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Model-Based Definition: A Key Value Driver for Future Product Development

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Autodesk

Learning Objectives

- Learn how to apply Model-Based Definition to fully define 3D CAD models and create accurate product documentation
- Understand the added value of Model-Based Definition for downstream processes in the supply chain.
- Estimate time savings when maximizing Model-Based Definition to define 3D CAD models
- Learn about collaborating with data at the center

Description

Manufacturing errors and quality issues are one of the biggest obstacles for product makers when it comes to achieving business goals and remaining competitive. The reason is often a lack of understanding between collaborating areas of the supply chain because CAD model documentation is difficult to understand or it's incomplete. In this course, you'll learn how Model-Based Definition in Inventor software can provide an alternative approach to creating understandable and accurate documentation that's ready to be reused downstream. The content of this Autodesk University course will focus on how Model-Based Definition can help fully define a CAD model earlier in the design process than ever before, while unlocking new potential for automation in areas such as manufacturing and quality management. The benefits of Model-Based Definition are highlighted as part of a direct comparison between the traditional and a forward-thinking approach that can provide greater clarity, accuracy, and efficiency in the product lifecycle

Speaker

Melanie Thilo helps her customers realize their full potential with Autodesk products and solutions. She has more than 10 years of experience in mechanical design engineering and project management. Melanie Thilo has worked in various industries and different companies.

Eugen Taranov has been working as Technical Sales Specialist for several IT companies since 2018. Currently, he helps Product Design & Manufacturing customers to align their digitalization initiatives with their key business objectives.

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What are typical challenges in Product Development?

Technical documentation represents an essential part of the product development process. It is nearly impossible to drive any efficient manufacturing and quality assurance of parts without providing needed information to all involved parties. Traditionally this information has been communicated in form of 2D drawings. Even though 2D drawings enable a smoother product development process, they can still be seen as a source of inefficiencies, disrupted workflows, and errors that negatively impact the overall business goals of product manufacturers.

Product Development is an iterative process. Until product development teams align on a functionable and manufacturable design it typically comes to several iteration loops between design, product validation, manufacturing, and quality assurance. It is the design engineer who is responsible for adjusting the design to the specific requirements of downstream processes and ensures that the design intent is captured within of technical documentation. In the meanwhile, the technical documentation has to be kept up to date with the current version of the 3D Model. A process that is repetitive, error prone and inefficient.

Every single step within of the product development cycle has its own specific requirements to the product design. A design has to perform, has to be manufacturable, to ensure consistent product quality, and has to be measurable. Until the optimal design for all these requirements is found it keeps iterating. The result is a back and forth between the teams involved in the product development. With every change the number of file versions increases. Accordingly, the number of technical documents that capture the design intent of the 3D model also grows. At the same time derivates have to be kept up to date with the current version of the 3D Model. From a data management perspective managing several sources of information becomes challenging. Every design update triggers a chain of manual and repetitive tasks for the design engineer. For instance, the update of the derivates and the communication of the updates with all involved parties.

The use of 2D documentation can result in different challenges and consequences depending on the stage of product development.

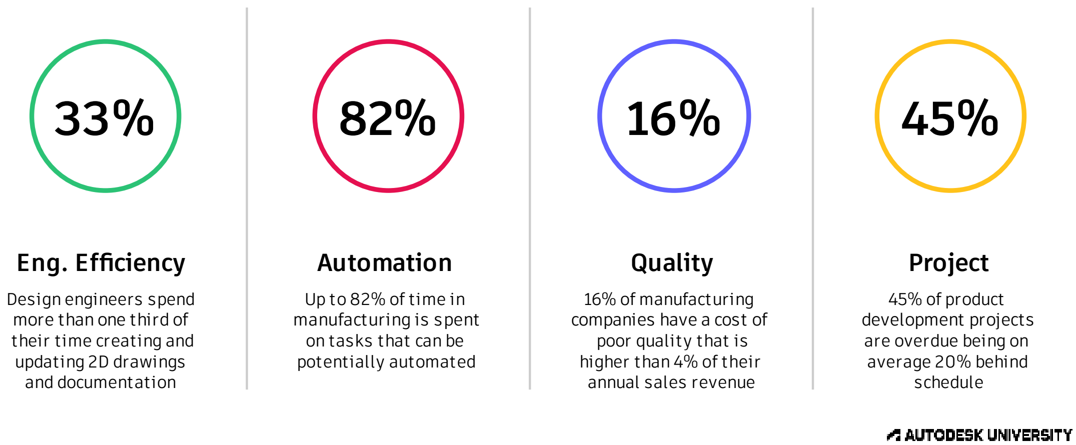
Until a design is ready for series production, it must be changed several times. This iterative process requires constant updating of the model and drawing. Otherwise, the product documentation is outdated. This can lead to incorrect manufactured components or expensive rework.

Validating a design requires a lot of additional information to understand the design intent of a 3D model. When information is missing, critical design issues can remain undetected and negatively impact the product performance

2D Drawings are not machine readable and require a lot of experience to be interpreted correctly. The product specification defines the manufacturing strategy. The manufacturing strategy decides if a component meets its function or not. The correct interpretation of product specification requires a lot of experience to choose the right manufacturing strategy. This means, only with a clear product specification can a component meet its intended functionality.

The manual creation of inspection plans is a time-consuming and error-prone process. Undetected tolerance violations can lead to a decreased product quality.

