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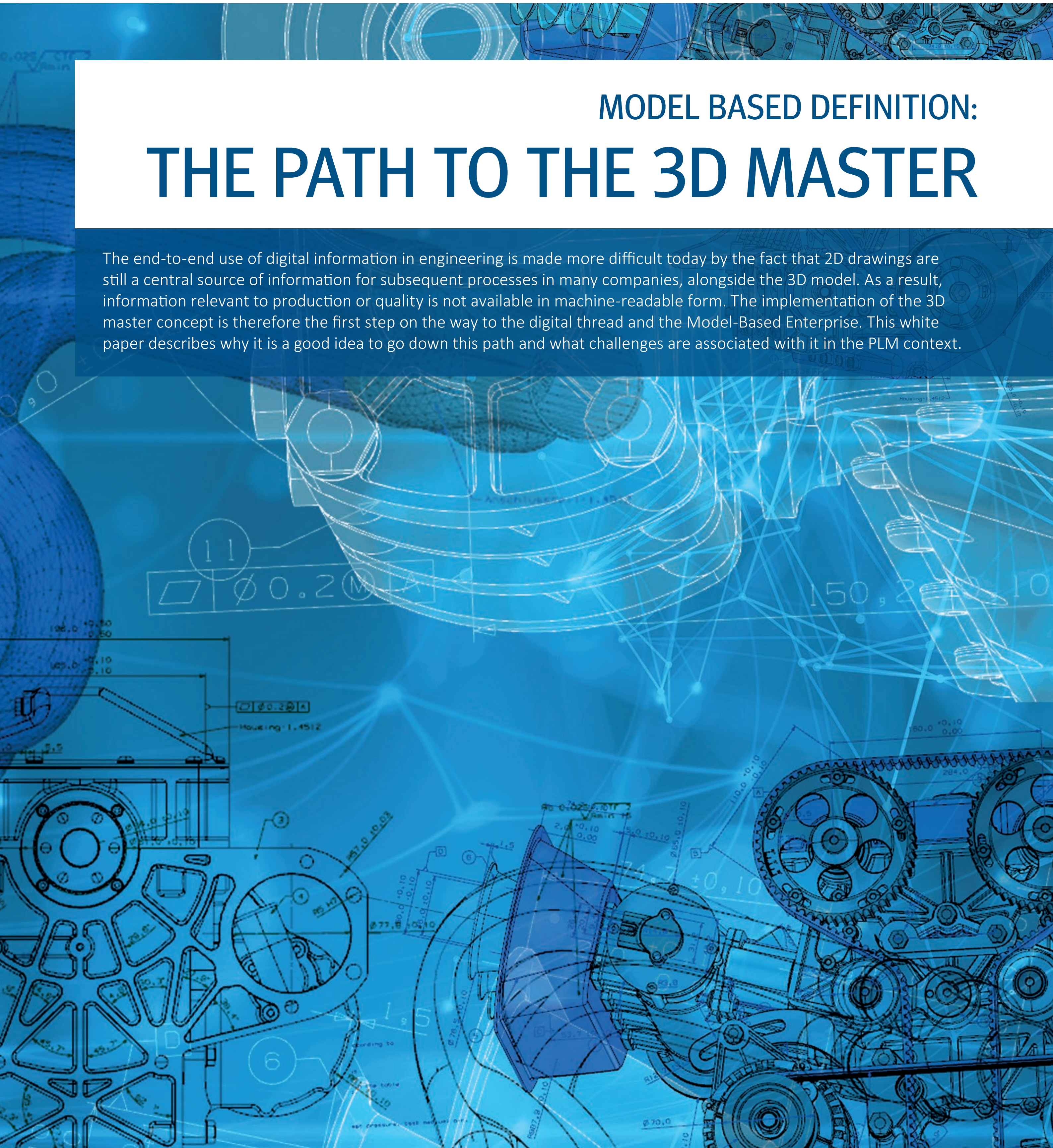
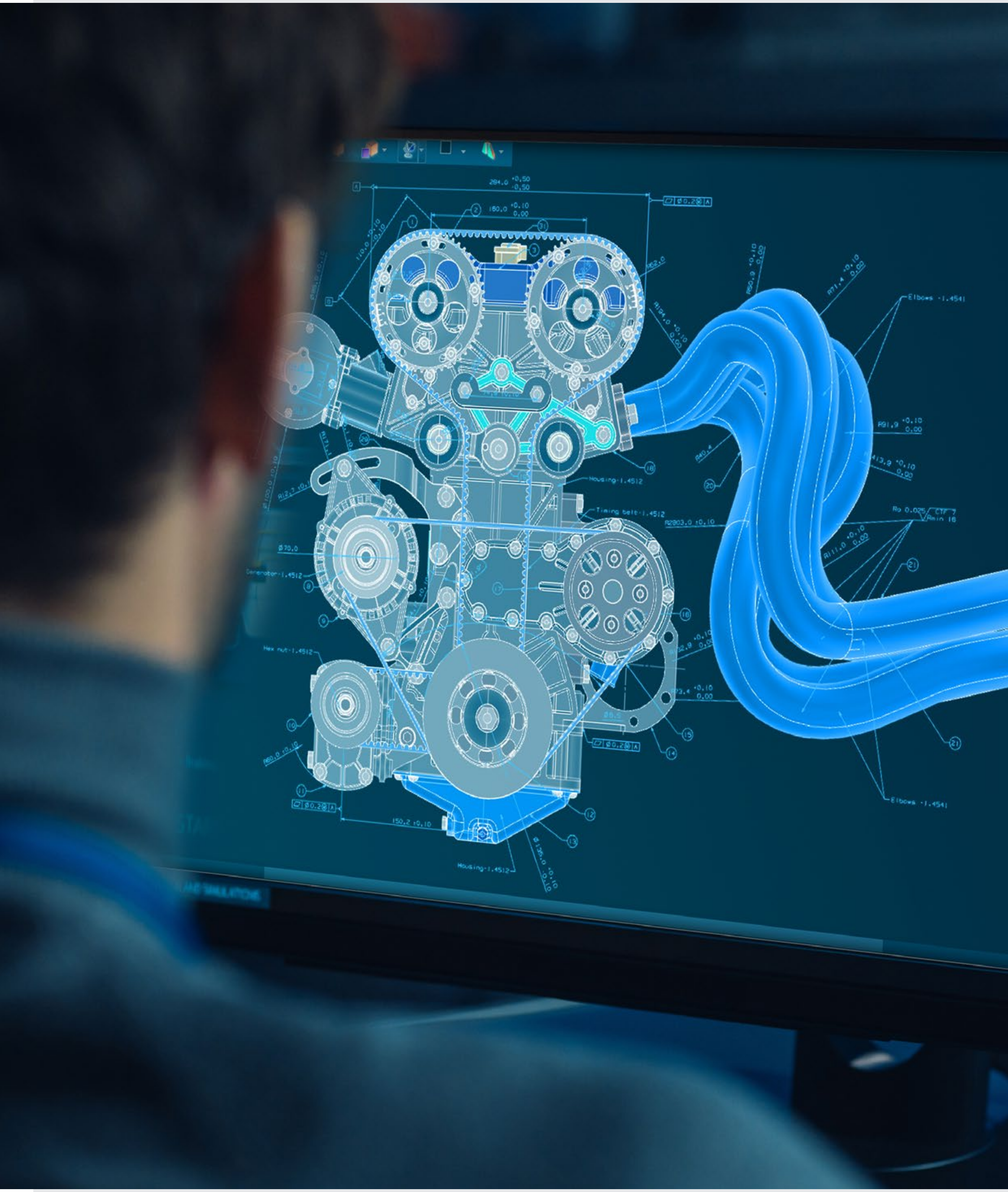
WHITEPAPER

