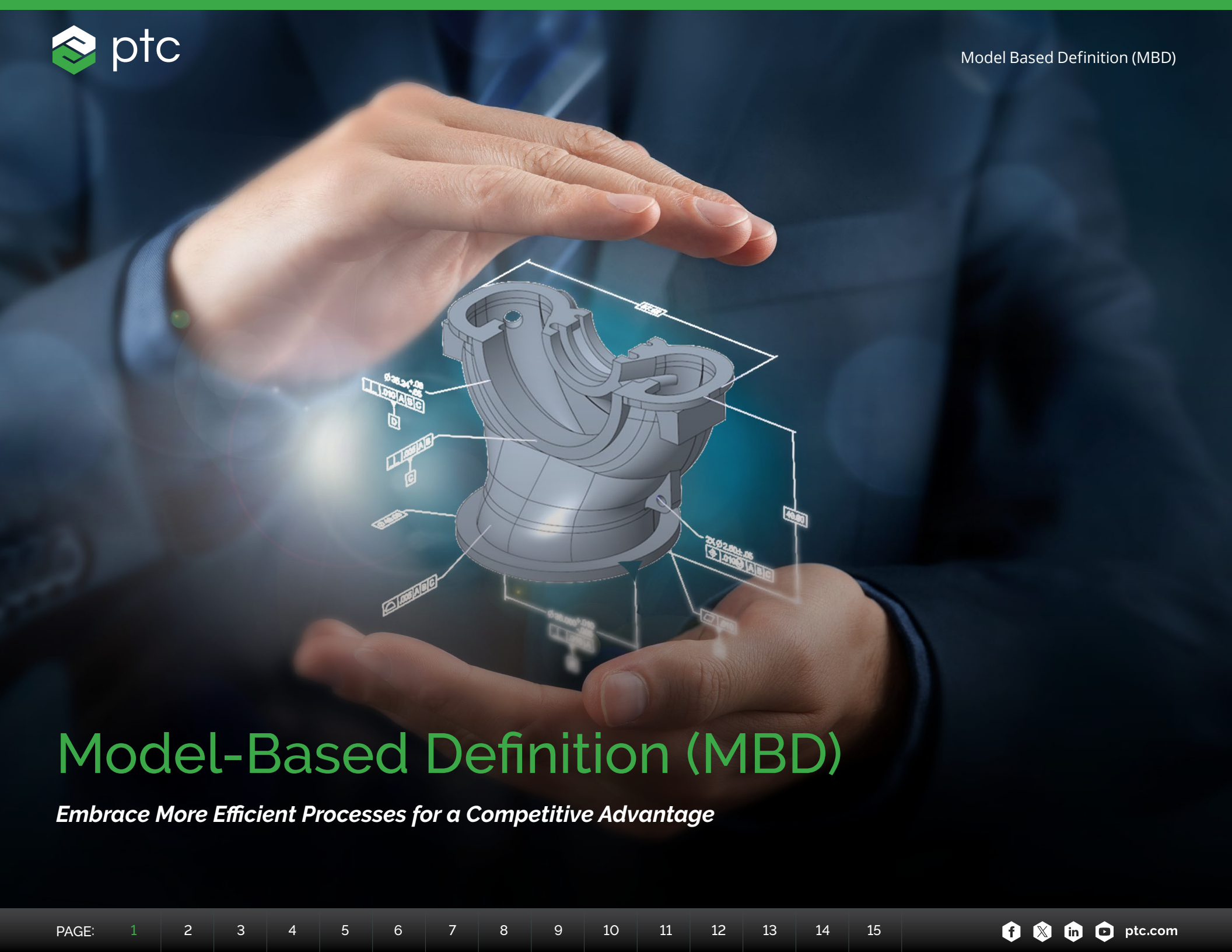

Model-Based Definition (MBD)

Embrace More Efficient Processes for a Competitive Advantage

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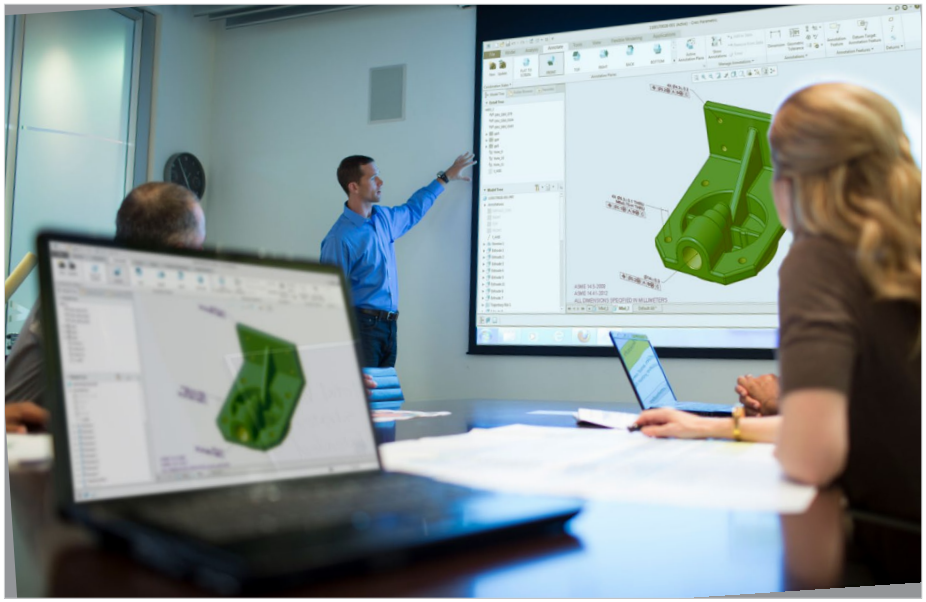


Level Up Your Processes with MBD

Your organization can realize significant benefits by harnessing the power of Model-Based Definition, or MBD, in its product development process. MBD uses 3D Computer Aided Design (CAD) models as the primary source of information for design, production, and quality.