Current State & Industry Challenges



Challenges mentioned in the use case are based on industry studies and research. Accordingly, the efficiency in product development is greatly affected by design engineers spending one third of their working hours on updating technical documentation during the design finding process.[1]

The efficiency also results from a low grade of automation in manufacturing. With up to 82% of tasks on the machine floor being done manually there is a huge automation potential that can be unlocked within of many manufacturing companies.[2]

Product quality represents a massive cost driver over the entire product lifecycle. Starting with rework and scrap in manufacturing and ending with warranty claims and returns in the post sales. According to an indicator known as Cost of Poor Quality around 16% of manufacturing companies spend 4% or more of their annual revenue due to poor product quality.[3]

Only 55% of all product launches take place on schedule, according to the 2019 product manager survey* from Gartner, Inc. Product managers who typically launch on time are more likely to meet their internal targets within a year of launch. For the 45% of product launches that are delayed, 20%, on average, fail to meet their internal targets.[4]

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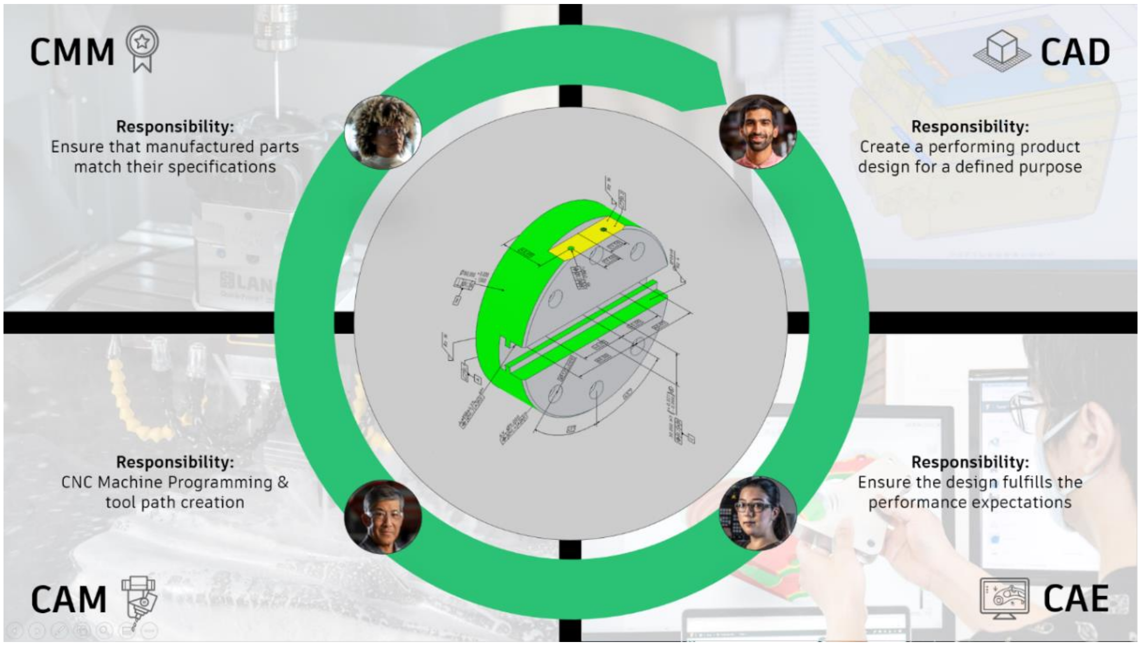
[1] MBD (Model-Based Definition): 2021 Edition (capvidia.com)
[2] Human machine: A new era of automation in manufacturing | McKinsey
[3] MBD (Model-Based Definition): 2021 Edition (capvidia.com)
[4] Gartner Survey Finds That 45% of Product Launches Are Delayed by at Least One Month

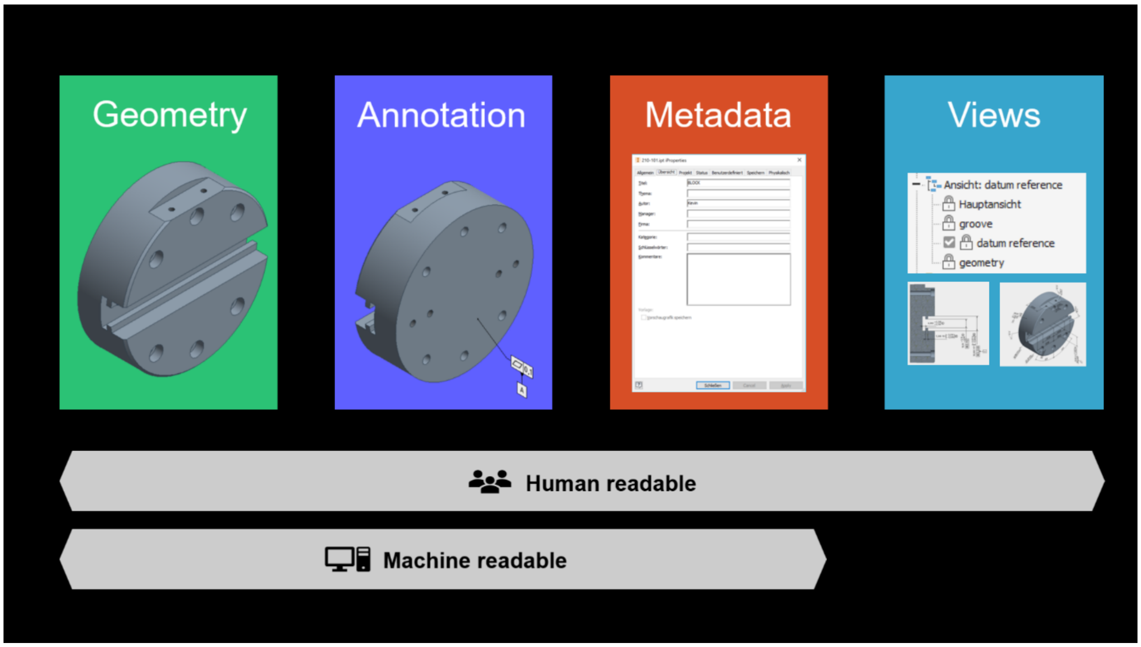
How can MBD result in better outcomes?