MODEL BASED DEFINITION:

THE PATH TO THE 3D MASTER

The end-to-end use of digital information in engineering is made more difficult today by the fact that 2D drawings are still a central source of information for subsequent processes in many companies, alongside the 3D model. As a result, information relevant to production or quality is not available in machine-readable form. The implementation of the 3D master concept is therefore the first step on the way to the digital thread and the Model-Based Enterprise. This white paper describes why it is a good idea to go down this path and what challenges are associated with it in the PLM context.

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Abstract

Companies have been using 3D CAD applications to design mechanical components for their products and production systems for decades. This has not, however, completely eliminated the use of 2D drawings in downstream processes. The end-to-end use of 3D mechanical engineering data in work preparation, toolmaking and quality assurance, as well as in technical documentation and service operations, is an important indicator of the end-to-end digitalization of information flows within a company and in the supply chain. Or to put it another way, 3D models are a key, albeit insufficient, component for the digital thread and the digital twin.

If 3D models are to be used throughout the processes, they must include not only geometry data but also dimensions, tolerances, information about surface quality, and other production-relevant attributes in their role as 3D masters. To date, however, only a minority of companies have consistently implemented the concept of model-based definition (MBD). Instead, many processes are still based on information that is provided by means of drawings and therefore cannot be processed automatically. The reason for this is that the benefits offered, such as time savings in downstream processes and greater process reliability, are offset by the relatively large amount of effort required to change the processes. This white paper describes the complex interrelationships in the PLM context and why it is nevertheless advisable to chart a path to a model-based enterprise.