MBD improves product quality, lowers cost, and reduces time-to-market by speeding up the engineering-manufacturing-inspection cycle and eliminating errors. That's why MBD has been a consistently growing trend in product development. In a letter to shareholders, Amazon founder Jeff Bezos shared his philosophy on powerful trends: "If you fight them, you're probably fighting the future. Embrace them and you have a tailwind."

There are many misconceptions about MBD. Some people think that it means going drawing-less. It's not; you can still generate drawings as part of MBD. In fact, MBD makes the drawing creation process easier. Some people think that you can't use MBD with external suppliers because "the drawing is the contract." MBD ensures that the product you get is what you ordered. Some people think MBD is too new to adopt or a fad. MBD is not new. It's been around since the 1990s. It's been validated by ANSI, ISO, and the US government. It is a proven process. Some people believe that you have to re-invent your organization to see the benefits of MBD. You don't. You can start a pilot using MBD techniques on a single development project, with near-immediate benefits in development time, cost, and quality.

If other product development organizations in your market reap the benefits of MBD, then they have a competitive advantage. Are you willing to risk being less efficient by not investigating how these tools can transform and modernize your approach?

This eBook will explain what MBD is, its benefits, how to get started with MBD, the Technical Data Package, and how your organization can evolve into a Model-Based Enterprise (MBE). You will also learn how Creo provides a complete solution with both native and advanced tools for MBD. Let's jump in!

What is MBD?

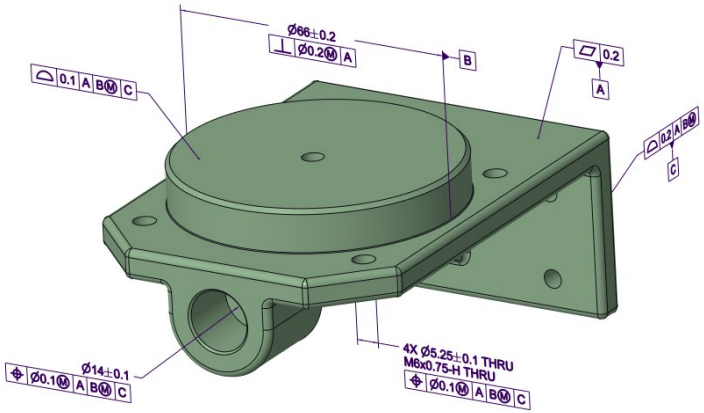
To help eliminate any confusion or uncertainty about what exactly MBD is, let's explain this concept. According to ASME Y14.47, Model Organization Practices, MBD is:

An annotated model and its associated data that define the product in a manner that can be used effectively without a drawing graphic sheet.

If a company primarily uses 2D drawings as the mechanism for capturing and sharing information, they are drawing-centric. If a company uses MBD as the main mechanism, they are model-centric.

Both drawings and MBD models capture what is called Product and Manufacturing Information (PMI). These are the details necessary to build and inspect physical parts and products to ensure that they meet requirements. PMI includes:

- Dimensions
- Geometric tolerances
- Datum Feature Symbols
- Datum Targets
- Notes
- Symbols
- Surface Finishes
- Tables



Accurate 3D geometry plus annotations are the foundation for MBD.

"MBD information is digital and accessible to both humans and machines, so it can easily be used by manufacturing, quality inspection and other downstream suppliers. This can help to automate the process, save time, reduce cost and eliminate human errors."