Major business challenges can be linked to inefficiencies that occur during the product development process and the process of technical documentation represents a significant complexity driver at this stage. Assuming that this process can be improved, companies should also be able to improve their overall situation. To improve technical documentation MBD could be considered as a more efficient and future oriented alternative.

What is Model Based Definition?

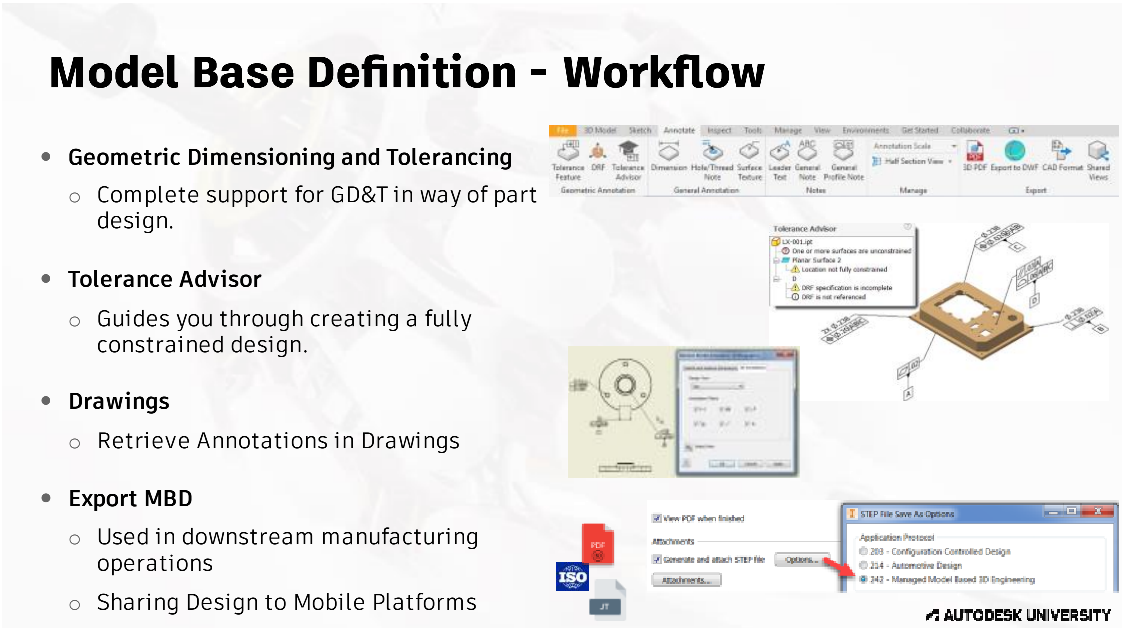
Model-based definition is an approach to create 3D models that contain all relevant information for product definition. With MBD, the 3D model becomes the single source of truth that drives all engineering activities. MBD is a powerful toolset for adding annotations, geometric dimensioning and tolerancing (GD&Ts), and other manufacturing information (PMI) directly to a 3D part.



Model-Based Definition (MBD) refers to a fully defined 3D model. The types of information can include:

1. Geometry is the ideal description of a part
2. Annotations, like Geometric dimensioning and tolerancing, Surface Finishing and other additional information important for downstream use.
3. Metadata, like material information and other iProperties
4. Views structure information and make it easier to understand the annotations

Because MBD is a user centric approach all the information attached to the model is human readable. The game-changer is that geometry, GD&T annotations, and metadata are machine readable, too. This makes MBD highly valuable from an automation and digitization perspective.



In Inventor 3D models can be detailed with MBD via the “Annotate Tab”. Annotations and GD&Ts can be attached to the 3D model and referenced to selected geometry features directly in the 3D environment. Additionally, annotations can be linked to customizable views to ensure information can be consumed easily.

Inventor Tolerance Advisor – an integrated Sigmetrix technology[5] – supports the user to define GD&Ts compliant with industry standards. The Tolerance Advisor also notifies on the fly the fully constrained surfaces of a 3D model.

MBD can be retrieved from the model to easily create drawings. This workflow reuses tolerance information from the model in the drawing and other downstream processes.

