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VR is part of a modern PLM

How do you integrate VR Collaboration into your running PLM System?

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Virtual Reality - fancy and useful in PLM

"You never really know a man until you understand things from his point of view, until you climb into his skin and walk around in it" Harper Lee, to kill a mocking bird

Virtual Reality (VR) is the future of collaboration. In a VR environment no one will literally get into another's skin, but you can choose an avatar and mirror the other participants view during the meeting. You can review prototypes in real scale with teams, long time before the production started and eliminate errors early. The potential is massive, but to be honest: While a head mounted display (HMD) is easily set up and ready to use, **enabling professionals to operate with VR efficiently means reshaping processes and coaching teammates.** It requires you to reflect what might create the highest benefit for every stakeholder and what will most likely flourish the productive communication instead of annoying all involved employees.

In this whitepaper we will explain how the integration of VR into your running development processes and product lifecycle management(PLM) can be realised. To sketch an idea of implementation we combined the knowledge and experience of vr-on and InMediasP in order to guide you through the necessary steps for combining VR and PLM.

The professionals at vr-on GmbH have been working in the field of virtual reality since the mid-90s and thereby garnered well-grounded experience in the field of automotive and aerospace vr-applications. The experts at InMediasP GmbH are known for their consulting services regarding product development processes and implementing innovative processes as well as individual system solutions into industry processes.

First, we will set the stage for some general concepts in Product Data Management (PDM) as well as in PLM and how they are shifting today to Feedback Architekture 4.0 (See Künzel et al., 2016). Thereby we will explain the rising importance of the digital twin in today's production and show how the virtual twin adds additional value to review processes. Combining those two steps, we will introduce our vision of a PLM-System with a virtual twin alongside. Although the digital twin is a quite broad concept with a wide range from an earlier product planning phase to processing field data of a product in real-time (e.g. for purposes like predictive maintenance), we will concentrate on the usage of a digital twin in product development (digital prototype) in this whitepaper. Last but not least, we will give some practical implementation ideas by explaining the possible use cases that can be realised with VR.

PLM is shifting towards new opportunities

For the sake of avoiding talking at cross purpose, we briefly explain what we understand with the terms PLM and PDM in this chapter. The product lifecycle management (PLM) is the process of managing the entire lifecycle of a product from requirement, product planning and development, process planning, manufacture through the operating system to service and disposal of manufactured products (See Eigner & Stelzer 2009). Product data management (PDM) or product information management (PIM) is the business function often within product lifecycle management (PLM) that is responsible for the management and publication of product data (See Eigner & Stelzer 2009). To integrate the VR technology into your processes you'll have to analyze those processes and identify the necessary cost for an implementation as well as possible saving potentials. **To implement VR means supporting the ultimate goal of PDM**. This goal includes the insurance that all stakeholders share a common understanding, that confusion during the execution of the processes is minimized, and that the highest standards of quality controls are maintained (See Eigner & Stelzer 2009). Since VR is a very visual communication tool for everyone to be understood immediately, the earlier mentioned PDM goal is addressed perfectly.

Tradtionally the product definition in regard to design information used to be quite static and linear. Dedicated hours of product planning used to be send into a dark void without knowing how the customers might actually use the product. The lack of feedback from later lifecylce phases such as production has the following consequences: How the product is actually used, or what the results of tests and studies are, is not getting easily into the prototyping phase. Todays established lifecycles of a product development consist of the concept phase, development phase and manufacturing phase until the product gets delivered to the customer. Addressing the approach of Dr. Künzel in his article Engineering 4.0, the future of those processes will be shaped in a circle (See figure 1). In his whitepaper he concluded, that phase-oriented models and hierarchical reviews of different technical disciplines are aimed at requirements that Engineering 4.0 will address in the future. This circle demands a great amount of communication between experts of different fields who will need a communication and interaction platform without having to travel around the globe to attend meetings. Technology around the IoT now facilitates the usefulness of a PDM even further by enabling a feedback structure for the production process. VR in this context is a key tool to ease the communication of complex data between different fields and departments.