The 3D master in the context of the digital thread

The key task of the digital thread is to link data and information from products and systems on their journey through the entire lifecycle in a traceable manner (see Figure 1). Thanks to sensor technology and the Internet of Things and Services, products and production systems are generating ever-increasing volumes of data that can be used to maintain them more efficiently and improve them while they are in operation.

Some data is independent of each other, other data is closely related and influences one another. You cannot make changes to one piece of data without changing the other. The challenge here is the fact that the data itself is often unaware of this relationship because it is lying dormant in numerous small or large data silos that are not linked with each other. Or because it is embedded in documents, making it difficult to extract. The aim of the digital thread is to digitally establish and manage these relationships by means of links between the individual data objects.

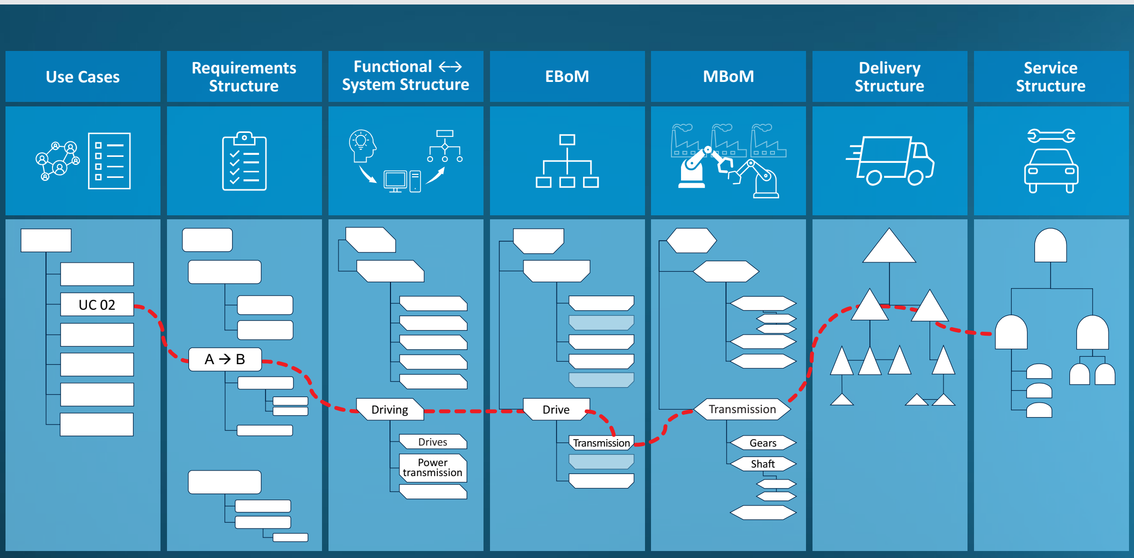


Figure 1:End-to-end digitalization throughout the lifecycle

The purpose of the digital thread is to make companies more efficient when it comes to product development, manufacturing and operations and to avoid errors, especially when changes are made. It is intended to support the digital transformation and corresponding business models. And it is the key to traceability, which makes the product lifecycle fully transparent. Without the digital thread, it is impossible to trace how a product was created and how, for example, a possible error came about. Without it, there is no virtual representation of a real-life product or asset. The digital thread provides the foundation for the digital twin.

Along with electronics and software, the mechanical design is a key part of the product definition upon which focus is now being placed. An approach involving a model-based definition (MBD) or 3D master provides the basis for end-to-end digitalization in mechanical engineering. It combines the 3D model with annotations for product and manufacturing information with the aim of defining all the relevant information in a central location and making it available in a format that can be read by both humans and machines. This then makes it possible to automate the reading and reuse of the data, thus minimizing manual transfer. In effect, it replaces the use of conventional drawings for documenting the design.

You can only digitally connect what exists in digital form. If a delivered product is to be described in its entirety in a digital twin, all the relevant product data has to be digitally available. In reality, many companies still have a way to go before they are able to do this. Gaps exist in the digital process chains and flows of digital information – from the production-ready 3D modeling of mechanical components to the integration of electrical/electronic components and software modules to the consistent integration and use of simulation data.

Irrespective of the growing proportion of value added by electrics/electronics and software, smart products also have a geometric shape, which today is usually modeled in 3D. The 3D models from design engineering are therefore a key component of the digital thread. Despite persistent media discontinuities, they are – together with 2D drawings – perhaps the most important information carrier for communicating product information within a company and across company boundaries. And unlike 2D drawings, they are also easier for even non-experts to understand, which avoids misunderstandings and reduces complexity. 3D models play a central role in all phases of the product lifecycle.

