Visualization vs. Communication

Enabling the Model-Based Enterprise with 3DPDF

A 3DPDF Consortium Whitepaper

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Introduction

Within industries such as discrete manufacturing, heavy construction, architecture/engineering, and process plant construction and operation, the word "visualization" is commonly heard. It is however lacking in clarity – what exactly do we mean by "visualization"? Is the ability to simply "see" a three-dimensional object collection or product at any level or scale, which is the generally accepted definition of visualization when used in this context, a sufficient description?

The concept of the model-based enterprise (MBE) originating from, and now embraced by, the U.S. Department of Defense to reduce procurement and lifecycle costs, demands that model-based definition (MBD) data be leveraged throughout the product lifecycle and across job roles. As originally conceived, visualization, when used to describe a lightweight presentation of the MBD data, is insufficient to meet the goals of MBE. The introduction of support for interactive 3D data within the ubiquitous PDF standard has opened up new avenues for organizations to iterate and improve their business processes by leveraging this rich 3D data in a variety of difference ways, well beyond simply "seeing" the representation.

This paper will give the reader some context for understanding where visualization is important in enabling the model-based enterprise, and where something more is needed to fulfill the objectives of MBE.

Terminology

This paper makes use of a number of terms that are either new to this topic, or if not new, benefit from a clearer definition, and the reader is advised to keep these definitions in mind when reading.

Visualization	As it is commonly used in the manufacturing industry, visualization is used to perform any number of activities, such as digital pre-assembly, human factors analysis, or simply being able to interrogate a design feature of one sort or another – also called view/measure/markup. Almost always refers to 3D data.
Communication	Although not commonly used like visualization, the term communication is being used in the context of this paper to refer to the act of providing all the relevant information, not just 3D data, needed by someone in a given job role where the information is contextually correct for the role, presented unambiguously, and with no barriers to consumption.
Derivative	The term derivative is being used increasingly to describe a format-specific representation of a design authority that is one or more transformations removed from its original authoring environment. For

	instance, a product designed in a CAD system would be considered to be the design authority when represented in its native format; publishing that design to STEP or JT would be considered to be a derivative representation of the design authority.
Rendition	Outside of manufacturing, every industry considers document management, also called Enterprise Content Management, to be a key IT strategy since the production and management of documents is central to every business. In this context, a document – usually authored in Word, Excel, or PowerPoint – is that particular industry's equivalent of the design authority in manufacturing. The term rendition is commonly used in these cases to describe what a PDF is; a "rendition" of the authored document that is used for distribution to provide (and collect) information relevant to a particular job role. That definition is exactly the same in the context of this paper, with the exception of the fact that included in our case is 3D data within the PDF file.
Transformation	The act of processing data contained in one format, to a second or derivative format. For instance, going from a native CAD format to STEP or JT, is a transformation process. Similarly, going from JT or STEP to a format native to any application, is also a transformation process.
Exchange	Exchange is a meta-concept; one that is defined using other concepts. In this case, as is commonly used in manufacturing, exchange means the transformation of a native format into a derivative format, the delivery of that derivative format data to one or more third parties, and the transformation of it back into one or more proprietary formats.
Publishing	In the context of this discussion, publishing is another meta-concept; the act of taking a derivative format and incorporating it with other data to create a rendition, which then becomes a distributable information package – a document if you like, but entirely digital and interactive – to be used in a large variety of use cases, including but not limited to regulatory compliance, communication with customers and suppliers, process compliance, etc.

Defining the Model Based Enterprise

According to the U.S. Department of Defense, the term model-based enterprise (MBE) can be defined thusly:

A fully integrated and collaborative environment founded on 3D product definition, detailed and shared across the enterprise, to enable rapid, seamless, and affordable deployment of products from concept to disposal[1]

Figure 1 - Model Based Enterprise, courtesy of National Institute of Standards and Technology

As a strict definition, this is accurate, but in practice what does it really imply? The consensus among manufacturers who are implementing this strategy can best be summarized in the following way.

