Driving Digital Continuity
in Manufacturing

A White Paper by Dr. Michael Grieves

Introduction

Digital continuity underpins our ability to have confidence that when we use a piece of information to make a decision that this information accurately reflects the current state of our collective knowledge. We also understand that if a better version of that information is created that we will be informed of that change.

Digital continuity has nothing to do with truth, as in “single version of the truth.” Digital continuity has to do with “knowing” - knowing that information can be relied on to make decisions.

In the 21st century economy, we cannot afford to not know that the version of design we are using has been obsoleted by a newer design. We cannot afford to have engineering send the same designs to manufacturing that manufacturing knows cannot be built properly or cost effectively. We cannot afford to not know what machine to machine communications are occurring that will result in a major manufacturing failure.

This “knowing” information across the product lifecycle has become critical as information has gone from being on physical pieces of atom-based paper to digital bits.

This paper will explore just what digital continuity is, how its consistency is dealt with throughout the lifecycle and especially in manufacturing, and the threats to successfully realizing digital continuity.

Defining Digital Continuity

Digital continuity is the concept that digital data and information can be relied on as unique, authoritative, and consistent as it is being used across the product lifecycle in Product Lifecycle Management (PLM).

These characteristics of being unique, authoritative, current, and consistent are given the term “singularity.” Singularity means that there is one state of information that we can rely on throughout the entire product lifecycle.

Prior to information being digital, continuity was not a major problem because information was on paper that could not be easily duplicated or, if duplicated, copies could be easily distinguishable from originals. The paper original could be examined for authenticity.

The issue with paper information is that, in order for it to be shared, it had to be moved from place to place and only one location at a time had access to it. Information that was updated or modified on that paper was only available to people who had physical access after the changes were made.

The digital revolution changed that paradigm and copies of information, even very complex information such as CAD models, could be easily duplicated. Copies were and are indistinguishable from the original.

The problem changed from information access, now that information could be simultaneously and instantaneously accessed by anyone anywhere, to an issue of confidence that the information one was working on was unique, authoritative, current and consistent.

Therefore, the idea of digital continuity is that we are dealing with digital information that has a characteristic of singularity and that no matter where it is used in the lifecycle it can be relied on as unique, authoritative, current, and consistent. If we implement digital continuity correctly, we have all the advantages of the singularity of paper documents, but with the instantaneous and simultaneous ability to access the latest, updated information.

With singularity and digital continuity, we avoid the problem of duplicate information that almost always becomes inconsistent as changes are made by different users. The idea is that everyone populates and consumes information from a singular, common source.

Digital continuity requires that everyone and everything accessing specific information obtains singular or the exact same information.

Digital Continuity within the Product Lifecycle

Figure 1 shows the model of information continuity throughout the product lifecycle as it existed prior to the digital age. What information continuity did exist, via papers, blueprints, and even prototype physical models, was of a primarily forward movement from product engineering to manufacturing to support. In product creation, product engineering would prepare designs and then “throw them over the wall” to manufacturing who had the responsibility for building those designs.

Figure 1

Manufacturing eventually figured out how to build the designs it was sent from engineering or at least a reasonable facsimile thereof. The finished product was shipped out of the back door as manufacturing waved goodbye, never to see the product again.

While manufacturing performed what is called quality control, in order to make sure that the product was worthy of being shipped, what manufacturing really did was specification control that evaluated the details of the physical product to ensure compliance with the original design specifications. Neither product engineering nor manufacturing had continuity of information that would affirm the product actually performed in operation over its life the way that was expected.

The support and maintenance group, whether the product manufacturer’s, the customer’s, or even a third party, then attempted to keep the product in operational condition with little idea about how the product was engineered or how it was manufactured.

The digital age of the 21st century changed that model. As shown in Figure 2, the idea behind digital continuity is that all phases of the lifecycle are represented during each individual phase. While we still have a progression in time from product creation to product operation and support, the information from these phases is integrated within the other phases. There is digital continuity both within and across the different product phases. While each product lifecycle phase has its main focus on its particular functions, the other lifecycle phases are active information exchange participants. This dramatically decreases information "siloing". Information siloing is defined as information compartmentalizing that is, intentionally or unintentionally, not shared outside of functional or sub functional areas.