The digital thread is a long-term, strategic course of action that needs to be well prepared. Companies must systematically adapt the model-based approach in all the departments involved in product development and transform themselves into model-based enterprises. The first step in this direction is turning conventional 3D models into 3D masters that contain all the geometry-related digital information required for the downstream processes. The second step is making consistent use of this information. The 3D master can then be supplemented with additional information for the digital thread. This white paper describes what a 3D master is and what advantages it offers.

Current challenges and limitations of 3D product definition

In light of the fact that companies have been modeling their products in 3D for decades, the question arises as to why they are still communicating information relevant for manufacturing to downstream processes on the basis of drawings instead of adding it to the 3D model in the form of product manufacturing information (PMI). In many companies, the drawing is still the primary document, i.e. the master. This means that the information contained on the drawings cannot be read by machines and thus cannot be reused automatically.

There are a number of different reasons behind the inadequate end-to-end digitalization of 3D model data. First of all, a lack of appropriate automation means that 3D annotation in many CAD systems was and still is not faster, or not much faster, than creating drawings, which in turn means that there is little incentive for users in design engineering. The main benefits of MBD and the 3D master become apparent in the downstream processes, which however are not yet fully digitalized at many companies. This applies in particular to quality assurance, where the stamped inspection drawing is often still the measure of all things.

Even when working with external manufacturing partners, it is the drawing that is usually the contractually binding document, especially when dealing with partners in countries that are not able to keep pace with technical innovation. The 2D-based processes have been in place for years and work well, which means that no great difficulties have yet been experienced. Only gradually are companies coming to realize that there is considerable rationalization potential here in terms of shortening throughput times and reducing errors.

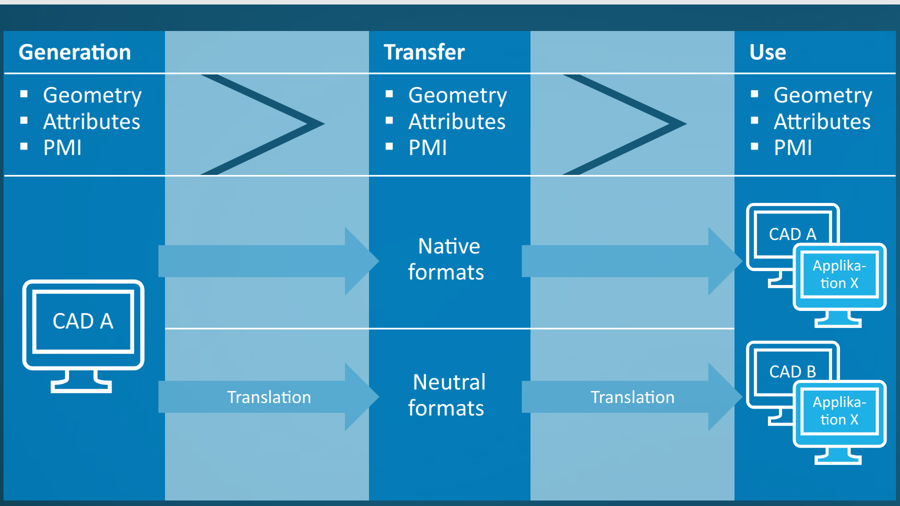


Figure 2: Generation and use of 3D model data

One major obstacle standing in the way of end-to-end digitalization is not only the heterogeneous CAD and CAM system landscapes within companies but also first and foremost in their supply chain. This means that the 3D-annotated models are not usually exchanged in native formats – which is already problematic for reasons of know-how protection – but rather in neutral formats such as STEP, JT or 3D PDF. No steps however have been taken to ensure that the PMI information arrives correctly and in a machine-readable format.

Whereas geometry can now be reliably exchanged using B-Rep representations, PMI information is transferred either graphically or semantically. However, only semantic information is in a machine-readable format. The challenge is that in some cases there is still no generally binding definition for transferring this information, which makes it difficult to output PMI in neutral formats and import the information into the target systems. In addition, many machining operations are based directly on the CAD geometry, which means that a tolerated CAD geometry is more important for their programming than a 3D model designed to nominal size but annotated. The requirements for 3D product information in the CAD system are subject to change, i.e. a drill hole must, for example, be created with a hole feature because although a revolved cut produces the identical geometry, it is not identified as a drill hole.

PLM capabilities required for 3D masters

If the model data is to be used throughout the processes, companies need to implement a number of technical and organizational measures. The primary aim of the first step is replacing the drawing-based communication of product information and implementing a model-based approach. Companies need to turn the 3D model into a true 3D master that includes not only the geometry but also all the data relevant to manufacturing, quality and functionality that is required in the product lifecycle.