If you are implementing a model-based enterprise strategy, you will:

- Fully detail the 3D model(s) with all the necessary product manufacturing information (PMI) needed to make the product in accordance with MBD practices
- Eliminate the 2D drawing as both the model authority and the primary means of communicating design intent
- Provide visual representations of the model to support analysis functions such as computer-aided engineering, digital pre-assembly, and viewing/measuring/markup applications
- Re-use the MBD data for all product documentation and information transmittal requirements, such as request for quote (RFQ), quality documentation, training, maintenance and support, and similar lifecycle functions
- Manage the above using product lifecycle management (PLM) and enterprise content management (ECM) tools and processes

[1] http://model-based-enterprise.org/model-based-enterprise/Default.aspx

Assuming this is a non-trivial effort, what's the value? According to research done by the National Institute of Standards and Technology in conjunction with the Department of the Army and the Defense Logistics Agency, the savings achievable through MBE practices can result in:

- Reduction in non-recurring costs of between 50% and 70%
- Acceleration of time to market by as much as 50%

These benefits are, across the product lifecycle, beyond significant, and make MBE something every manufacturer places at high priority in their operational strategy.

Many of the individual elements of an MBE practice, such as what's required to fully detail an MBD definition, are not covered in this paper. Our focus here is to take two practices, which we have defined as visualization and communication, and define the difference between the two, show why both are important, and where they should be employed.

For more information on MBE, a good place to start is the home of model based enterprise concepts, www.model-based-engineering.org

What is Visualization?

We've defined visualization above, but since a picture is worth a thousand words, let's try to show by example what we mean. Consider the part shown in Figure 2 below. This is a single part, with a number of machined features. The part is fully detailed, with all of the product manufacturing information (PMI) data, such as datums, tolerances, and manufacturing support data, attached.

In this visualization application, you have the ability to navigate both visually by identifying features of interest, and using the product structure. The view presented is fully 3D, and can be zoomed, panned, or rotated to provide the user with the correct orientation. Sometimes referred to as "model-spinning", this is the presentation of a typical "visualization" application.

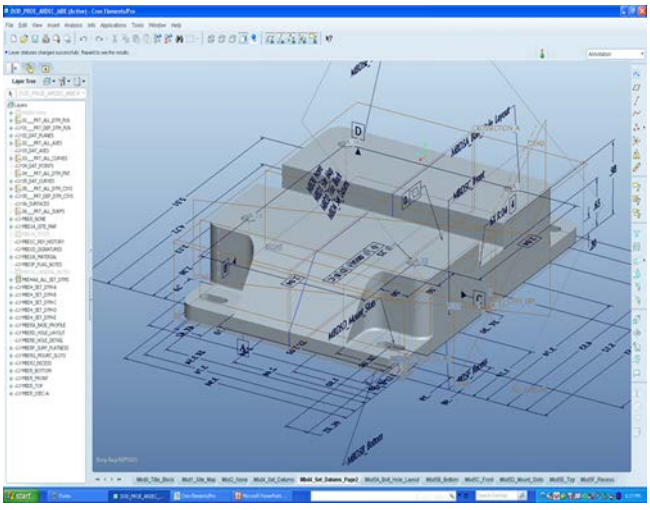


Figure 2 - Visualization Example

In order for this to be useful, two things must be true: the user has access to a licensed copy of the visualization application, and the user has the necessary training and skill to use the application to gain the information required to perform the task at hand.

Unfortunately, visualization applications typically are proprietary software which much be purchased, maintained, and users trained

prior to deployment. All of this implies a cost, often significant, that limits the ability of the visualization application to deliver on the MBE benefits for many, but not all, use cases or business processes. In the cases where it is not the right solution, one additional item is missing – the presentation of other information beyond just the MBD data itself, to support the information required for the person in that job role to efficiently complete their task. It is this last point that helps us define how visualization differs from communication.