– Michael Fridman
Product Manager
PTC

Benefits: Speed Up the Design – Manufacturing – Inspection Cycle

Efficient Creation of Deliverables

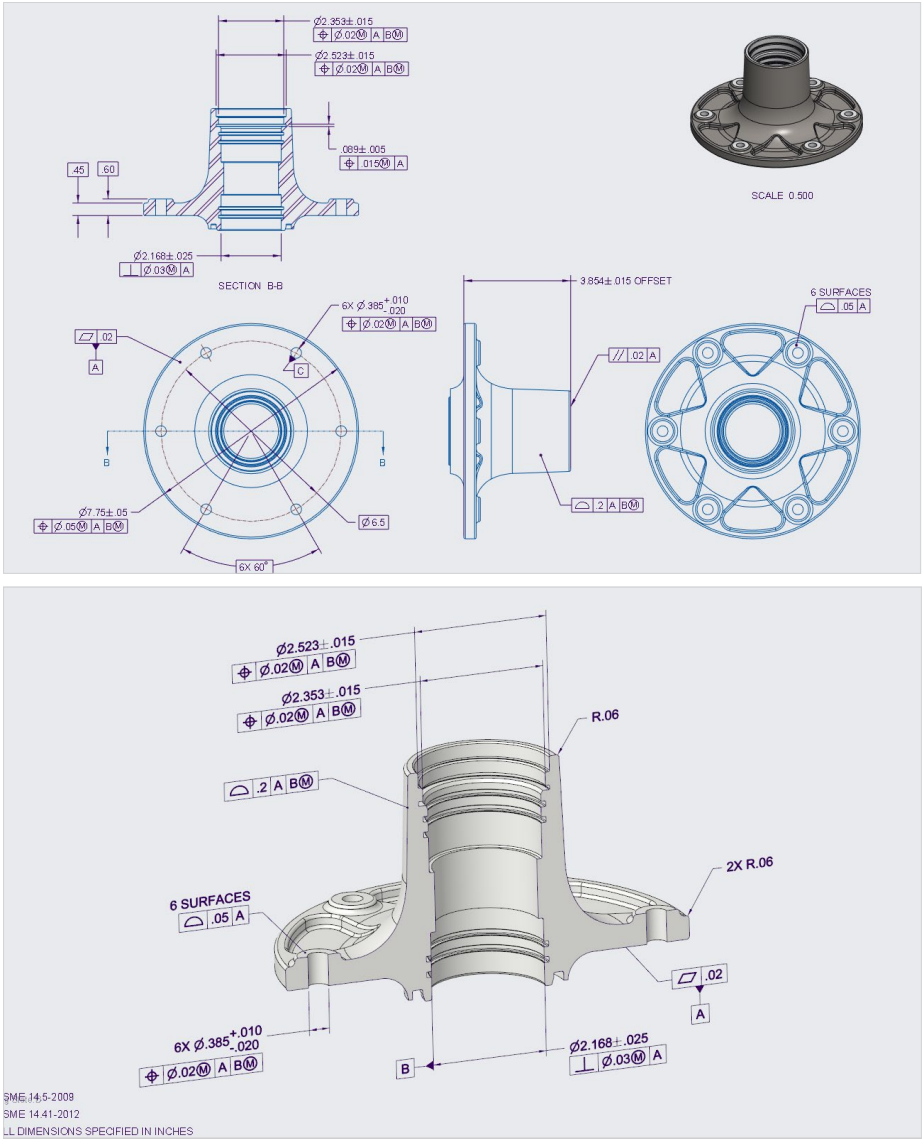
With MBD, organizations can choose not to create 2D drawings as deliverables. The process of creating 2D drawings can be time-consuming and tedious. After an engineer has created a 3D model, they have to create the new drawing object, place views on the sheet, and then detail the drawing with dimensions and other PMI (that often already exist in the model).

Traditional drawings must also be checked to ensure that they comply with the numerous requirements of ANSI and ISO standards. Furthermore, companies can incur a lot of overhead with 2D drawings, including maintaining drawing formats and managing additional datasets.

Since the model already contains the product's intended geometry, MBD teams can also choose to follow minimally dimensioned practices instead of fully dimensioned drawings. In traditional 2D workflows and standards, drawings must contain all the dimensions necessary to manufacture and inspect the product. With MBD, engineers and designers can save time and improve clarity by including only the critical dimensions and tolerances.

Semantic References

One of the keys to efficiency with MBD is something called semantic references. Many types of PMI are specific to defined areas of a part's geometry, like surfaces, edges, and holes.



Annotated 3D models eliminate the interpretation issues of 2D drawings.

Examples include:

- A dimension can specify the distance from one surface to another.
- A geometric tolerance like a surface profile can define the allowable deviation from the desired form.
- A surface finish symbol can specify the allowable roughness of the part.

The various 3D annotations used in MBD can contain the relevant geometry it pertains to. These are known as semantic references.

Semantic references can be queried by designers, reviewers, and manufacturing engineers so that when they pick 3D annotations, the relevant geometry highlights, and vice versa. Inspection engineers who need to validate certain quality aspects can highlight the corresponding model elements and understand what should be inspected visually.

The relevant geometry references can also be understood, read, and measured by manufacturing and inspection equipment, like CNC mills, lathes, and Coordinate Measuring Machines (CMM). Semantic references empower the efficient flow of information from the engineering team to downstream supply chain processes. This is how companies realize the value of MBD.

Risks of Not Implementing MBD

What if you aren't using MBD? What happens if you remain drawing-centric? Are there repercussions? To answer that question, consider performing a "Gemba Walk" to examine your own processes. (A Gemba Walk is a step-by-step review of existing processes and speaking with your employees to discover how your organization is actually operating, versus relying on assumptions about how it is operating.)

If you aren't using MBD, you are probably performing your manufacturing and supply chain operations using one of the following methods:

- If you are manufacturing your components internally, then your teams are probably relying on separate CAD models and drawings to configure your CNC toolpaths, mold bases, additive manufacturing, or other processes.
- If you utilize external manufacturing, then you might provide a PDF file of the drawing and STEP file of the model.
- In a worst-case scenario, you provide an external supplier with PDF files of your drawings only. They are most likely recreating your models from scratch to perform manufacturing and inspection. This is especially common with overseas manufacturing.

In all these situations, people are manually configuring manufacturing and inspection machines with information that could have been provided automatically with MBD. The 2D drawing/PDF can become outdated quickly. Changes to the 2D drawing – especially redlines – are not automatically updated in the 3D model, potentially resulting in poor quality and waste.

All these methods squander time and can introduce unnecessary errors into your process, which can waste materials, money, and even more time. Would you willingly continue following an error-prone process when a more reliable one exists?