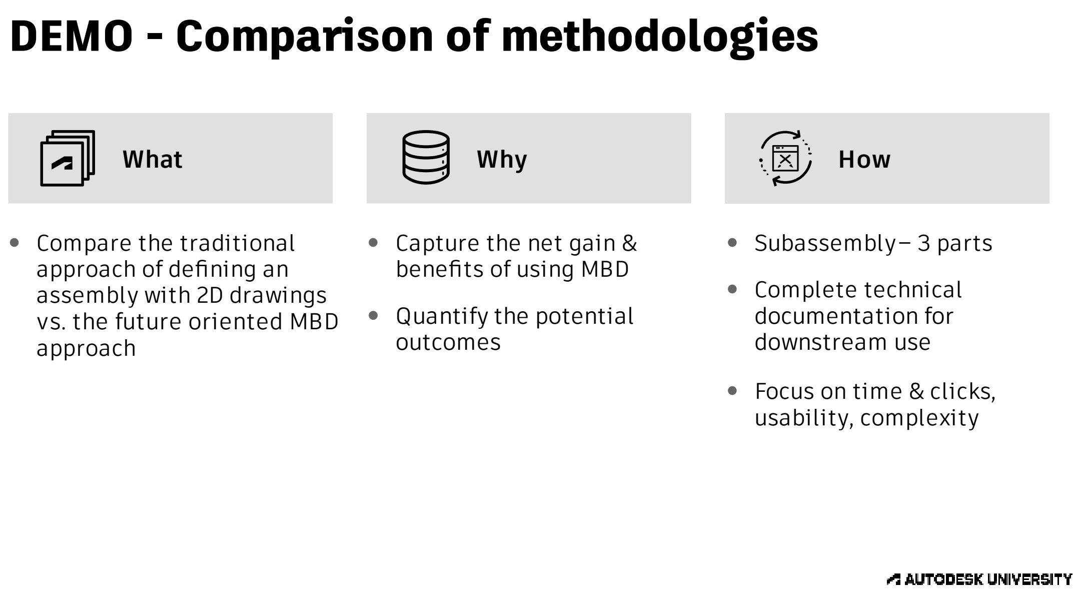
MBD can be exported in various supported neutral formats for downstream use. Common file formats are:

- STEP AP242 (e.g. for manufacturing)
- JT (e.g. for visualization)
- 3D PDF (e.g. for documentation)
- QIF (e.g. for inspection)

For collaboration purposes MBD can be shared with peers by using the browser-based Autodesk Viewer. It is easy to access via the “share view” button.

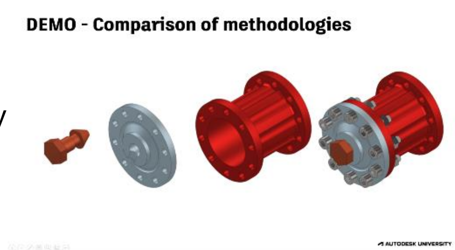
[5] GD&T Software - GD&T Advisor by Sigmetrix

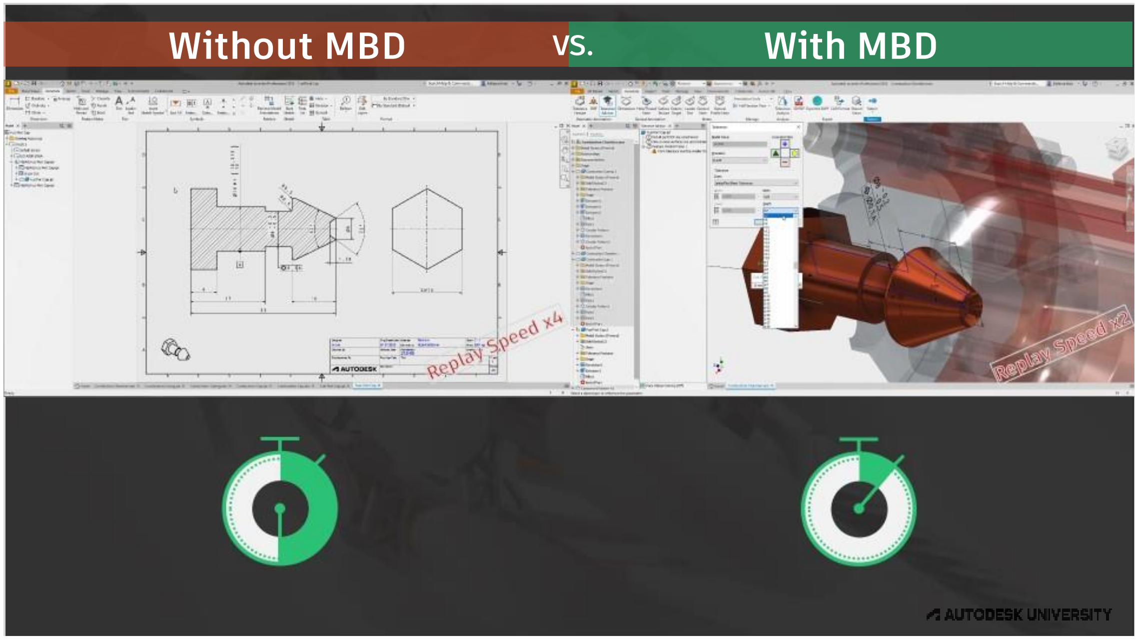
Comparison of methodologies



One of the key objectives of this AU Class is to capture the added value of MBD for the product development. Added value can be seen as a positive outcome based in the change of the technical documentation process when moving from the traditional 2D Drawings to a fully defined 3D model with MBD.

To capture these benefits these 2 mentioned approaches were compared side by side in a real use case with the goal to completely define a 3-part subassembly for downstream processes such as manufacturing and quality control. The focus was set on time savings, complexity reduction and further quantifiable outcomes.





A side-by-side recording outlines the main differences between the approaches.

On the left
Creating the technical documentation for the subassembly by using 2D drawings.

On the right
Applying GD&Ts directly to the 3D model.

The replay speed has been set differently due to the overall length of the recordings. The real time that passes as the models are defined is indicated right below the recordings for each approach.
The procedure is identical – the parts included in the subassembly are defined one by one. Starting with the flange, moving on to the lid and finishing off with the pin.

Traditional approach by creating 2D drawings

Using 2D drawings to define the subassembly every single part file has to be opened separately. A 2D drawing is derived and the user starts creating needed 2D views to properly communicate the geometry. Once the views are defined GD&Ts have to be attached manually one by one. For correctness duplicate information has to be avoided to eliminate any chance of confusion. The definition of the model requires the user to rely on his experience to maintain the compliance of the GD&Ts with industry standards and to make sure that the model is fully defined.
At the end the layout of each single 2D drawing has to be adjusted to make it consumable for downstream use. This includes tasks such as scaling the sheet, make sure GD&Ts and other annotations are not overlapping, ensuring enough clearance between different views.