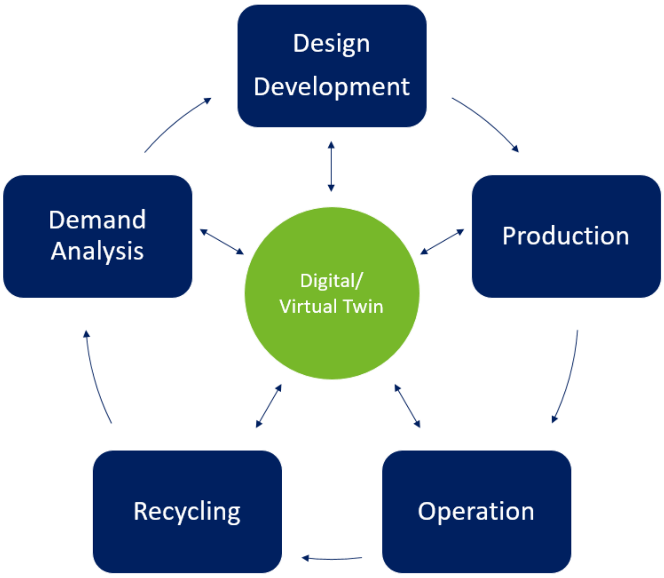

Figure 1: Feedback circle in Engineering
Source: Own Illustration after Künzel et al., 2016

However an innovation process to adapt these trends might seem risky when there are running processes which secure a steady income.

While running processes integrate customers and distributers earlier in the business processes, the new and innovative form of a hybrid process drives to make the changes to modern technology less hasty (See Künzel et al., 2016). Proven business models in sales and leasing can be thereby extended by new service concepts, enabling endless ideas emerging in form of additionally services. With products becoming smarter this feedback can be implemented early on. The concept of a digital twin is the key to this ability to track user behavour and improve the product after the delivery.

The digital twin enables feedback architecture for virtual engineering

A digital twin (or a digital prototype as mentioned above) connects the models via digital thread in order to simulate almost all aspects of the product aiming to predict more accurately the physical product's behavior. All this can be implemented in a prototyping phase long before the first and expensive physical prototype is built. By copying a digital twin into a VR environment as a virtual twin your nontechnical teams or even potential customers are enabled to get a glimpse of the product in the early stages of the prototyping in order to provide precious feedback. Moreover, early user trainings support during development and save time later in the implementing phase. In the scenario seen in the figure above, the Digital Twin/Virtual Twin and the Digital Thread are closely related and depend upon one another to drive full business value.

Dr. Künzels team concluded in their above-mentioned article *Engineering 4.0* that the key element to best nurture a digital twin is the feedback architecture. This is an adaption of a known workflow from software engineering teams working with lean developing into hardware engineering teams. While making changes on the physical prototypes might be quite difficult to realize, the trend of products becoming smarter and thus providing feedback will become a crucial part in product management in the next years.

In feedback architecture this and many other information will be transferred systematically from later phases into earlier lifecycle of the product. This allows the product to be easily and accurately updated and developed according to the requirements of e.g. production or the end user (See Künzel et al., 2016). The architecture is implemented in a virtual twin, emended by a holistic, model-based IT-based management software that eases the development, production, operation and recycling.

Virtual engineering aims to connect the physical and the real world with digital prototypes. The basis for this approach is an already settled 3D-Model based usage in prototyping (See Bullinger 2002; Sendler 2009). This includes Augmented Reality (AR), Mixed Reality (MR) and Virtual Reality tools. These tools enable the visualization of blueprints, provide early feedback for non-experts and help implementing iterative and collaborative workflows in development processes, while reducing waiting time to build physical models and the cost of physical models. But of course, this is just the starting point. The usage of VR is scalable. Aside from product and manufacturing visualization, trainings of colleagues, testing of beta customers, maintenance visualization (MRO) and virtual updates are possible scenarios, providing additional new business and service models or marketing tools. In today's production world, product data is transmitted via optical fiber networks around the world in seconds, while people discussing the digital data are still trapped to maintain in the physical world.

VR enables a participative, agile and cooperative workflow by uniting customers, suppliers, development partners and technical service providers into one virtual room. A VR prototype also helps in setting up factory workflow and training with digital tools, enabling rationalization and automatization from an early state on (See Künzel et al., 2016).

As many great possibilities occur with the use of VR, the main disadvantage is the missing implementation into PLM as we explained in the former chapter. The following chapter gives some hints about what must be considered for an PLM integration.