Getting Started with MBD: Resources

Since MBD has been around for decades, there are plenty of resources available for organizations just getting started. Here are some industry standards to ensure compliance with best practices.

Often, companies do not want to send their original CAD models with MBD to external suppliers. To protect their intellectual property, they can export the native CAD files to a CAD-neutral format that supports MBD, like STEP AP242.

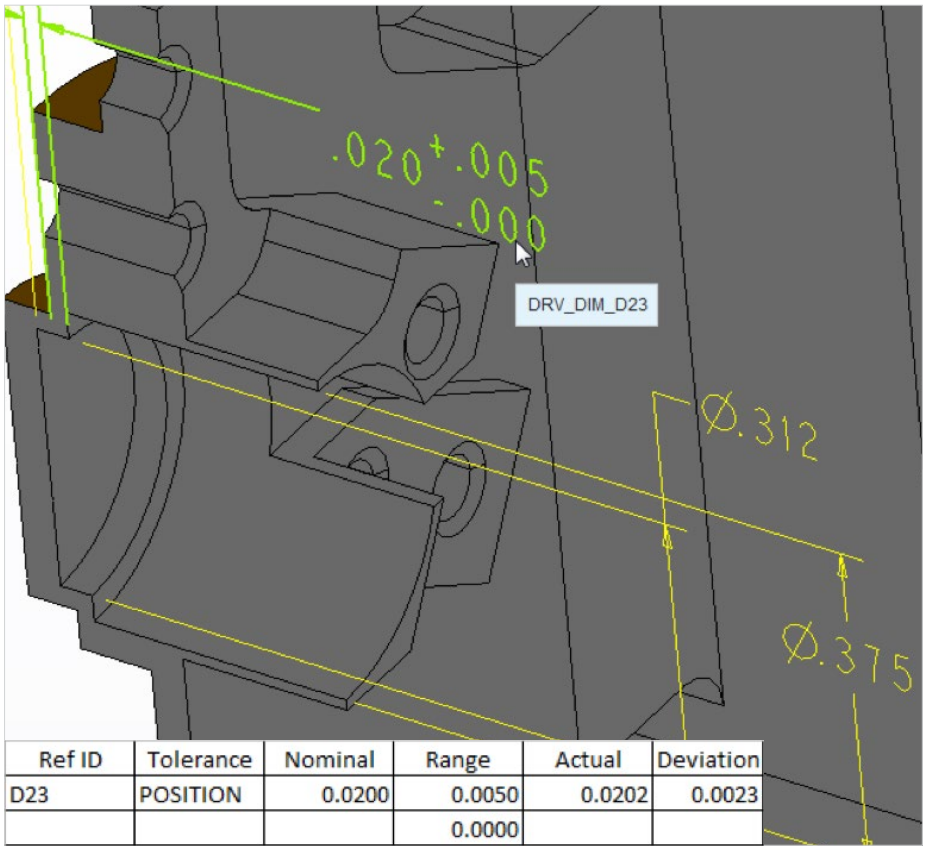
ASME Y14.41: *Digital Product Definition Data Practices*, establishes requirements for preparing and revising datasets for MBD. This can be considered the "American" version.

ISO 16792: *Technical Product Documentation*. Released by the International Organization for Standardization, this can be considered the international version.

MIL-STD-31000: The U.S. government recognized the benefits of MBD early, allowing the use of 3D models in Technical Data Packages starting in 2009. The CAD images in Appendix B were created in Creo. This military standard is readily available for free from several websites.

NIST: Through its MBE PMI Validation and Conformance Testing Project, the National Institute of Standards and Technology provides free CAD models and STEP files for multiple test cases of MBD implementation.

PTC provides additional resources for companies wanting to get started with MBD here.



Ref ID	Tolerance	Nominal	Range	Actual	Deviation
D23	POSITION	0.0200	0.0050	0.0202	0.0023
			0.0000		

MBE Dimension Model with a Dimension Verification Sheet Result.

The Technical Data Package (TDP)

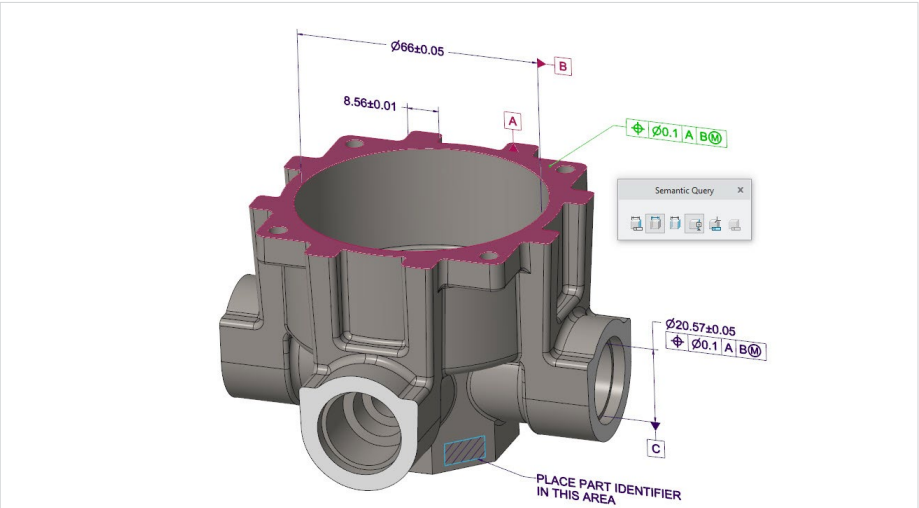
A Technical Data Package (TDP) is a collection of files that defines a product. It also supports manufacturing, supply chain, quality, and logistics support activities. One of the core elements of a TDP is a 3D model or models with the Product and Manufacturing Information (PMI) necessary to support fabrication and inspection.