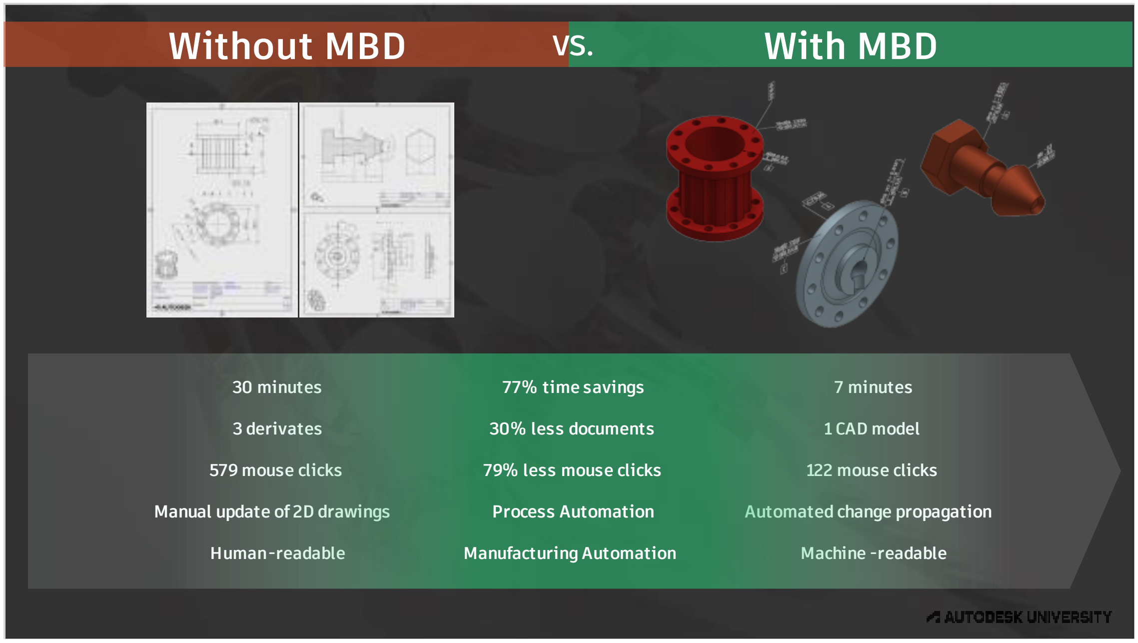
Future oriented approach by using MBD

At the same time on the right, applying MBD GD&Ts can be applied directly to the 3D model in assembly mode without switching between environments. Working in the assembly mode allows applying tolerances in context (e.g., where they make sense on interacting parts and surfaces). Since the MBD approach leverages the parametric model there is no need to apply dimensions – these are defined within the geometry that is human as well as machine readable. Tolerances attached to the model are checked by the Tolerance Advisor regarding their compliance with industry standards.

Drawings vs. MBD

All facts mentioned above can be seen as potential benefits of MBD compared with the traditional 2D drawing documentation approach - making MBD a faster, easier and safer way to define product design for downstream use.

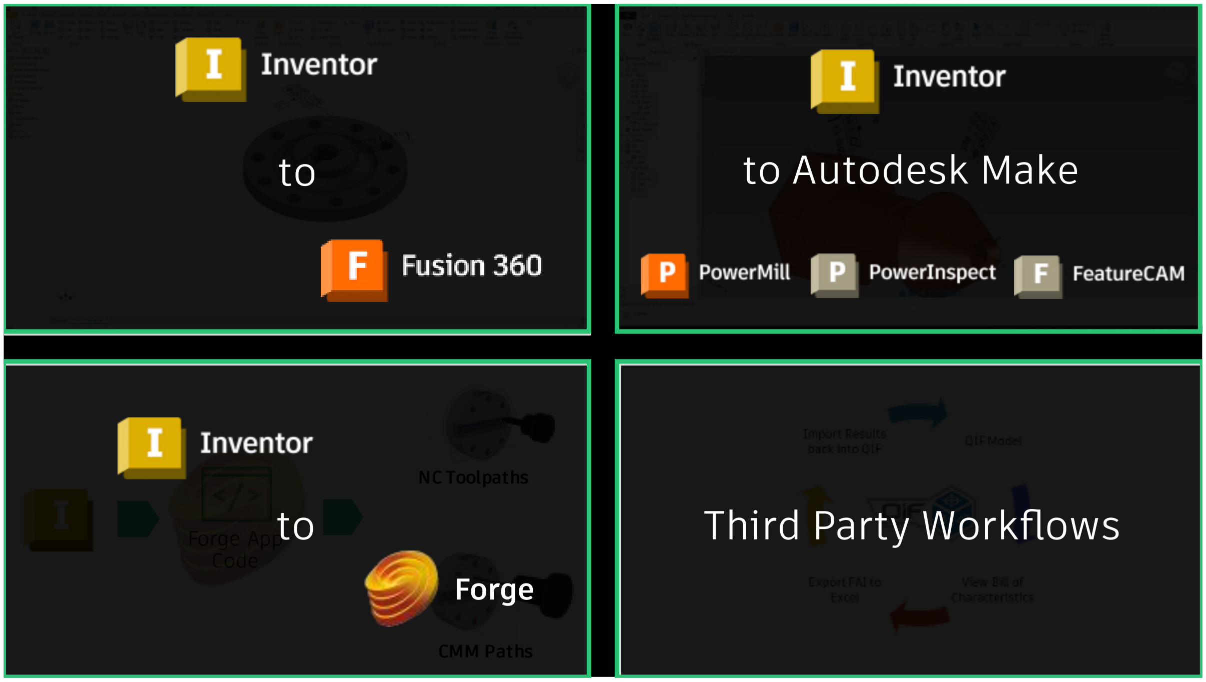
Without MBD	With MBD
The drawing is derived from the 3D model. Sometimes information like GD&T is replicated non-associatively to the model.	The 3D model is reused and detailed with information like GD&T.
Human-readable	Human- and machine-readable
A drawing is always a translation from 3D in 2D. Understanding a drawing takes a lot of experience.	As humans think in 3D, the model is easier to understand and needs less interpretation.
Sometimes a lot of time is invested to create an appealing layout.	MBD focus on function.
Every component is toleranced individually. It is difficult for the design engineer to identify correlations because the work is done in different documents.	Tolerances can be easily defined in assembly context
GD&T has to be checked manually for accuracy and standard compliance. This requires high expertise and experience.	The fully integrated Tolerance Advisor assists in creating accurate and standard compliant GD&T