The model-based way of working is predicated on the model-based definition (MBD) approach, which pursues precisely this objective. In this case, a distinction must be made between which information is required directly in the 3D model and which is merely linked to it in order to be able to handle the information appropriately. The details of the material definition, which can be stored in a material database, is an example of this. For this reason, the 3D master concept must be embedded in the overall PLM strategy and supplemented with additional PLM capabilities.

Companies require certain PLM capabilities if they are to be able to implement MBD. The most important capabilities required for implementing a 3D maser concept are highlighted in red in the heat map in Figure 3. The heat map is based on the PLM capability map developed by PROSTEP. It is the key element of PROSTEP's methodology for assessing the current state of capabilities in the company and defining the target state. The particular capabilities, focus and the approach used to implement them must always be adapted to the individual circumstances. Each company must define their own requirements with regard to each of the capabilities.

The capabilities responsible for generating the data are listed in the upper section of the capability map. In the context of the 3D master, focus here is placed on mechanical design and E/E design as the core disciplines for generating the geometry and PMI. The other capabilities highlighted, such as simulation and production planning, use this data to generate additional process data.

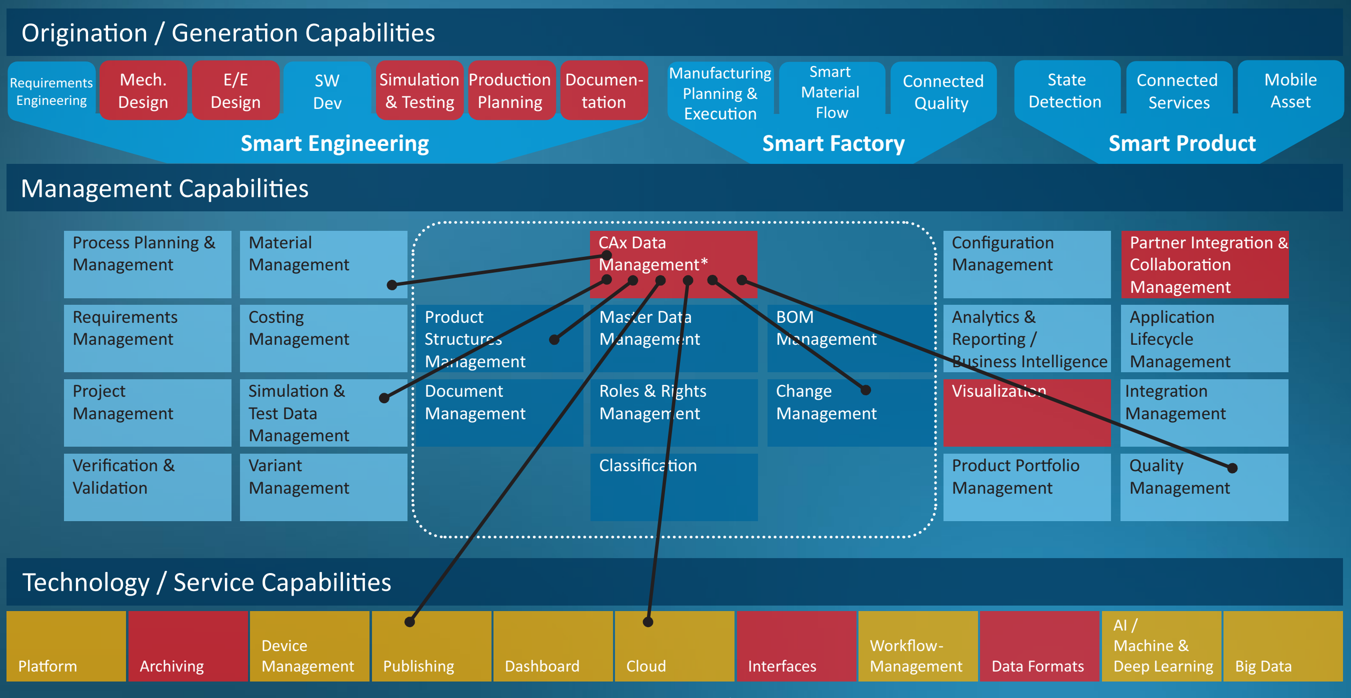


Figure 3:Heat map for the 3D master

The middle section, Management Capabilities, describes the capabilities needed to handle and manage the data. CAx data management is the key capability for the 3D master in this section. It is responsible for storing the data and embedding it in the overall PLM context in a suitable manner.