The concept of a TDP predates MBD. The U.S. government has had a military specification for TDPs since 1971. However, in 2013 the U.S. Department of Defense made MBD a requirement for Technical Data Packages.

In addition to the annotated 3D model, a TDP can also contain the following electronic files in addition to the annotated 3D model:

- PDFs of 2D drawings (MBD does not have to mean "drawing-less")
- Bill of Materials (BOM)
- Requirements and specifications
- Schematics for electronics and cables
- Software documentation
- First Article Inspection (FAI) sheets and other quality documentation

The TDP can contain any other files that benefit your organization, such as those related to manufacturing process planning; maintenance, repair, and overhaul (MRO); and integrated logistics support (ILS). The TDP becomes a consolidated, easily communicated single source of truth for your engineering definition.



Semantic PMI embedded in 3D MBD model.

"Product MBD/Quality lives and dies by the PMI (Product Manufacturing Information) embedded in the 3D MBD model. Our MBE vision is to attain trusted product models, managed for confident reuse throughout our enterprise."

– Curtis Brown, Principal Mechanical Engineer, Honeywell FM&T

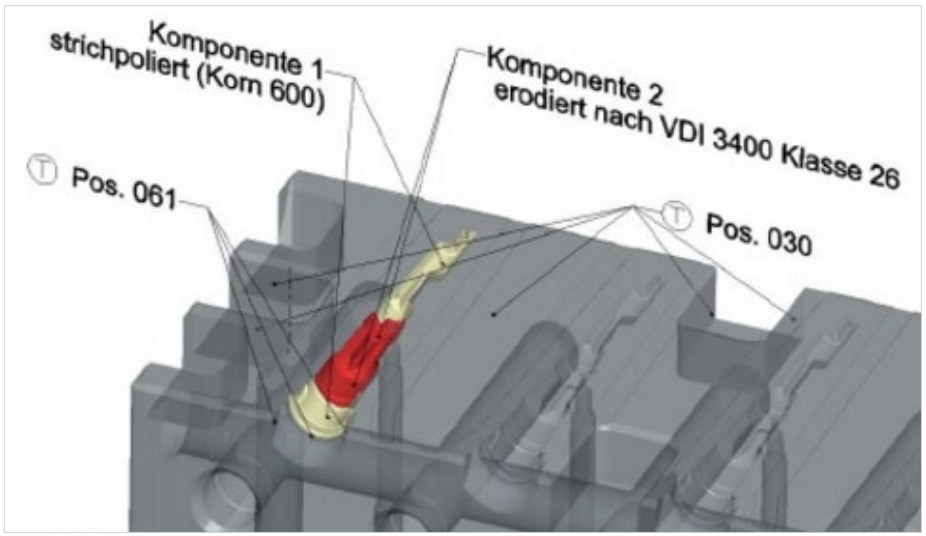
Growing from MBD to the Model-Based Enterprise (MBE)

If you've heard about MBD, you've probably heard another term as well: MBE, Model-Based Enterprise. ASME Y14.47 defines MBE as an organization that uses model-based definitions for the purpose of commission, operation, service, and decommission of a product.

This enables companies to achieve:

- Process efficiency
- Lower costs
- Faster time-to-market

MBE enables companies to achieve the digital thread for their products – the known configuration of the engineering datasets, its derivatives, production instructions, and service information throughout the product's lifecycle and across the entire organization.



Split lines in a complex plastic part.

The Department of Defense (DOD) Engineering Drawing Modeling Working Group developed a capability matrix that product development organizations can use to assess their MBE journey:

- Level 0: You are drawing-centric
- Level 1: You switch to model-centric, using a neutral file for manufacturing
- Level 2: You use native CAD models in manufacturing
- Level 3: You are now an MBD organization, using the annotated model and a lightweight viewable as your deliverable
- Level 4: Manufacturing is fully integrated into the process
- Level 5: You are considered an MBE as the internal enterprise becomes integrated
- Level 6: Your manufacturing, internal enterprise, and external enterprise (supply chain and customers) are integrated. Your deliverables are a TDP accessed via the web

There's a lot involved going from a drawing-centric organization to an MBD organization and then to an MBE. It helps to understand that MBE is a journey, not a destination. But like all great journeys, the rewards are well worth it. Achieving MBE optimizes and streamlines your core processes, enabling you to maximize efficiency and profits.

> "I'm a big fan of MBD. MBD is not a hype anymore, its boiling over and yes there are hurdles not roadblocks that we can overcome. We have successfully carried out tests and trials and have been able to document the positive business outcomes and benefits."

– Stephan Prosser, PLM Professional, P & G

Benefits of Creo for Your MBD Solution

While most major CAD packages support MBD in some form or another, many other platforms require additional licensing and cost to create 3D annotations for MBD or import and export to the standard STEP AP242 format.