The key differences and outcomes of the analyzed methodologies were significant time savings, a reduction of files that had to be managed and a lower user complexity when leveraging MBD. Thanks to a unified source of information (3D model + PMI) the need to propagate changes into several derivates was significantly reduced. Additionally, it is important to point out that MBD unlocked automation potential when compared to the traditional 2D drawing approach. Information that had been attached to the 3D Model with MBD could be propagated automatically into derivates created for downstream use. The PMI included inside of the 3D model can be also used to automate processes in manufacturing and quality control since this information is machine readable.

Downstream Use of MBD in Autodesk Solutions

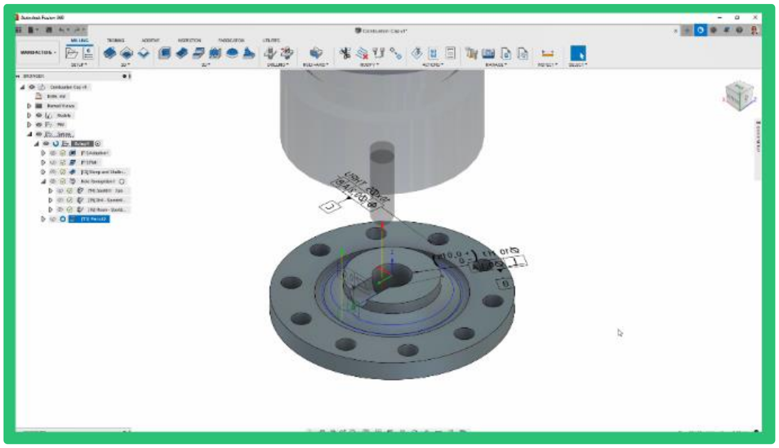
Model Based Definition unleashes its full potential in downstream use. In the following you will find four examples that are already available today.



Inventor to Fusion 360

Autodesk established some one-click workflows to bring data from Inventor to Fusion 360. This allows you to exchange data easily if you would like to create tool path strategies, advanced simulations, electronic design, or run a generative design study. So MBD can be used downstream for manufacturing purposes.

The Import PMI Data on File Upload preview feature lets you open designs created in other CAD applications, and then visualize the designs' PMI (product manufacturing information), making clear the original design intent.[6]

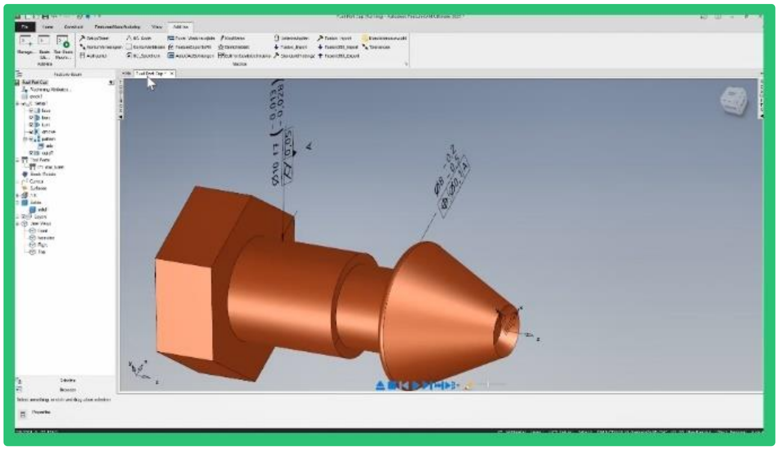


Having visible PMI on the model helps you to choose the right manufacturing strategy. You don’t have to switch between drawing and 3D model all the time, and you always see all relevant information. Of course, you can also hide the PMI when you don't need it at the moment.