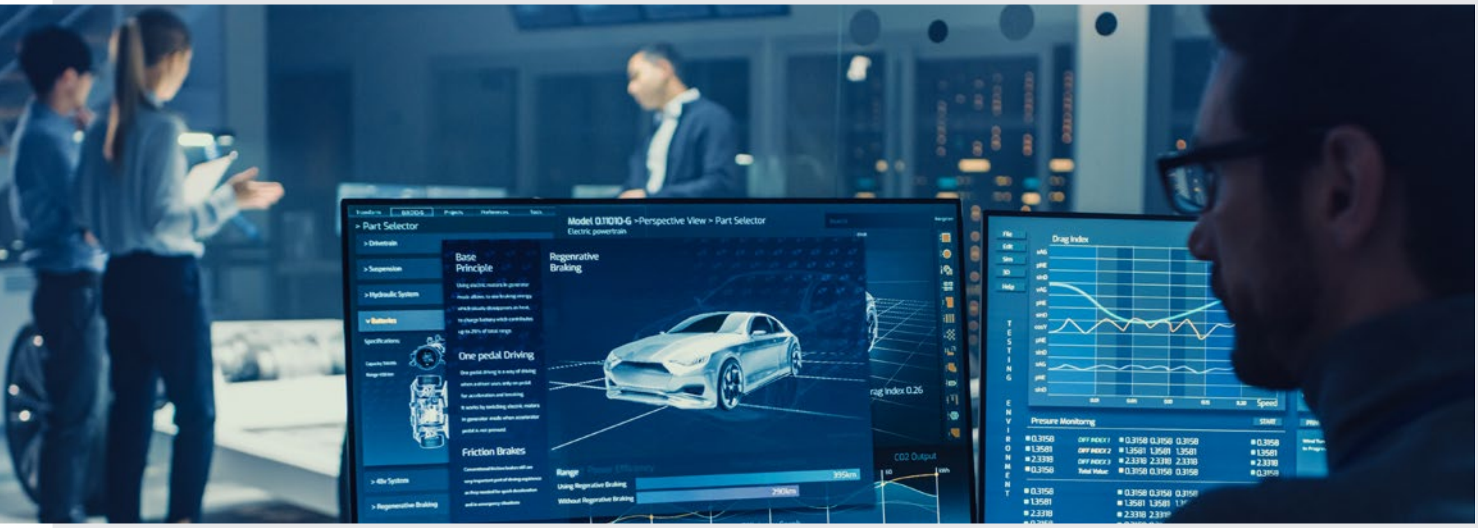
Partner integration means integrating internal and external partners in the creation and use of the 3D master. Visualization provides suitable, and if necessary simplified and lightweight, representations for different use cases. There might also be optional relationships to other capabilities. Material management, for example, maps the material parameters of materials approved for production.

The technology and service capabilities in the lower section of the map are available throughout the processes. Interfaces and data formats are used in the context of the collaboration. Publishing describes the provision of data, and if necessary an entire data package, for a specific purpose. The need for PLM capabilities depends on the situation of the individual company.

Implementing the 3D master concept

Switching to the 3D master concept represents a challenge for companies in many respects. On the one hand, they have to change the approach taken in design engineering and the engineering offices, whose activities today usually include not only 3D modeling but also deriving drawings and preparing them so they are production-compatible. On the other hand, the processes in the downstream departments have to be adapted so that the information in the 3D models, which include PMI, can be read and reused. This includes clarifying which of their external manufacturing partners are capable of processing PMI and how they can be provided with support during the transition. In this context, it must be clarified from a legal point of view to what extent the 3D models can be used as a contractual basis and drawings can be omitted.

On average, design engineers and draftspeople use half of the time they expend on design engineering creating 3D models and the other half creating or modifying drawings. Although doing away with the creation of drawings initially saves them a considerable amount of time, most of that time is then eaten up by the effort required to add PMI. How much time they need to do this also depends on the extent to which the CAD system used provides supports in the form of automation. In addition, especially during the transition phase, time is required for defining the new way of working, for training and for familiarization.



Users have to learn how to use the PMI features that their CAD application provide and they have to learn how to add PMI to the 3D models in such a way that their colleagues in other departments can keep on top of things and to ensure that it can be used in downstream processes. Standardized geometry elements, e.g. hole features, that already include predefined PMI are one possibility. Uniform enterprise-wide guidelines, like the ones that should exist for the CAD modeling methods, are also required for 3D annotation. It is common practice, for example, to represent manufacturing information on defined layers in the model and to assign it to views named in accordance with naming conventions to ensure that dimensioned views of the 3D model can be printed like a set of drawings if necessary. This type of systematic approach is helpful, particularly when coordinating with external partners, who may not yet be able or willing to automatically read and further process the PMI in the annotated 3D models.