Creo has supported MBD with every basic license for years, including:

- Automatic conversion of model dimensions to 3D annotations
- Creation of additional manual, reference, and ordinate dimensions
- Display of linear and angular tolerances that are built into all model dimensions
- Creation of additional PMI like geometric tolerances, datum feature symbols, datum targets, notes, symbols, and surface finishes
- Ability to show 3D model annotations as details in a 2D drawing
- Import and export of STEP AP242 (as well as older MBD formats like AP203 and AP214)
- Semantic query tools that highlight the geometry references for a 3D annotation, and vice versa

> "MBD is how design intent is developed, reviewed and analyzed and MBE is how the information is consumed. The key driver for going down the MBD path is Cost of Quality. Our pilot project has been a success and is promising."

– Chris McKee, Specialist Senior Engineering Support, Honeywell Aerospace

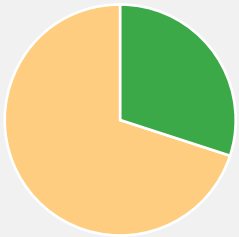
When considering a platform for your MBD implementation, ask your vendor what additional licenses are required in order to create, import, or export an MBD model.

GD&T Advisor and GD&T Advisor Advanced Extensions

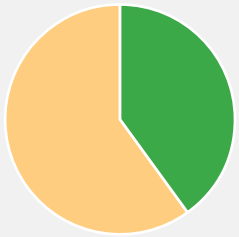
Many designers and engineers can struggle with applying Geometric Dimensioning and Tolerancing (GD&T) to their models. That's why PTC partnered with Sigmetrix to provide the Creo GD&T Advisor. This tool provides expert guidance to ensure that you apply GD&T correctly and in accordance with the ASME Y14.5 or ISO 1101 and their associated standards. The GD&T Advisor can reduce the time and mouse clicks required to apply GD&T by up to 75 percent.

Benefits

50%
Reduction in prototypes built

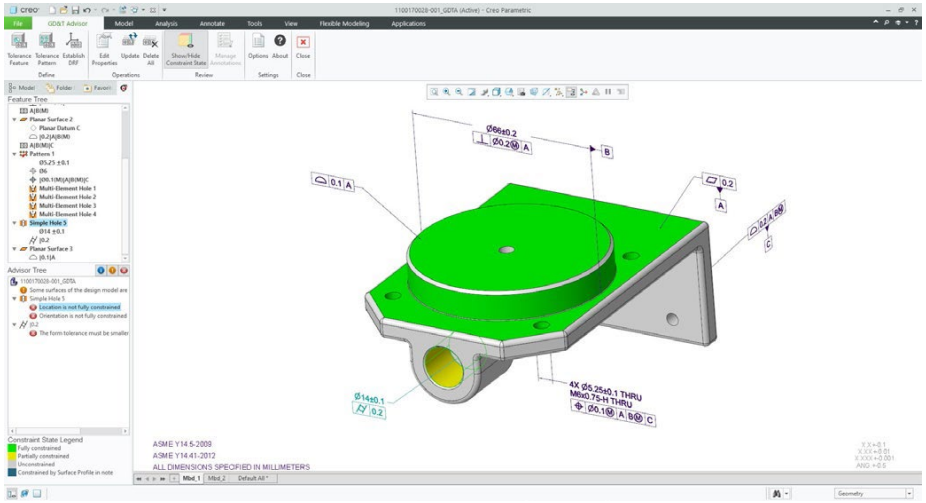


30%
Reduce non-conformances by using 3D models



40%
Reduce non-conformances due to in-accuracies in drawings

Source: Aberdeen

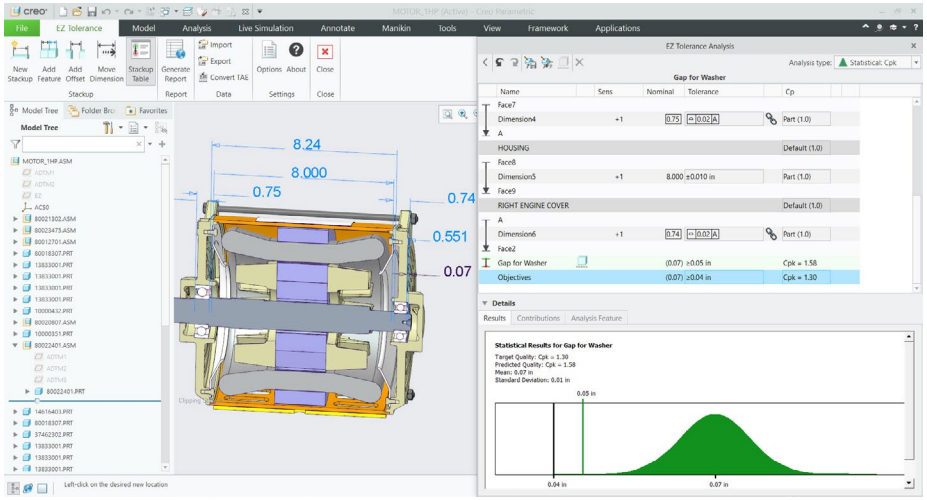


Informative advisor messages guide and educate the user.

The GD&T Advisor helps users create functionally and syntactically correct GD&T. It also provides visual indications of syntactic errors and under-constrained geometry. The intuitive help messages guide users in addressing errors related to dimensions, geometric tolerances, values, datums, datum reference frames, and more. It also manages your semantic references for you, which is a great help especially for patterns or stacked annotations, where you would otherwise need to collect many surfaces tediously. The annotations are reusable in production drawings, tolerance analysis, and more.