Communication: Leveraging Visualization

The primary differentiators between a visualization-based use case, and a communication-based use case, are the following:

- Any number multitude of different data types – 3D, 2D, text, PMI, metadata, audio, video, product structure, animations, etc. – might be needed to completely inform the user of everything needed to execute the task described by that use case
- It must be assumed that the ability to consume is ubiquitous; that is, the consumer's device has to be capable of consuming the data as delivered, in the context in which it was authored, and that the consumer has the necessary skills to interpret the information accurately
- Visual data is related to, and can be referenced to, the other data types present when delivered
- The data as delivered can be archived or persistent to meet the regulatory or compliance needs of either or both the author and the consumer

To illustrate the concept above, let's take the part from the previous section, and present it in a form that exemplifies communication. Figure 3 shows this part in the context of a PDF document representing a rendition of the original MBD data shown in Figure 2. Using a PRC file to provide the visualization data, the author of this PDF file has also included meta-data from an external business system, shown as a table on the right hand side of the PDF file. The main view window contains a fully interactive 3D model of the part above, but the representation is much clearer and easier to understand. In addition, the author of the MBD data (not the PDF rendition) created in the original MBD data "detail views" showing specific areas of interest to, in this case, a manufacturing engineer,

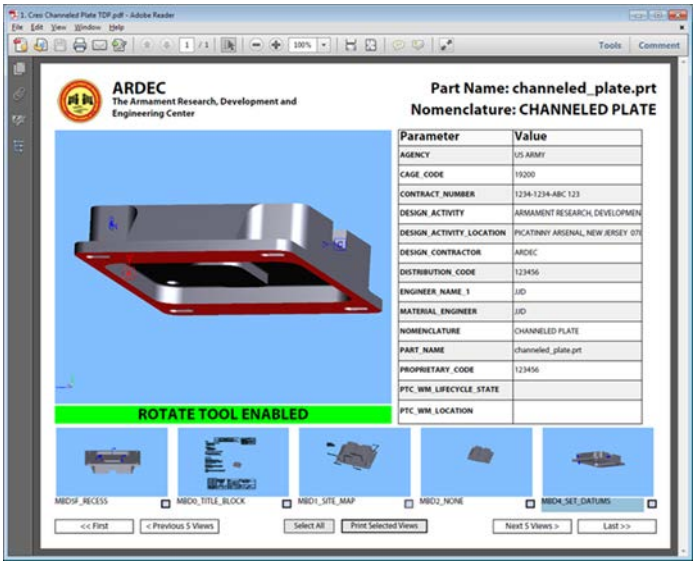


Figure 3 - An MBE-Ready 3DPDF Document

who could be either internal to the organization, or a supplier (such as one receiving an RFQ). The various detail views are represented as "thumbnails" which can be viewed in a banner fashion in sets of five using the provided navigation buttons. If a detail view is selected, the main viewing window is replaced with that view, which is also fully interactive. For example, if the engineer only wants to see the datums, he simply selects the appropriate thumbnail.

While this example is simple, the range of communication solutions that can be deployed is extensive, and can be very complex. In a following section, we will describe in more detail why 3DPF is unique from any other platform in its ability to address the communication needs of manufacturers, but first, let's talk briefly about why both visualization and communication are needed.

The Value of Both

It would be easy, but dramatically incorrect and costly, to conclude that the ability to "communicate", negates the need to be able to "visualize". Consider the diagram in Figure 4, which describes a simple product development process over three steps: work in process design approved, and released. On the vertical axis we have frequency of change, and on the horizontal axis time. As you would expect during the initial phases of the development process, change activity is at its highest. Design iterations are frequent and range from minor to major.