The 3D master does not automatically ensure a higher level of end-to-end digitalization in the direction of manufacturing. If the companies are using an end-to-end CAx process chain from one vendor, this is usually a given. The situation is more difficult if they are working with CAx applications from different vendors or are collaborating with manufacturing partners who are using a CAM application from another vendor. In these cases, the PMI must be transferred using neutral formats such as STEP or JT, for example. This is possible, but a point that needs to be clarified is whether and in which neutral formats the respective applications in the downstream departments can semantically evaluate the PMI.

Changing the approach taken is a task the requires some effort on the part of both the people who create the annotated 3D models and the people who use them. It is therefore important to find a sponsor for the transition among the management staff who recognizes the medium and long-term benefits and accepts the efficiency losses during the transition phase.

Use and benefits of the 3D master

The introduction of a 3D master increases speed, accuracy and efficiency in product development but first and foremost in pre-production and quality assurance. The aim is to shorten the time to market and improve product quality. Working together on a uniform model makes feedback loops faster and- thanks to the automation of certain process steps- facilitates faster transfer of information to production. However, not all the information on a drawing is in a machine-readable format and has to be entered again by hand. This is a time-consuming task that is prone to errors. It is primarily revisions and the elimination of errors that are work-intensive.

The 3D master offers the advantage that all geometry-related information relevant to the product and manufacturing is added to the 3D product model as PMI and can be used digitally. This improves communication of the information to other departments in the company or to external development partners and suppliers and avoids errors caused by inconsistencies between the 3D model and 2D drawings. It also facilitates the electronic archiving of the product data in a uniform, neutral format suitable for long-term archiving. 3D models that include PMI can be used for different use cases in the company – from digital tenders to work preparation and quality assurance through to technical documentation.

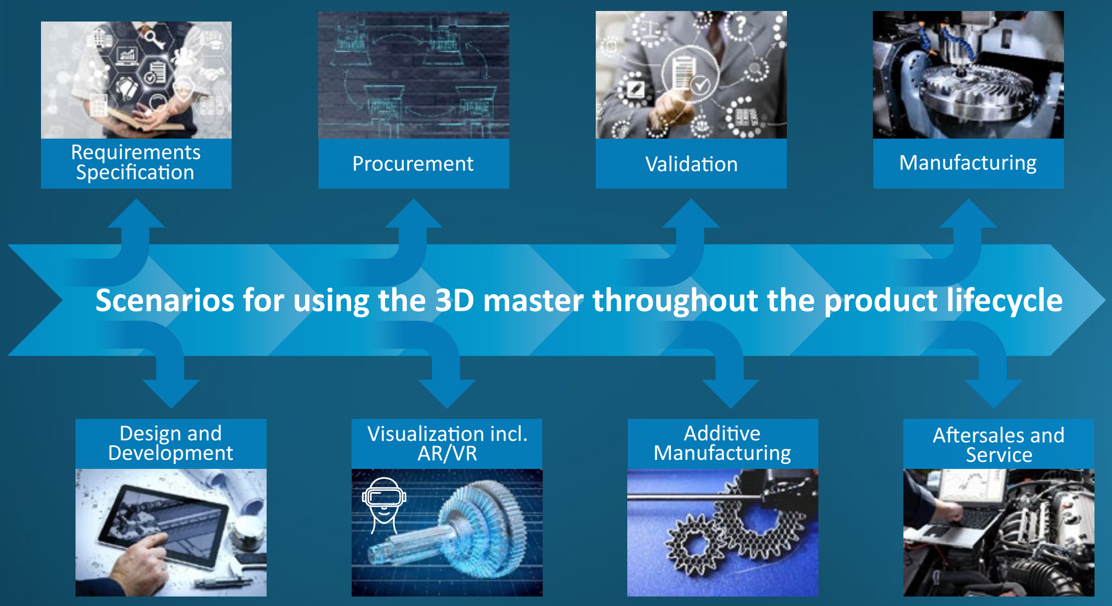


Figure 4: Scenarios for using the 3D master

The main benefit of the 3D master is machine readability and automated reuse of PMI for model-based engineering and digital manufacturing. This can result in significant time savings, especially when it comes to the CNC programming of mechanical processing, but also in the context of programming coordinate measuring machines. In addition, end-to-end digitalization of the CAx process chain avoids errors caused by manual input that result in costly changes or reworking.

If the potential offered by the 3D master is to be fully exploited, it must be possible to use the 3D models that include PMI along the entire process chain, and in particular after the design phase. This also means in quality assurance, for example, where today the stamped inspection drawing often still provides the basis for creating the test programs. In manufacturing and assembly, it must be possible for users to use the annotated 3D models in electronic form. To do this, they need robust, production-ready hardware and easy-to-use software that can visualize models in either native or neutral formats.