Considerations for a successful PLM integration

Implementing VR into existing development processes as well as IT infrastructure is a challenging task and requires an understanding about the development processes in general and the involved IT systems. Therefore, in this chapter we first give a brief overview regarding these processes and the involved tools. Then we explain where problems regarding the mentioned integration of VR systems in development processes exist and what kind of an approach is necessary to master these challenges.

Well established CAD and PDM software solutions have been used for more than 25 years resulting in a mature level of integration especially regarding the MCAD integration. There are many solutions for the most commonly used PDM and CAD system pairs, such as Teamcenter/NX, Teamcenter/CATIA, Windchill/CATIA etc. and the fundamental development processes, like release processes or engineering change processes, are also supported by PDM workflows. Such solutions are now becoming available to a broader spectrum of companies with affordable products like Teamcenter Rapid Start which is built for a fast and smooth introduction process or ARAS which is open source, flexible and cost-efficient.

VR and AR systems, on the other hand, are still new technologies and a lot of VR/AR software development teams still struggle with fundamental problems, e.g. with hardware related problems, making smaller companies doubt the adoption of these technologies. These technologies don't have a fully functioning interface to PDM systems and therefore the VR engineers work with downloaded data which are often outdated even at the same day in the early stages of the development process. The results of the performed VR supported investigations (VR Meetings or maybe just rendered images) are also only stored locally and cannot be supplied back to PDM systems. Therefore, these prepared VR scenes or in general the results of the VR Meetings (result documentation) are hardly reused even though they would have the potential to. Thus, the VR tools and processes are isolated from the development process itself and the PDM workflows. Consequently, these processes are only considered as "downstream processes" and are not integrated in the development process as they should be (see figure 2).

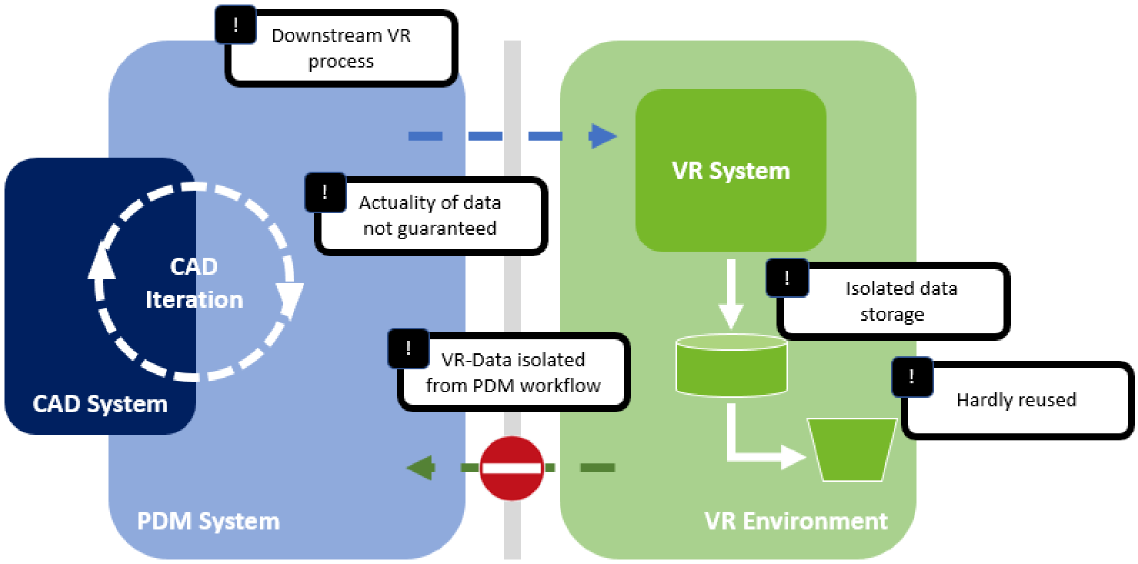

Figure 2: bidirectional data interaction between VR/AR tools and PDM systems is impossible
Source: Own Illustration

Problems regarding the bidirectional data interaction between VR/AR tools and PDM systems and can be summarized as follows: Data exchange between PDM systems and VR software is challenging, making VR specialists often work locally while investing a lot of time in manual data preparation, sometimes having to repeat the same procedures more than once for the same visualization scope. As a result, progress is not only slowed down but data cannot be easily re-used. Moreover, problems occur with the metadata as for example an alternative assembly-structure is often needed during a VR-session, making revisioning and further data update at the PDM software quite difficult (non-uniform structures).