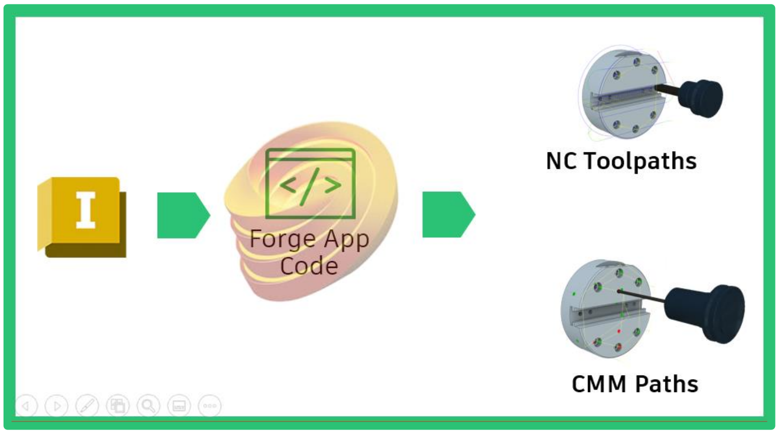
[6] Fusion 360 Help | Upload designs with PMI | Autodesk

Inventor to PowerMill, PowerInspect, FeatureCAM

Autodesk Make Solutions support PMI. This means 3D annotations are visible in the 3D model. As in Fusion 360, the visible PMI helps the CAM programmer to select the right manufacturing strategy. All relevant information is linked directly to the 3D model. The risk of wrong interpretation of 2D drawings is reduced.
One big advantage of semantic PMI is, that the assigned surfaces can be selected automatically. This simplifies CAM programming enormously and leads to better outcomes.

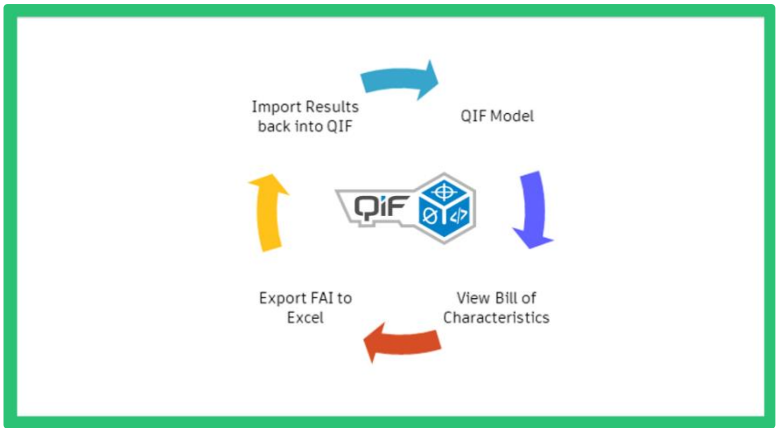


Inventor to Autodesk Forge



There is an enormous potential of automation and connected workflows within Autodesk Forge, a cloud-based developer platform that unlocks design and engineering data for creative problem solving.
For example, Autodesk Forge can be used to read PMI data from a model in Inventor. This enables automation when creating tool or probe paths in PowerMill, FeatureCAM or PowerInspect. Based on the measurements, a database could be created and visualized via dashboards.

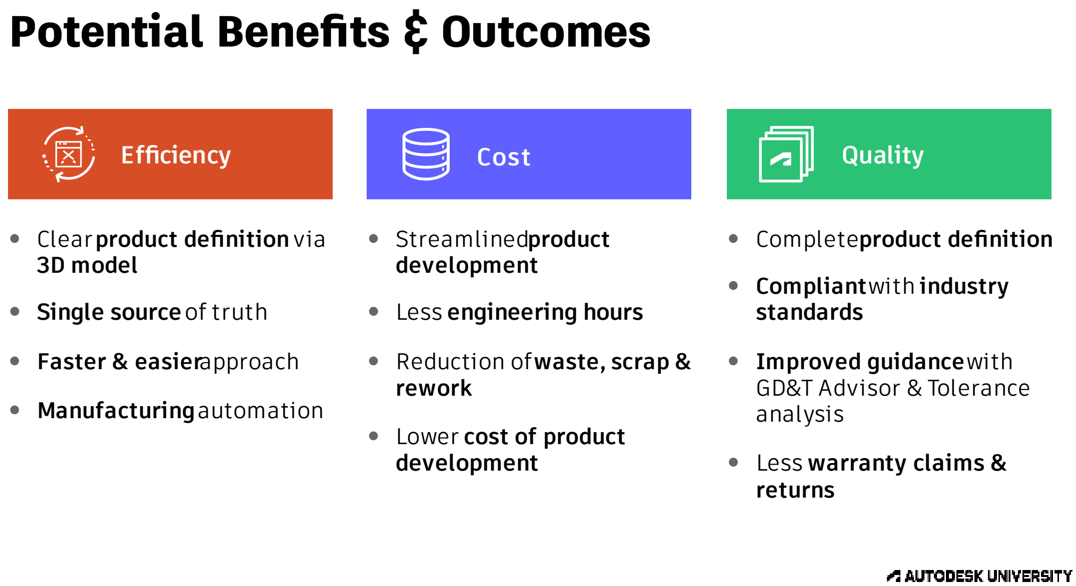
Third Party Workflows



There are several 3rd party applications available to use MBD downstream. In metrology, many vendors rely on the Quality Information Framework or QIF that can serve automation in quality management processes.
With Inventor MBD can be exported in QIF format and made available for quality management processes. Part of this process is the Bill of Characteristics (BoC), a list of all characteristics to be measured to ensure quality. This list can be created and populated automatically from the PMI to further automate workflows like First Article Inspection (FAI) and Production Part Approval Process (PPAP). Results from a measuring inspection can be harvested and populated back into the QIF, so that the loop between the physical part and the digital part can be closed – by comparing the 'is' vs the 'should be' side by side.

Potential Benefits and Outcomes

The potential benefits of MBD can be grouped in 3 main areas – Efficiency, Cost & Quality



Efficiency

With MBD most of the required information for downstream processes can be captured inside of the 3D model. The 3D model becomes a single source of truth for all involved parties by providing them with all required information. The creation of a fully defined 3D model also consumes less time and resources. Especially from a data management perspective the reduced amount of files is highly desirable. From a manufacturing perspective MBD creates a foundation for automation by contributing to a faster and streamlined product development.