Implementation of the 3D master concept means significant change for the companies and their employees – change that proves worthwhile. First of all, entering PMI once and reusing it saves time and avoids errors that cost even more time and money to correct. The information is available in downstream processes more quickly, which improves process flows in concurrent engineering. The implementation of changes also picks up speed because the information only needs to be changed once and can be updated more easily in the programs for downstream processes. The fact that all the information relevant for manufacturing is added to the 3D model ensures more consistent product data. The data can be exchanged and documented as a technical data package in a uniform neutral format suitable for long-term archiving.

Successful companies not only create MBD models but also apply model-based methods in downstream departments such as procurement, manufacturing and service to maximize the value of MBD. To do this, technically advanced companies are using MBD models in a number of model-based processes, in order to, for example, provide tendering processes with data, develop numerically controlled tool paths for machining and quality inspection, and create technical instructions. The value of an MBD initiative depends on how fully an organization implements it.

Possibilities for further development

For many companies, the 3D master is the first step on the path to becoming a model-based enterprise that communicates all information digitally and makes consistent use of this information. It supplies a complete geometrical description of the product, including the information required to manufacture the individual components. This makes it a core component in the context of end-to-end digitalization.

As mentioned at the beginning, the products and systems to be developed include an increasing proportion of electrics/electronics and software that interact with the mechanical components but are not an integral part of the 3D master. Their attributes and how they work are dictated by market and customer requirements and the constraints of the legal framework, which are defined and recorded during product planning prior to the creation of the first 3D models and accompany the product throughout its entire lifecycle. This means that the 3D master must be linked with additional information in order to create a complete digital product model that ensures end-to-end consistency and traceability in the context of the digital thread.

This digital product model is an information model or information network comprising different partial models that are linked to each other. In addition to the 3D master, these include not only requirements models, functional models and logic models, which are described using model-based systems engineering (MBSE) tools and methods, but also the versions of the software, which are usually managed in application lifecycle management (ALM) systems. This may mean that conventional PLM solutions are no longer sufficient for mastering the complex network of relationships between the information objects.

Companies implementing the 3D master concept should already be thinking about the next steps in the direction towards a completely digital product model that serves as the basis for the digital twin. In addition to geometrical dimensions, this digital product model also has different levels of maturity and validity over time, which are documented with the help of baselines. It can be linked to the operating data from production to monitor and optimize the operating status or to further develop the product during operation. This 3D master, expanded to include the time dimension and linked to the service life, makes additional demands on the IT and PLM architecture, which have to be taken into account when defining a PLM strategy.

Conclusion

The digital thread is designed to link information from product development, manufacturing and operations across systems, domains and enterprises. Companies need to be transformed into model-based enterprises (MBE) if this level of end-to-end digitalization is to be achieved. The information must be available in digital form and be capable of being used digitally. This is why the creation of a 3D master that not only maps the geometrical dimensions but also all the attributes that define the product and are relevant to manufacturing is an important step on the way to a completely digital product model.

As things stand today, end-to-end use of digital information is hampered by the fact that many companies do not yet fully describe their products in 3D. 2D drawings are still a key information carrier for downstream processes, which has the disadvantage that the information cannot be automatically evaluated and processed. In many cases, the drawings still provide the contractual basis for collaboration with external manufacturing partners. Therefore, the aim of the model-based definition (MBD) is to dispense with drawings altogether by adding dimensions, tolerances and other product and manufacturing information as semantic PMI to the geometry already in the 3D model. The result is models that can be read by both humans and machines.

Implementation of MBD and the 3D master concept mean that companies will have to make a fundamental shift in the way they think. On the one hand, they have to change the approach taken in the engineering departments and define uniform rules on how to add which information to the models to ensure optimum use of the models in downstream processes. On the other hand, they have to adapt the processes in the downstream departments and in their supply chain so that PMI can be read and reused automatically. Only then will the time and effort involved provide the desired benefits.

If implemented consistently, the 3D master concept promises considerable benefits. Companies improve communication between departments and with external partners and suppliers because all the relevant information is defined in the model, which also facilitates its archiving. The 3D models that include PMI can be reused for digital tenders or technical documentation. The evaluation of semantic PMI saves a considerable amount of time when it comes to the CNC programming of mechanical machining, but also in the context of programming measuring machines in quality assurance, thus shortening the time to market.

With the 3D master concept, companies are paving the way for a model-based enterprise and thus laying the foundation for a fully digital product model that not only includes the 3D master data but also information from other domains such as requirements management, electrics/electronics and software. PROSTEP provides you with support when defining and implementing this concept and selecting the required PLM capabilities. Please contact us if you would like to find out more.

PDF version of the white paper:
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Do you have any comments or questions?

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