Nevertheless, the potential of these tools is enormously high as we explained earlier. What is needed, are adjustments in the PLM System so that they support these new ways of communication. Therefore, InMediasP works together with vr-on to address all these issues. We aspire to create solutions and handle these challenges to get the most out of VR while accelerating and improving the product development process.

It is necessary to understand and define the main processes for the integration of VR into the PDM system, regardless of the planned use cases that are described below. For this purpose, in cooperation with vr-on and InMediasP, an approach is developed to enable data exchange between VR and PDM systems with the process of integrating a digital twin into a virtual world. This requires an interactive data processing operation, as seen in figure 3. The green domains are the fields of responsibility of vr-on and the blue belong to InMediasPs scope of duties.

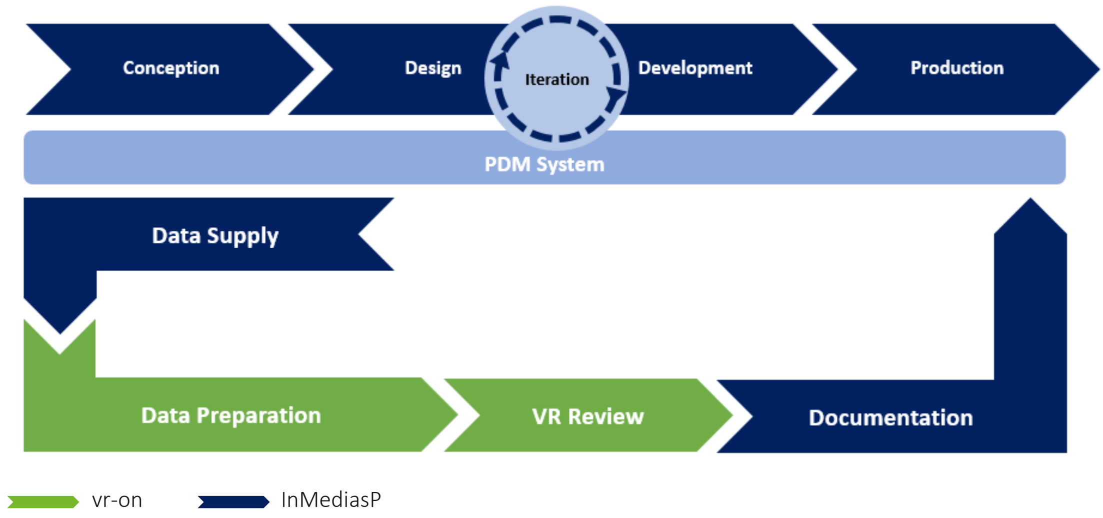

Figure 3: data exchange between VR and PDM system with a digital twin

VR & PDM integration entails the following steps which are illustrated in figure 3 above:

- **Data Supply:** Managing the PDM structures including versions and variants and supplying the geometrical data (and optionally material information) to the VR system. An embedded converter may also provide the geometrical data in the necessary format with the required quality, e.g. an fbx file with specific level of details.
- **Data preparation (manual or automated depending on the case-scenario):** Preparing the data to be used in a game engine, by setting up a more performative virtual twin.
- **VR Review:** Evaluation and validation of design, ergonomics and buildability by a virtual twin. Metadata and result documentation are generated.
- **Documentation**: After the VR session takes place, the results must be documented to the PDM system accordingly, making them available to the whole development team.

These four steps need to be designed according to the planned VR use cases and application needs of the company in general. Depending on the needs this process steps may be realized accordingly.

The application of VR depends on the type of product regarding the complexity and range. Furthermore, the type of development and order processing must be clearly defined, e.g. engineering to order or manufacturing to stock. Those factors as well as the user or usage behavior should be taken into consideration.