EZ Tolerance Analysis

EZ Tolerance Analysis seamlessly integrates with Creo to simplify tolerance assessment, saving time and enhancing workflow efficiency. By embedding tolerance information directly within 3D CAD models, it supports a model-centric approach to product development, eliminating the need for traditional 2D drawings. This enables stakeholders to access up-to-date tolerance data, facilitating early detection of issues and reducing the risk of rework.



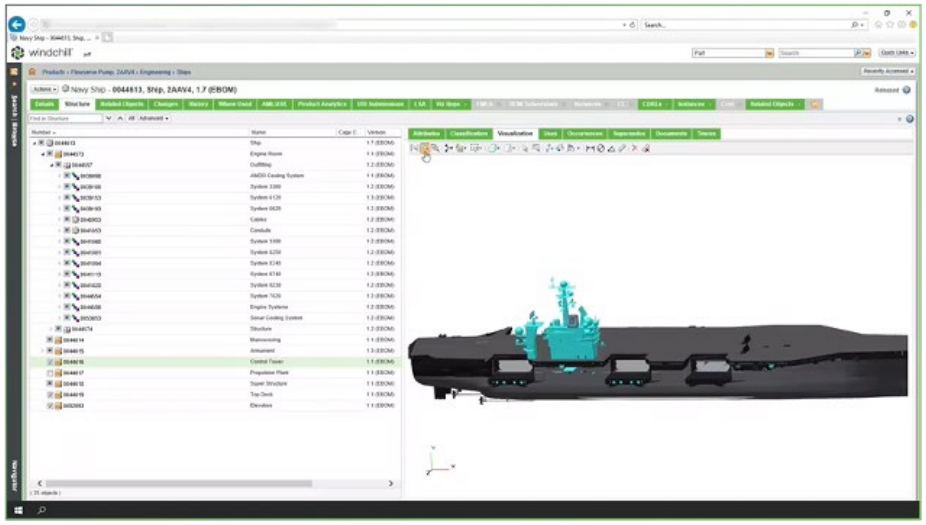
Users streamline design precision to simplify designs.

Furthermore, EZ Tolerance Analysis automates tolerance evaluation, ensuring compliance with industry standards and enhancing product quality. Its seamless data exchange between design and manufacturing teams streamlines the workflow, improving collaboration and reducing time-to-market.

Windchill

3D annotations in CAD models can be published in viewables generated for Windchill, PTC's Product Lifecycle Management (PLM) solution. This way, MBD is accessible to users across the entire enterprise and even into an external supply chain.

In Creo, you can also designate your MBD 3D annotations and their parameters as Control Characteristics. When the model is checked into Windchill, the Control Characteristics become available as business objects in PLM to support manufacturing process planning. This is another way engineering information can be leveraged across the enterprise.



3D annotations in Creo can be published for enterprise-wide and supply chain access in Windchill.

Getting Started with MBD in Creo

If your engineers and designers are familiar with creating and detailing standard 2D-production drawings, then they are well on their way to proficiency with MBD in Creo. They only have a few new concepts to learn:

Annotation Planes define the orientation of 3D annotations in your model. They can be located flat to the screen, on a pre-defined plane relative to the model (front, back, top, bottom, left, or right), or on a flat surface of the model.

3D Annotations are the PMI for your model, and for the most part are created the same way as they are in a 2D drawing. 3D annotations include:

- Linear and ordinate dimensions
- Datum Feature Symbols (DFS), Geometric Tolerances, and Datum Targets
- Notes
- Symbols
- Surface finishes
- Tables (added in Creo 11)

Combination States. A 2D drawing typically has multiple views on multiple sheets to reduce clutter and keep everything organized. In a 3D model, we can use Combination States to organize our 3D annotations so that they are legible and logical.

For controlling this display of parts and assemblies, Combination States also contain the following helpful elements:

- Simplified Representations to control which components in an assembly are visible.
- Cross Sections to see the interior of parts.
- Explode States showing how components in an assembly fit together.
- Appearance States to show different colors and textures for parts. This can be helpful when explaining fabrication or assembly steps.
- Style States to display various components in wireframe, hidden line, no hidden line, shaded, or transparent. Configuring different styles for different components enhances visualization for users.
- Layer States to control the visibility of different elements within the 3D model for a more focused view of the model's components.
- Orientation States to define specific views of the model, capturing the orientation of the model in a particular state which can be useful for downstream processes.

These three simple concepts can be taught to your designers and engineers in a brief amount of time. You can be up and running in MBD quickly with Creo.

Simplified MBD Maturity Matrix

Drawing Centric	Model Centric	Model Based Definition	Model Based Enterprise
MATURITY LEVEL 0	MATURITY LEVEL 1	MATURITY LEVEL 2	MATURITY LEVEL 3
2D Drawing is the Master	**2D Drawing** is the Master	**3D Model** is the Master	**Fully Loaded 3D Model** is the Master
• 3D Model is not verified • 3D Model is not configuration controlled • 2D Drawings are the Master • 2D Drawings are primary deliverables for internal and external customers	• 3D Model is verified • 3D Model may be configuration controlled • 2D Drawings continues to be the authority	• Design intent captured in 3D annotated model • 3D Model validated and configuration controlled • Technical Data Package (TDP) generated from these 3D models used for limited downstream consumption	• Fully loaded, 3D Models with associated artifact completely define the Product • Configuration management, automatic creation of "rich" TDP's, archival procedures in place • Rich TDP's directly used by all downstream users

Continuous Innovation with Creo

With every new release, PTC enhances Creo's MBD capabilities. Some of the major enhancements from the latest versions include:

Tables: Starting with Creo 11, Tables can be used in MBD. They can be created manually, using a Creo table file, or imported from Excel. They can be placed flat to screen or on an Annotation Plane (model surface).

