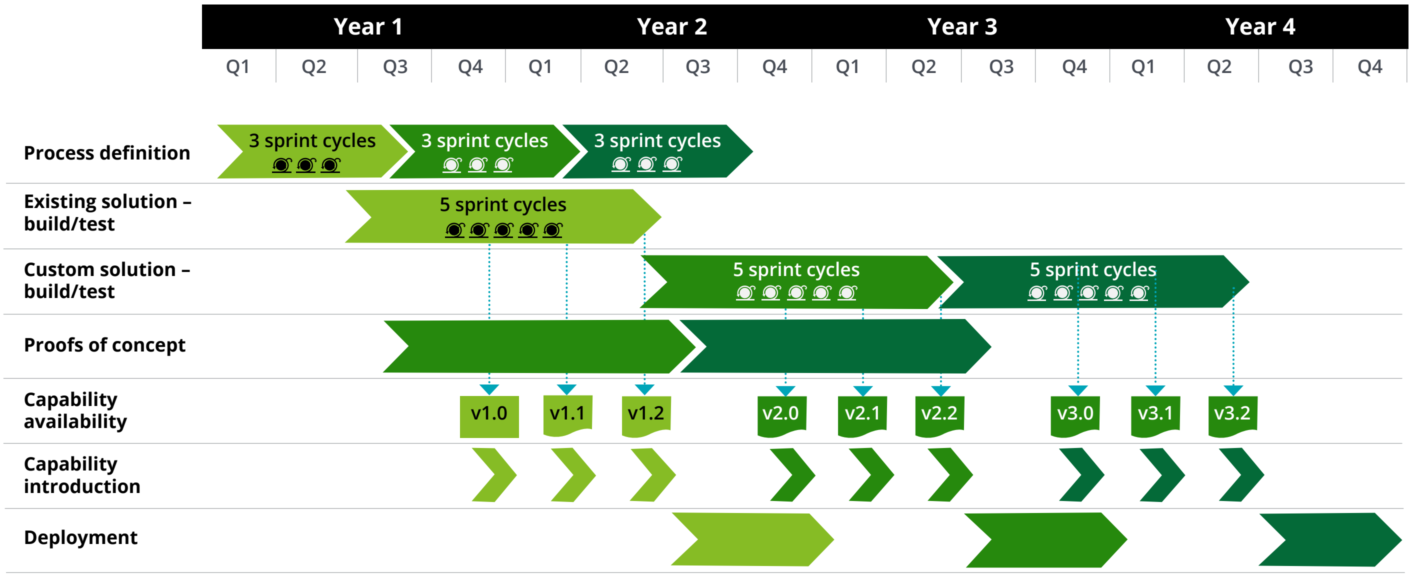
Aftermarket

- Connected customer: Customer issue management
- Connected customer: Connected field service
- Connected customer: OTA feature delivery
- Digital aftermarket: Sustainment engineering/as maintained configuration
- Digital aftermarket: Technical publications
- Digital aftermarket: Performance monitoring and optimization
- Digital aftermarket: Predictive MRO operations and logistics

3. Outlining a plan for development and deployment of capabilities

While defining plans for capability deployment, focus on grouping capabilities to create phased deployment plans to create incremental value and deliver the capabilities needed first. This sets the foundation upon which the most far-reaching and visionary MBE capabilities may be built and allows value to be realized incrementally, self-funding the next stages.

Sample road map for capability development



= Grouping 1

= Grouping 2

= Grouping 3

Guiding tenets

- **Focus on first customer:** Initial configuration/development will be done with a specific program/site in mind.
- **Continuous delivery:** Capability solutions will be deployed once the solution has achieved a high enough fidelity to drive value to the capability. There will be many deployments that build upon one another throughout a build cycle.
- **Capability availability:** Upon initial availability, capabilities will be introduced for the program/site that they were initially configured for. After intro, the capability package will become available to the rest of the organizational community for deployment.

4. Investing in differentiating capabilities and leveraging standards for the rest

There is no need to start with a blank sheet when defining future-state capabilities, processes, and solutions. Over the years, we've demonstrated that nearly 80% of what an organization needs are not unique to them, and we've developed a suite of predefined processes and preconfigured solutions that accelerate adoption of model-based capabilities. The results:

1. It jump-starts your implementation by providing industry-specific best practices and predefined key design decisions that need to be made. This transitions your transformation from asking individuals for their "requirements" (often anchored in their current practices) to instead asking: Why not adopt a standard? This can accelerate the process and help align departments, product lines, teams, and functions struggling to agree on a future state.

2. It prevents significant time lost to redesigning capabilities that are largely consistent between companies and that don't represent a competitive advantage for your organization. For example, an engineering change is just an engineering change, and your organization should be able to adopt a best-in-class leaned-out engineering change process versus using a custom process designed just for your organization. This helps to avoid those "stuck in legacy" ways of working from driving the solution back to legacy processes.