By analyzing these factors, the following parameters can be derived:

- **Visual quality in VR:** Low or high level of details (LoD), high quality rendered images (static) or low-quality images using just the simple CAD materials (dynamic), …
- **Feedback characteristic:** Depending on the case the form and the quantity of feedbacks may change dramatically
- **Need for the actuality of 3D-Data:** Users needs for current 3D-Data change depending on the stage of the product development process

The figure 4 illustrates the relationship between visualization quality, feedback characteristic and the need for the actuality of the 3D-Data, helping to analyze the application requirements.

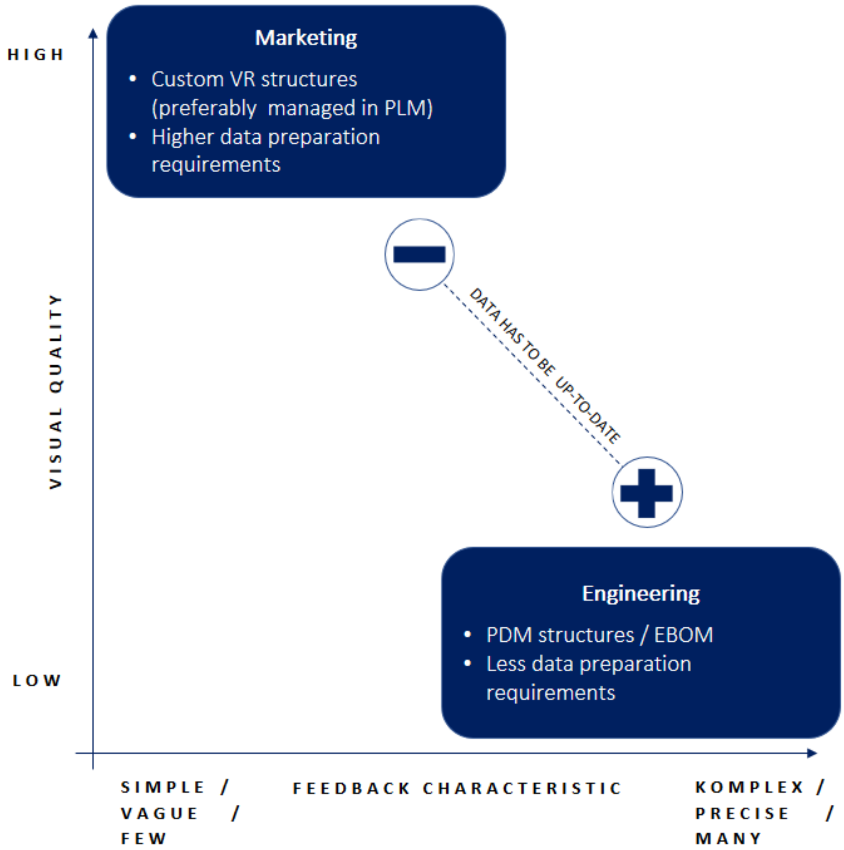

Figure 4: Relationship between visualization quality, feedback characteristic and need for the actuality of the 3D-Data

The visual quality is illustrated on the y-axis and the feedback characteristic on the x-axis and evaluated from low to high in relation to an individual use case. In addition, the feedback characteristic can be rated from simple to complex, from vague to precise and from few to many. Moreover, the up-to datedness of data is classified on the diagonal line from old to current.

The categorizations follow the progress of product development, because different target groups are addressed, giving diverse types of feedback in return. End customers simply judge whether they like it or not, the small technical differences in the data mostly don't matter (less need for the actuality of the data). Developers, on the other hand, provide detailed feedback based on up-to-date data and small technical changes.

In the following, we describe two different use cases that demonstrate the requirements for visual quality and feedback characteristics.

- A marketing campaign requires a high-quality visualization of a product, to present it as realistically and convincingly as possible to the customer. The feedback from the VR system to the PDM system is insignificant, because at that time the state of product development is already well advanced and minimal deviations of the product are not noticeable.

- At an earlier stage of product development, e.g. when merging various assemblies for the first time and the first design review, data must be up-to-date and the feedback is precise, as participants are most probably **engineers/designers** and **decision makers**. Minimal deviations seen in the VR environment are discussed and the results must be documented under the correct position with the right attributes in the PDM system to make this information available for everyone in the team. Some PDM workflows, like release workflows or workflows regarding the engineering change management, should or can be started accordingly based on this information.