General Profile Tolerance: Drawings often contain a standard note that specify a surface profile tolerance that applies to all surfaces that do not have their own profile tolerance explicitly defined. With the GD&T Advisor in MBD, you can define a General Profile Tolerance (GPT), and Creo will collect all its semantic references automatically. This is a significant time-saving benefit, as design engineers can skip tedious data entry and focus on geometric characteristics that are critical to performance, quality, and safety.

Standards Compliance: Every version of Creo increases compliance with ever-changing international drawing standards, including:

- Syntax checking against ISO 1101:2012, ISO 1101:2017, ASME Y14.5-2009, and ASME Y14.5-2018
- Support of ISO 22081 for general tolerances
- Compliance for ISO 1101:2017 Straightness and Line Profile geometric characteristic symbols
- ISO 13715:2017 edge indicator symbols and ISO 21204:2020 transition symbols

Symbols: The workflows for placing and editing symbols have been streamlined, including easier customization and immediate previews. Users can also relate annotations to symbols and surface finishes so that they will behave as a group.

Surface Finishes: New galleries for ASME Y14.36-2018, ISO 21920:2021, and ISO 25178:2016 are provided, along with updated interfaces and simpler workflows for placing and editing surface finishes, including a single panel for all options and variable text.

Welds: Symbols with semantic references are automatically created for weld features.

GD&T Advisor Advanced: This extension can now support assemblies in addition to parts. This license will allow users to validate any existing PMI annotations that were created outside of GD&T Advisor, within the Creo environment.

The improvements PTC has made in every version of Creo continue to refine and simplify implementation of MBD for companies that want to modernize their product development processes and workflows. Would your organization benefit from any of these enhancements?

Alternate MBD Metrics

Benefits of MBE:

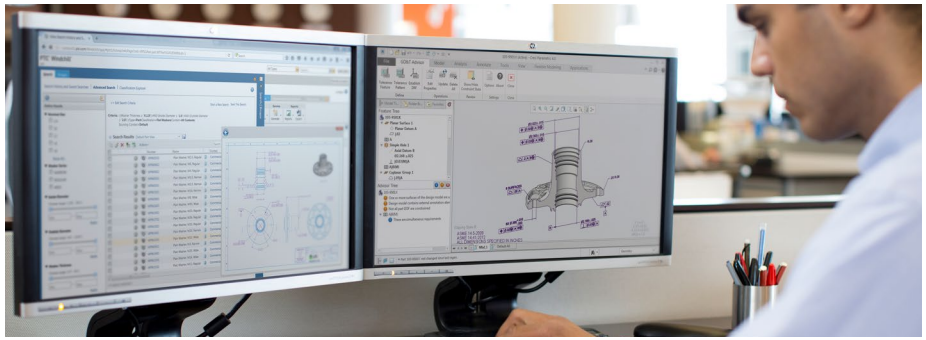
- Jabil increased number of projects by 400%
- Vaillant improved first-pass yield by 53%
- MBDA Missile Systems experienced 42% faster product development
- Nidec reduced Cost of Poor Quality (CPQ) by 40%
- Volkswagen decreased time to industrialization by 25%

Source: PLM L200 Use Case Technical Sales Deck_Model Based Enterprise (Power Point deck)

Try Creo Today for Free!

Take Creo for a test drive to see how it can benefit your organization. With a free trial of Creo, you can perform not just parametric modeling and MBD, but also Direct Modeling, advanced freeform and sub-divisional surface modeling, mechanisms, simulation, photo rendering, Augmented Reality, and more. The trial comes with learning materials and embedded tutorials so you can get started quickly.

Start Your Free Trial Today! ›



About the Author

Dave Martin is a Creo, Windchill, and PTC Mathcad instructor and consultant. He has implemented or used MBD at several companies, including Amazon and Blue Origin. He runs the Creo Parametric YouTube channel, with over a thousand videos on CAD and PLM. Dave is the author of the books "Top Down Design in Creo Parametric," "Design Intent in Creo Parametric," and "Configuring Creo Parametric," all available at amazon.com. He can be reached at dmartin@creowindchill.com.

The Creo Advantage

Creo is the 3D CAD solution that helps you accelerate product innovation to build better products faster. Easy-to-learn Creo uses a model-based approach to seamlessly take you from the earliest phases of product design to manufacturing and beyond. Combining powerful, proven functionality with new technologies including generative design, real-time simulation, advanced manufacturing, IIoT and augmented reality, Creo helps you iterate faster, reduce costs and improve product quality. Creo is also available as a SaaS product, providing innovative cloud-based tools for real-time collaboration and streamlined license management and deployment. The world of product development moves quickly, and only Creo delivers the transformative tools you need to build competitive advantage and gain market share.

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