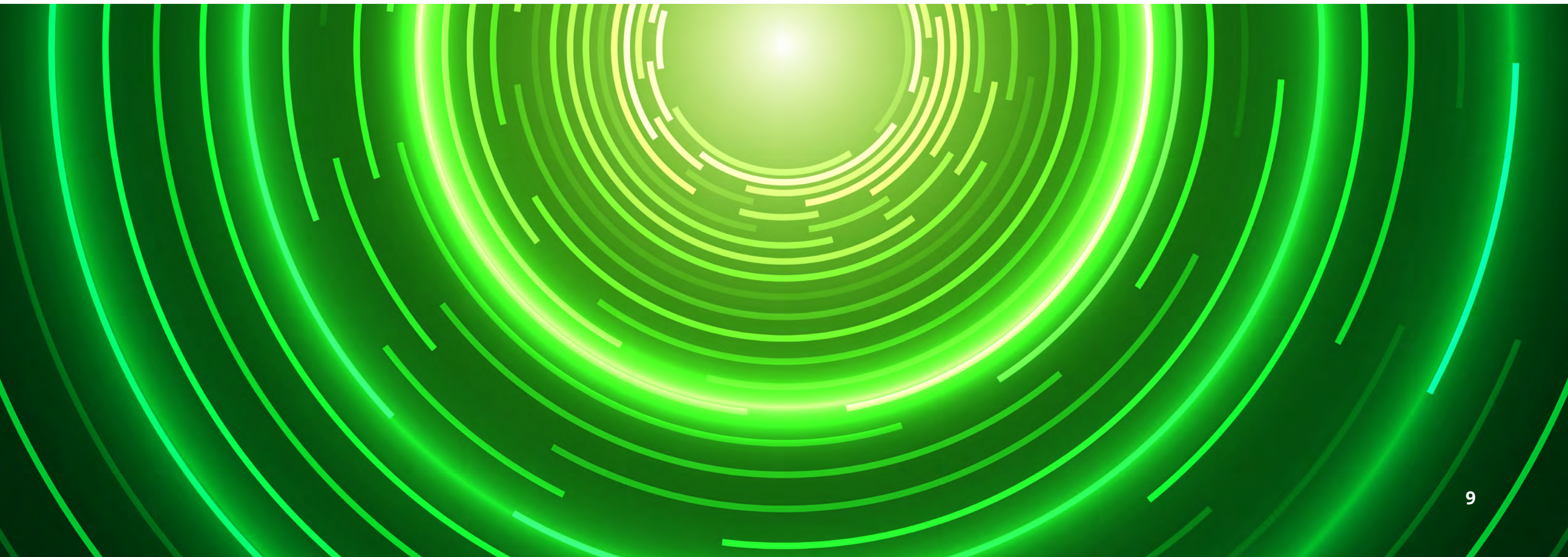
3. It allows time and focus to be spent on areas that are truly a competitive advantage for your organization (e.g., how you interact with your customers, define product platforms and strategies, manage the supply base across various tiers, etc.).

5. Transformation best practices and lessons learned still apply

The traditional principles of transformation initiatives remain important and are perhaps even more essential for achieving the intended outcomes.

Implementation lessons learned:

- Beware "random acts of digital."
- Transformation time, budget, and scope need to be objectively tied to (and governed by) realizing value.
- MBE is not an "engineering" function activity; it requires alignment across the functions (plus the customer and supply chain).
- Implementation should be business process based, not an IT implementation.
- "Start small but broad" by prioritizing the capabilities most valuable to your organization with a team of top talent representing the entire product life cycle.
- Include your design partners and supply base in your MBE journey.
- Beware of "boiling the ocean" (aka designing for all historical scenarios), which delays implementation and misses value. Instead, design for future programs and continued transformation. Understand the needs of legacy data, programs, and products, but be willing to leave them behind (or develop a transition plan to bring them along if/when the business case justifies it).



Moving toward a model-based future

Many industry incumbents are leveling the playing field with disruptors by adopting a model-based future. By virtue of experience with our clients, we know that enterprises don't need to start from scratch. The many challenges organizations face in bringing a product or service to market have solutions that are already in use by industry leaders. Bridging the gap from current challenges to future successes only depends on an enterprise's ability and willingness to take transformational steps. Taking near-term, value-based steps today can self-fund future steps toward becoming a fully MBE, where you can design more strategically, manufacture more efficiently, and serve customers more effectively.

Ready to get started?

Get in touch today to discuss your transformation to a model-based enterprise.

Brian Meeker
Principal, Product Engineering & Development
Deloitte Consulting LLP
bmeeker@deloitte.com

Vijay Santhanam
Managing Director, Product Engineering & Development
Deloitte Consulting LLP
visanthanam@deloitte.com

David Vanderpool
Senior Manager, Product Engineering & Development
Deloitte Consulting LLP
dvanderpool@deloitte.com

Traditional challenges | Future vision

Design & development

Traditional challenges

- Requirements are treated as an engineering capability and capture largely just product/technical requirements
- Connecting the product requirements to actual product definition is a highly manual activity that becomes a transactional/administrative effort
- Custom designs are proliferated across the design organization due to emphasis on design-to-specification for each new program
- 3D engineering models and associated 2D drawings are maintained in parallel, with the 2D drawing often still serving as the "source of truth"
- Mechanical hardware design is the primary focus, with software design being disconnected from the primary development cycle
- Program development plans follow a waterfall-based approach, whereby product verification and validation, which is conducted primarily on physical prototypes, sequentially follows design
- Disparate artifacts (work instructions, manufacturing representation of the products, etc.) are manually created for functions downstream of engineering and design
- Extensive time and effort is put into creating documentation and meeting design freeze dates for systemwide design reviews