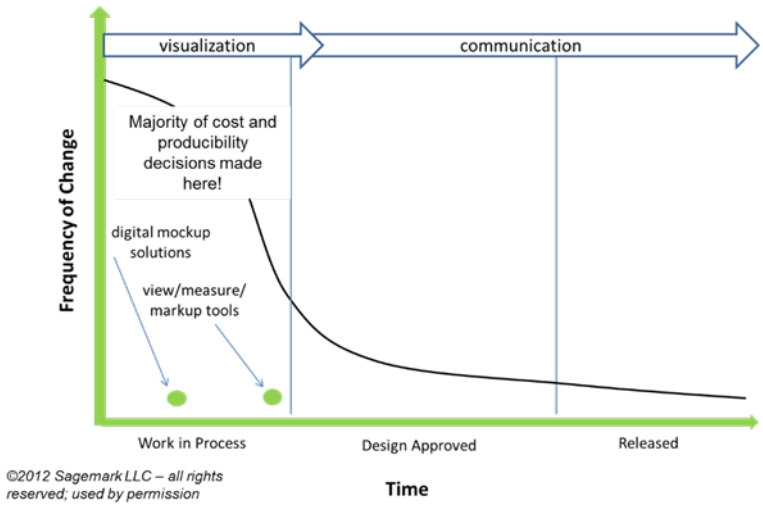


Figure 4 - Visualization in the Design Process

As a consequence, tools to very quickly evaluate things such as manufacturability, conflicts in position, and the effect of human factors, are needed to deliver analytical information to allow decisions to be made quickly and at a high level of quality. It is at this point in the development process where most of the cost and producibility decisions are made. This makes visualization tools not only necessary, but very well worth their cost of ownership in acquisition, implementation, training, and support. What is also true is that visualization applications represent specialized needs, and accordingly, satisfy the requirements of a small number of users.

Once the level of change activity starts to wane, a different dynamic presents itself. With the product definition largely established, the concern changes to how to effectively drive down cost and push quality up through the leveraging of that data downstream to support a wide variety of use cases, as we show in

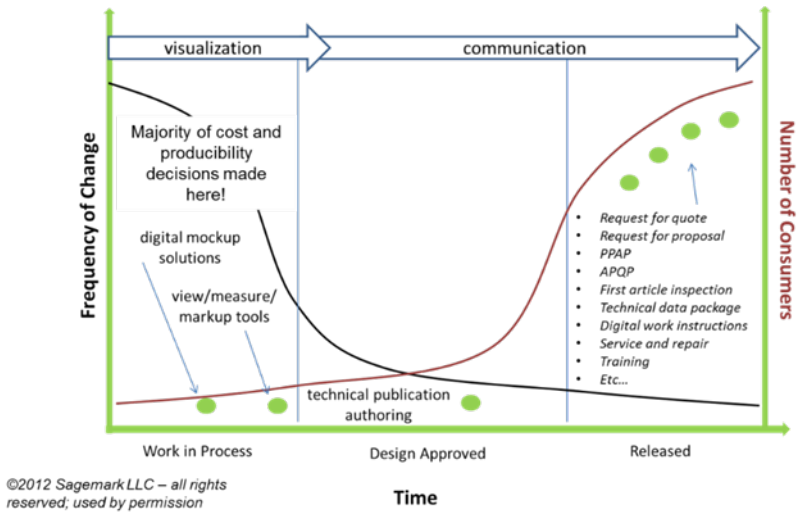


Figure 5 - Downstream use cases

Figure 5. The number of use cases here expands dramatically, as does the number of people who have the need to consume the data which, from an MBE perspective, you want to enrich with the addition of dynamic, interactive 3D data representing the product definition. More so than in the earlier phases of a product design effort, there is also the consequence of not having visibility or control over the environment of the consumer. For instance, if I am the primary manufacturer, and I wish to combine the product definition of various subassemblies or components to do spatial analysis (space allocation) or human factors analysis, I more than likely know who the person is that will perform the task, and have control over their hardware/software configuration. Conversely, the odds are that if I author an interactive maintenance procedure, the consumer is probably not in my organization, and I have no visibility to what software assets might be available to consume my work product.

3DPDF – The MBE Enabler

What sets 3DPDF apart from other derivative format representations, is its unique ability to create rich renditions of all kinds of data, including in addition to what is represented in the way of 3D information, such data types as 2D drawings, audio, video, animations and images – all encapsulated in a ubiquitously consumable form that includes forms, templates, digital rights management and signatures. A key point in addition to the ubiquity factor is the presence in virtually any organization of the infrastructure necessary to properly support the generation, delivery, consumption, and management of PDF documents. After all, it is used in every functional area of the company beyond engineering and manufacturing – finance, human resources, purchasing, marketing and sales – to name a few.