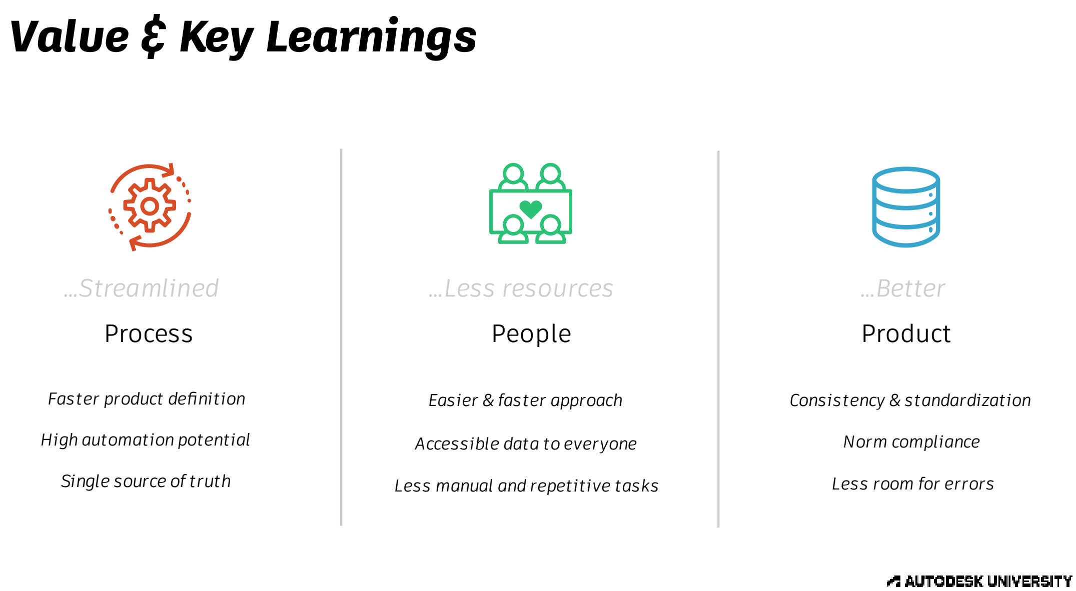
Cost

MBD can help to address challenges that represent significant cost drivers during the product development process. A streamlined and automated process means also that it is less time intense and error prone, resulting in less engineering hours, less rework, waste, and scrap.

Quality

The correctness and compliance with industry standards of the technical documentation will increase the value of the product over its lifecycle. A correct and fully defined 3D model is less likely to cause any misinterpretation - reducing errors during the product development and subsequently resulting in a better product quality. That will further help to reduce warranty claims and returns in the post sales stages.

Summary



To summarize the learnings of this AU class – MBD has the potential to streamline the product development, benefit the people involved in this process and help to create a better product. Product definition is faster if all necessary information is created in the 3D model first. For example, tolerances can be defined at an early stage of new product development. This information in the 3D model can be used to align internally with manufacturing or quality department or externally with suppliers. The drawing is not created until the 3D design is complete and aligned with all relevant stakeholders. This saves a lot of time in product design. With a single source of truth, a streamlined process can be achieved. Single source of truth means to have all information in the 3D model and use it downstream. By having all required information in the 3D model, you democratize information and break down silos.

Further process benefits can be seen in the area of automation. If machine-readable information like geometry, annotations or metadata is available, this indicates a high potential for reducing manual and error-prone tasks in quality assurance and manufacturing.

The MBD capability is available directly inside of the design environment and provides easy to use tools to the design engineer. 3D Models defined with MBD will require less resources due to an easier change propagation. This leads to less manual and repetitive updates of technical documentation as the 3D model iterates.

Following industry standards with the help of the GD&T Advisor promotes a common sense of the product. This includes consistency and standardization. Risks are minimized by a unique product definition. In this way, consistent quality can be guaranteed even when changing suppliers. This results in better products.

What stops companies from implementing MBD?

Despite all the potential benefits MBD can bring to the product development there are few companies out there who have implemented MBD as a technical documentation standard. The reasons here fore can have different backgrounds.
Technical documentation is not considered to be a value driver, so there is less interest of making investments and manage changes in this area of the business.
Additionally, many engineering companies operate with established workflows and processes for decades now. It takes a lot of motivation and courage to drive change and try out new approaches.

Technology is easy – People are hard

Low adoption might be a result of not recognizing the potential benefits and added value to overall business goals. It takes a long-term mindset to understand that technical documentation can be a game changer for product manufacturers.

Considering the potential benefits of MBD and how it can contribute to overall business goals, we would like to remind you that MBD can be easily applied with Autodesk Inventor without additional installation or cost.

Glossary

MBD

Model Based Definition describes the method of providing a 3D model with 3D annotations (dimensions and tolerances), metadata, surface quality, notes and attributes to specify complete product information.

GD&T

Geometric Dimensioning and Tolerancing is a symbolic language which clearly describes the nominal geometry and its permissible deviation.

PMI

Product Manufacturing Information
Product information is information required to define the product beyond of the 3D geometry. Manufacturing information also includes information about which manufacturing steps are necessary to achieve the defined product information in the finished product.

Abbreviations

CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CMM	Coordinate Measuring Machine

Links and Resources

Model Based Definition (MBD) in Inventor

In this collection of articles you can learn more about the capabilities of Model Based Definition (MBD) in Inventor.
https://knowledge.autodesk.com/community/collection/model-based-definition-mbd-inventor

Autodesk Viewer

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Inventor Help | About 3D Annotation and Model-Based Definition

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