Future vision

- Product requirements are viewed as critical to business success, and cross-functional teams are engaged at the beginning of the development phase to develop holistic sets of requirements
- Requirements are linked/embedded in the 3D model, enabling model-based system engineering (MBSE) activities
- Design reuse and modularity across programs become the focus as design organizations shift toward platform engineering
- Engineering design activities become entirely centered around a 3D model-based design (MBD), enriched with information required for all downstream-consuming functions
- Software development becomes a focal point of the overall product development life cycle and is tightly linked with all hardware design
- Program development plans shift toward an agile way of working, and verification and validation is conducted simultaneously with design activities via automated simulation and analysis tools
- As changes occur to the model, downstream views and associated background data are automatically updated
- Design reviews are conducted on a live version of the model via virtual and digital tools without the need for creation of additional documentation

Production & supply planning

Traditional challenges

- Supplier collaboration activities occur late in the development cycle, which limits their impact, as 75% of cost is already locked into the design
- Organizations have limited visibility beyond the first tier of their supply base, resulting in inefficient supplier management and difficulty reacting to unexpected constraints
- Suppliers are often treated as manufacturing subcontractors and are expected to just build the design as-is, which limits the impact of supplier know-how and lessons-learned best practices
- Engineering handoff to manufacturing occurs late in the design process, often as paper documents, leaving the manufacturing organization to manually create their own product and process artifacts
- Initial manufacturing of a product often results in identification of process bottlenecks and manufacturing design inefficiencies, leading to significant rework for both engineering and manufacturing teams
- Design processes are not updated to keep up with the introduction of digital and advanced manufacturing capabilities (e.g., additive manufacturing), which leads to either rework or missed value targets
- Design changes are primarily driven by engineering, with limited review of the impact on manufacturing and supply chain prior to implementation of a design change

Future vision

- OEMs and suppliers collaborate early in the design cycle via a single common model that is used as the source of truth across the supply chain
- AI-assisted supply chain control towers provide real-time supply base information, giving the enterprise deep visibility across the supply base and positioning it to support a more resilient supply chain while holding lower levels of inventory
- OEMs focus on forming partnerships with strategic suppliers to leverage supplier best practices and their internally developed manufacturing capabilities
- The manufacturing organization is engaged early in the design process to ensure all PMI is fully captured in the model, enabling manufacturing inputs to be derived directly from the 3D model (eliminating manually generated, static artifacts)
- During the development phase, digital build review activities are conducted by consuming the 3D model into virtual process simulations, enabling both product and factory floor layout optimization
- The manufacturing organization provides design parameters as requirements to be used to develop complex parts ready for advanced (e.g., additive) manufacturing directly from the 3D model
- The full life cycle impact of a design change, including thorough manufacturing and supply chain assessment, is reviewed prior to approving the change

Service & aftermarket

Traditional challenges

- Aftermarket is often an afterthought in terms of new product development, despite often being the largest revenue-generating and differentiating capability
- The aftermarket and engineering organizations operate independently, with limited communication early in the design phase
- The aftermarket function creates its own artifacts for how the design/product will be serviced, maintenance procedures, and service timelines
- Service/MRO/depots often do not have access to the latest product definition; substantial time is wasted when a product arrives for service identifying product configuration and service history, which, in turn, leads to suboptimal service planning and timing

Future vision

- The aftermarket becomes a critical revenue stream for organizations, as a "data as an asset" approach enables predictive maintenance and over-the-air delivery of customer-specific product upgrades
- The aftermarket organization collaborates directly with engineering early in the design process and shares real-time feedback on field operations
- Service technicians interact directly with the 3D model via AR and VR tools when performing sustainment operations, reducing the need for disparate service artifacts (e.g., service manuals)
- The service organization is provided real-time access to the 3D model; tight version effectivity and configuration management allow for service technicians to quickly identify the configuration of serialized products, increasing the speed of service and streamlining aftermarket planning

As used in this document, "Deloitte" means Deloitte Consulting LLP, a subsidiary of Deloitte LLP. Please see www.deloitte.com/us/about for a detailed description of the legal structure of Deloitte USA LLP, Deloitte LLP and their respective subsidiaries. Certain services may not be available to attest clients under the rules and regulations of public accounting. This publication contains general information only and Deloitte is not, by means of this publication, rendering accounting, business, financial, investment, legal, tax, or other professional advice or services. This publication is not a substitute for such professional advice or services, nor should it be used as a basis for any decision or action that may affect your business. Before making any decision or taking any action that may affect your business, you should consult a qualified professional advisor. Deloitte shall not be responsible for any loss sustained by any person who relies on this publication.

Copyright © 2022 Deloitte Development LLC. All rights reserved.