PDF Overview

A brief overview here of PDF will help highlight some of these capabilities. First and foremost, PDF is an ISO standard (ISO 32000). It has several elements, shown in Figure 6. While most formats for geometric representation focus on the geometry, product structure, and (sometimes) the product manufacturing information (PMI), PDF brings a set of data definitions, part of the standard, that describe how these other data forms can be consumed. It also adds the capability to contain forms for

the collection of data, digital signatures, digital rights management, and the ability to include data of any type at all within the PDF package as an attachment.

In addition, PDF also supports the ability to customize behaviors between the data in the PDF file, such as cross highlighting or cross referencing, and it also support linking to external sources of data.

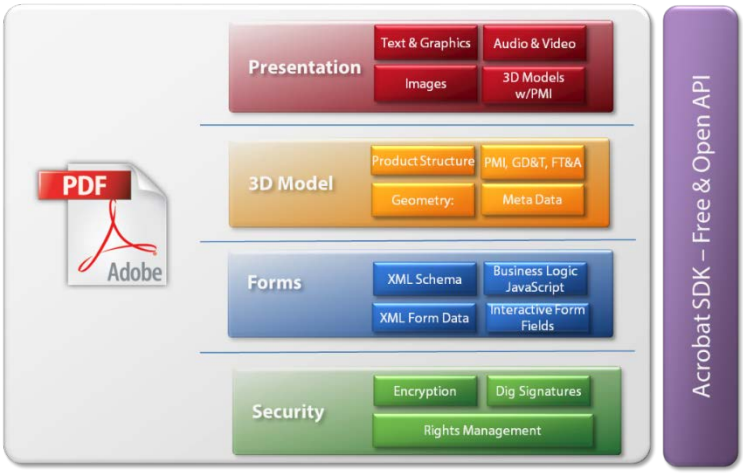


Figure 6 - PDF (ISO32000) Architecture

3D Data in PDF

There are two ways in which interactive 3D data can be represented inside a PDF file, and possess the capability of being consumed via Adobe Reader.

- U3D is a tessellated form of geometric representation that was developed by the 3D Industry Forum, and submitted to ECMA as a standard. It is now on Edition 4 and further development has ceased. ISO 32000 references ECMA 363 Edition 1. U3D contains support for product structure, lighting, and animations, but does not support PMI information.
- PRC is both a tessellation and precise (BRep) form of geometric representation that is undergoing the ISO standardization process, with approval expected in early 2013. PRC is managed by ISO DIS 14739, and work has already begun to expand PRC in version 2. PRC supports product structure and PMI information, and such features as lighting and material definitions, but does not currently support animations.

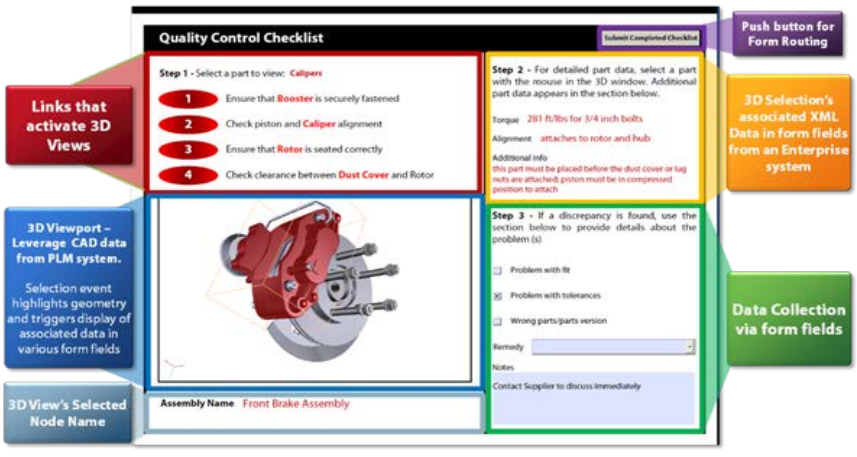


Figure 7 - PDF Component Organization

PDF also contains some other unique features, not commonly understood in the product development domain, such as templates and portfolios. Collectively, these features and the data representation capability, both traditional and 3D, allow the creation of very functional, rich documents from templates, a brief example of which is described in Figure 7. The number of use cases, against which the combinations of these elements can be

combined to produce a solution, are virtually unlimited. Several examples are provided as Appendix A, but a partial list relevant to manufacturing is:

- Marketing brochures
- Interactive order forms
- Shop floor work instructions
- Inspection instructions and documentation
- Assembly instructions
- Maintenance and service
- Interactive catalogs
- Training documentation
- Request for Quote
- Technical data packages

The Publishing Process

The publishing process employing 3DPDF practices, is very straightforward, and is familiar to most IT departments. The difference in an MBE context is the addition of the need to produce a PRC (or in some cases a U3D) file to incorporate. The diagram in Figure 8 shows this process. There are a number of advantages to adopting 3DPDF:

- Publishing is an established process in most, if not all organizations; adding 3D support leverages those processes and associated investment
- The ubiquity of Acrobat Reader on almost any device delivers the potential of consumption without barriers or cost; proprietary clients and controls for Office applications have significant issues with enterprise support and security
- Renditions tailored to specific use cases, along with ubiquity, assures maximum ROI through common use by combing 3D data with virtually any other form of data needed to fulfil the purpose of the rendition
- The pervasiveness of PDF has fostered the creation over many years of a rich ecosystem of tool providers, educational organizations, and subject matter experts

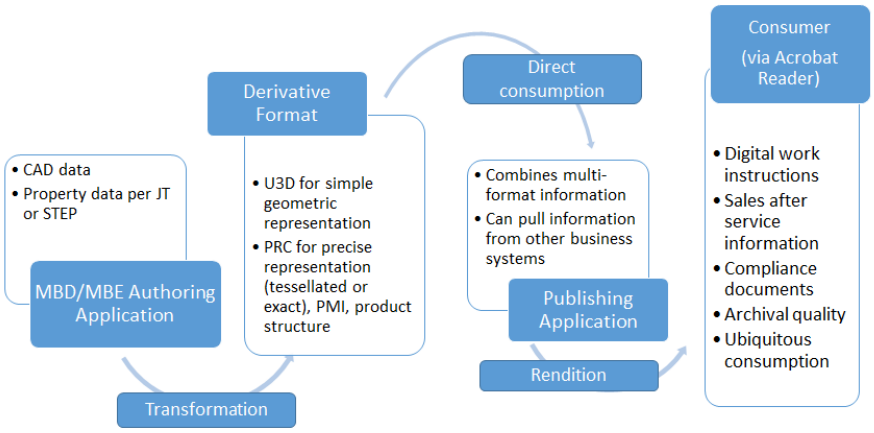


Figure 8 - 3DPDF Publishing Process

Let's review the high-level value proposition that 3DPDF is uniquely suited for communications purposes:

Ubiquitous access	Acrobat Reader is on 98% of devices worldwide
Multi-type data	ability to support 3D, 2D, audio, video, images, generic data, text, metadata
Customization	can incorporate Javascript, define custom templates, enable behaviors on the data
Infrastructure	Any enterprise has an established infrastructure, such as ECM, to accommodate PDF, already in place
Neutrality	A true international standard guarantees it is driven by the community and protects your investment in tools, processes and data
Value	Both the initial investment threshold, and the deployment cost, are very low relative to enterprise solutions, and the ROI payback potential significant

Summary

The goal of this paper was to answer these questions:

- What is the difference between visualization and communication?
- Why both are essential to an effective model based enterprise (MBE) strategy?
- Why is 3DPDF is ideally and uniquely positioned to fulfill MBE objectives?