The challenge of bidirectional data interaction between PDM and VR-System and mapping of non-uniform structures (VR and CAD structures) shows its importance in such cases (figure 4).

On one hand, PDM has to support the handling of non-uniform product structures (VR vs CAD structures) and provide the necessary data to the VR software including structure, positions, materials etc. via an integrated interface. On the other hand, this interface has to provide the necessary elements of a results documentation belonging to a VR session to the PDM system and the PDM system has to manage this sum of data accordingly. The scope and the type of data which are bi-directionally transmitted via the interface depend on the need and use cases of the user.

In summary, VR-technologies combined with PDM offer a wide range of possibilities as long as the involved processes are clearly defined and the responsibilities explicitly regulated. If that is the case, tailored solutions can be developed and successfully implemented.

How to get started with VR?

After gaining a deeper understanding on the process and implementation side, we now take a closer look how the use cases benefit most from VR and how to start. The best use cases generating the highest benefits are based on our experience *VR Meetings, VR Reviews* and *VR Trainings*. Additionally, VR Studies enable companies to understand the user's behavior and these findings can be added to the prototyping phase. The use case you may choose might be a first step into VR technology but will certainly not be the last and most probably expand into other fields in the company. However, for the actual implantation of VR, we advise our customers to start with the most preferred aspect in form of a pilot project and scale the usage of VR at a later state. For a better understanding we provide a short checklist.

Starting on VR
❑ Indicate most urgent project ❑ Get VR Hardware ❑ Ensure your teammates have some experience with VR, Game Engines or 3D-Data, ❑ Try out new tech in your team to give your VR project a boost ❑ Expand the VR technology into other departments and phases of product development

Figure 5: Checklist on starting with vr projects

For all use cases a VR presentation without the possibility of collaboration is useless. Collaborating in VR means, on the feature side, to transmit audio in real-time and a fast network wide distribution process. As mentioned before, the main advantage regarding the VR usage is to enhance communication between experts and non-experts (or experts in another fields). The necessary requirements for VR, beside the VR-headset, is a high-performance PC. We strongly recommend using a PC with at least a GTX 1080 to achieve a good quality in VR collaboration. With a Game Engine like Unreal or Unity you will be able to implement most of the named features. However, you must keep in mind that many of our suggested features need to be sketched out for you and for your specific needs.

When implementing VR in the early design phase you need functionalities that enable you to sketch ideas on a whiteboard, generate and transform objects without too much detail and import/embed PowerPoint or other formats in VR. Later, when VR is implemented during the development phase, the design review use cases should enable you to switch between geometry and material variants to select a product line. For this data export, notations and screenshots help to fixate the decisions. Later, when the product is in the manufacturing line, a VR-Training requires animation, collaborative aspects, mirroring the view and spatial audio. On a higher scale manufacturing can be planned/reviewed according to the new model, which requires the ability to generate and transform objects on the feature side.

VR Meeting Features	VR Review Features	VR Training Features
❑ Whiteboard	❑ Switch geometry	❑ Spatial audio
❑ Generate objects	❑ Switch material	❑ Mirror others view
❑ Transform objects	❑ Start animation	❑ Start animation
❑ Import of Web application	❑ Make Annotations	❑ Make Annotations

Figure 6: Features sorted by usecases

To prevent co-workers from grinding their gears over this new VR technology, small steps should be taken to build confidence in the new technology and later transfer it to the new processes. Cultivate the knowledge gained in smaller projects first and let one unit teach and inspire other units in the company. This is a recommended approach in Human Change Management and increases the chances for acceptance of this new technology.

To mirror an actual meeting, users should be supported by a moderator throughout the meeting and do not require specific expertise for software operation. In order to supply the outcome of those meetings into the PLM system, a concept is needed to make easy annotations during the session. The decision-maker should for example be able to release the data directly in VR session and it will be automatically transferred to the PDM. Since no additional documentation or authorization is necessary, the virtual twin simplifies and accelerates the decision-making process.