In summary, the answers to the questions are:

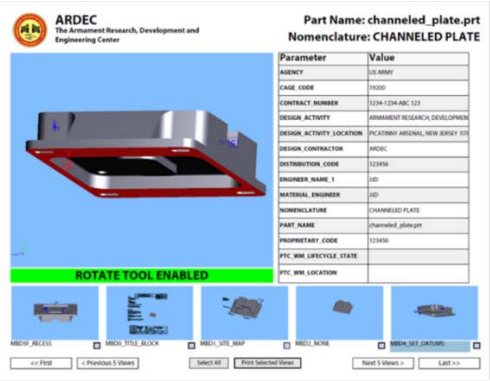
- Communication incorporates visualization with other relevant forms of data to provide all of the information needed by the consumer of the document to fulfill their job role, whereas visualization alone does not
- Visualization contributes high value earlier in the product development process when change activity is high; communication's value is delivered after product development has stabilized and the 3D product definition can be leveraged across a wide variety of use cases
- Only PDF, with the inclusion of 3D, can combine all the needed forms of data into a ubiquitously consumable, high value, fit-for-purpose form that is supported by existing infrastructure, is archival quality, and addresses regulatory and compliance requirements

In closing, there are three thoughts for the reader to consider:

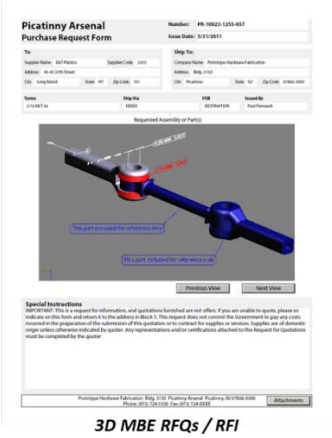
- 3DPDF is a fundamentally different kind of tool than any PLM tool or component – it is extremely "agile", whereas PLM systems or components are not – by design.
- MBE is all about leveraging an investment in MBD to realize ROI deeper into the organization; however, if there is no or limited ability to consume the data, there is no (or limited) ROI
- Consumption of MBD data downstream is a function of agility and fit for purpose, yes, but the biggest barrier is ubiquity and "price to consume"

For more information, or to find out who is supporting the 3DPDF community, please visit the 3DPDF Consortium's website at www.3dpdfconsortium.org, or send an email to info@3dpdfconsortium.org

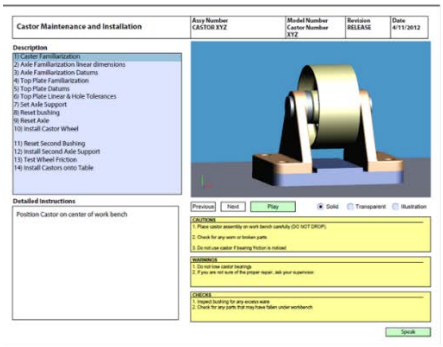
Appendix A – Example Use Cases



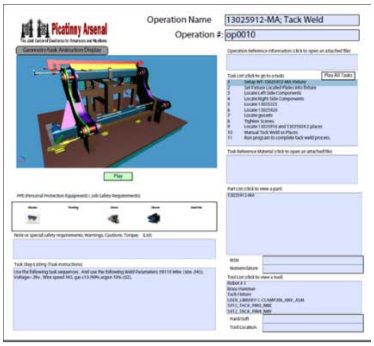
3D MBE TDP
(no 2D Drawings)



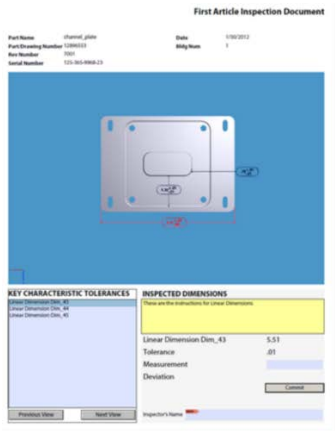
3D MBE RFQs / RFI
(in assembly context)



3D MBE
Shop Floor Assembly



3D MBE
Welding Best Practices



3D MBE
First Article Inspection

Field Repair
Instructions