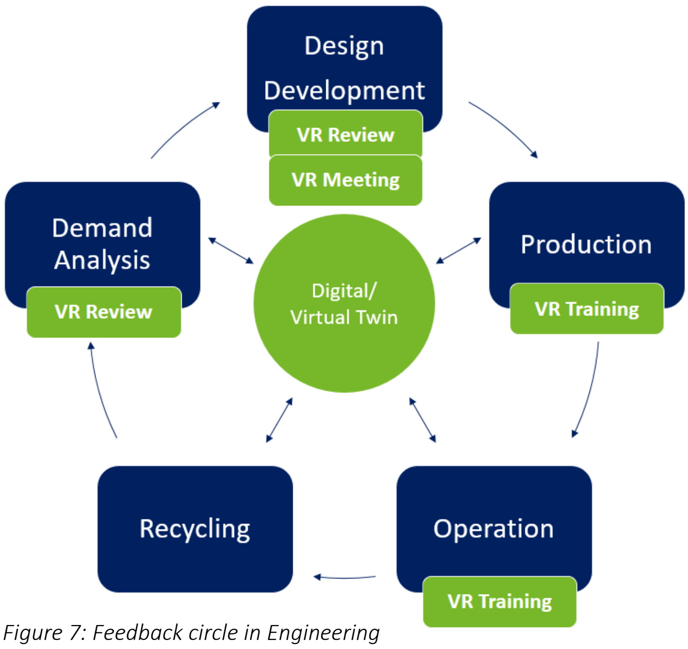

Figure 7: Feedback circle in Engineering

The benefits for globally working teams is the ability to connect and communicate directly with the team with a data set which in result reduces the need for real prototypes. Expenses for physical prototypes and business trips can be saved. Via VR-Collaboration several variants can be shown and compared in a presentation. As a result, complex iterative processes are accelerated. This will reduce the time to market launch significantly. In the development process, this approach must encrypt the presentations and allow access to the data exclusively for users with appropriate rights in order to provide the high security requirements. In STAGE, data integrity remains always at the creator of the data.

The best and most concrete argument however is always the factual numbers. With our online calculator for potential savings you'll find that you'll already save approx. 100.000 € per year (a lot of travel time and travel costs) just by considering your five globally distributed teammates, who meet maybe five times a month. Less travel time means less stressfully crowded hours in traffic, train or plane for your colleagues. Less travel cost means more budget for the organization to invest in new ideas and technology sky rocketing and monitoring the production. Packed with all those ideas on features and technical requirements it is time for some final thoughts.

Final thoughts

We hope to have given you some first ideas and more concrete concept of how VR can be usefully implemented into your PLM.

The future of PLM is shaped in a circle demanding a high amount of interdisciplinary communication between different fields. A common and fast understanding of the product means using an intuitive visualization tool like VR with a digital twin in the center. Thereby we concluded that VR without co-working functionalities are only half as powerful. The main challenge for starting in VR is to analyze the own PLM correctly in order to identify the requirements for VR software. First tools for analyzation and indication of the usage were sketched during this whitepaper. Additionally, we illustrated requirements and features for VR Collaboration.

All those advices and ideas we gave sound wonderful, but they all also seem to need quite some time and costs and of course maybe risks, especially regarding having some possible resistance from colleagues that are skeptical about new ways of work.

On the other hand, the complexity of tests and adjustments in production will increase in the coming years. Experts of multidisciplinary fields like design, marketing and production working decentralized must communicate using the 3D-Data frequently. All of them aim to build a product that meets those high daily and regulatory constraints and requirements. The question is where a company tackles those challenges with the right tool and mind set or waits until the changes force a fast reaction. Summed up, the company that can connect their employees through physical distances and maintain leadership in distributed teams will lead their industry.

We discovered that VR-Tools in PLM is for the following cases an advancement.

- If you have bigger VR-meetings with non-experts
- When you want to classify ergonomics of your products
- When spatial effects are of weight for the well-being
- If there is review of a control panel necessary
- When security regulations need to make sure that nothing is covered
- When Teams are distributed and come together regular and would need to travel
- When data can be reused several times for example in training

Of course, the processes in companies are as individual as the people working for them. In case you have questions regarding the tool itself or doubt the system and process integration of VR is too challenging, don't hesitate to contact us and we, the experts of vr-on and InMediasP, will be happy to assist you about any of your concerns.

Virtual Reality is creating new challenges and chances for PLM and we are proud to be part of this development.

For further information regarding our services check our websites by clicking on the logos:

Check our tool STAGE and further services

Check our services regarding the system and process integration

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