Breaking down information siloing fosters cross-functional cooperation. This in turn leads to productivity gains as wasted resources from not having the right information at the right point of time is reduced or eliminated. All functional areas can synchronize their activities so that they can immediately have access and use information as it becomes available. Customer-perceived product quality is improved when supportability is addressed early in the product's life.

In the product creation phase, not only is the product engineered to meet its functional requirements, but the product is also designed for manufacturability and supportability.

When the product moves to the manufacturing phase, digital continuity means that the information about manufacturing or manufacturability is consistent with what was engineered. Information about actual manufacturability is fed back into the engineering phase in order to address potential future manufacturability issues.

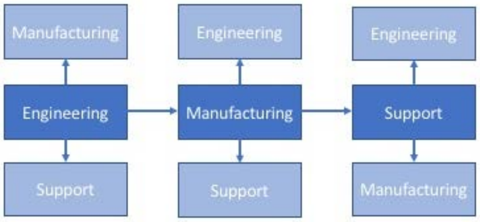

Figure 2

The creation of a Digital or Virtual Twin[1], which is the exact as-built of the product that will be shipped out the factory door, is created to improve the supportability and sustainability of the product once it is in operation.

In the operations/support phase, digital continuity means that information about how the product was engineered and how it was manufactured is available to the group responsible for maintaining the product to its designed functional performance.

Information about the actual performance of the product is fed back to engineering and to manufacturing, so that improvements to the product and its manufacturability can be assessed and improved in order to produce a next-generation product with much more confidence as to how the product will perform in actual use.

This informational continuity was not possible when papers and blueprints contained the information about the product. It is now only in this era that digital continuity can create, use, and update the information that we need in order to make products that perform the way the users need it to perform.

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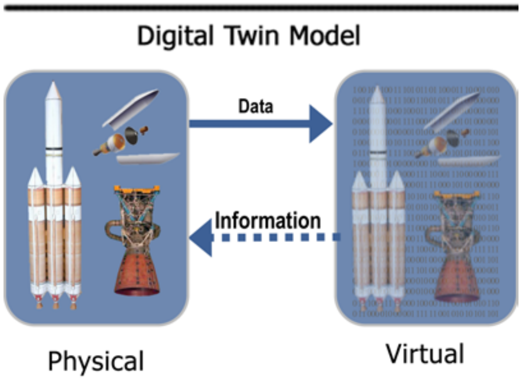
[1] For a full description of the origin of the Digital Twin and the types there are, see https://www.researchgate.net/publication/307509727_Origins_of_the_Digital_Twin_Concept

Digital or Virtual Twin:
A set of virtual information constructs that fully describes a potential or actual phyical manufactured product from the micro atomic level to the macro geometric level.



Digital Continuity Within Manufacturing

In the manufacturing phase, digital continuity goes from being extremely important and useful to being critical. Up until now, we have been working with virtual models in simulation. i.e., within a computer.

While a lack of digital continuity here can be costly and time-consuming, because of inconsistent and incompatible assumptions, no physical damage occurs. In addition, humans are involved in interpreting the results in determining whether they are consistent and reasonable with real world expectations.

When we move on to the factory floor, this changes especially considering the movement to the Industrial Internet of Things (IIoT). When we have physical equipment performing actions based on the digital information that it receives, we move from digital continuity being important to digital continuity being critical. Two virtual robots in simulation having inconsistent information about where the other robot is positioned and then having a virtual collision does no harm. These same two physical robots on the factory floor that have an actual collision incur costly damage and could be a significant threat to humans around them.

Some have proposed simply having machine-to-machine (M2M) communications in IIoT. Without the ability to have human mediation and intervention, the opportunity to have machines run amok in the 21st century version of the Sorcerer's Apprentice is a real possibility[2].

What digital continuity requires in the age of IIoT are two elements: a Digital or Virtual Twin of all the intelligent equipment on the manufacturing floor and an "OverWatch" and Control (OWC) capability by a Manufacturing Operations Management (MOM) system.

A Digital or Virtual Twin capability means that we would have full visibility into the digital information going into and out of manufacturing equipment, along with an understanding of its exact, current state.

However, while this is necessary it is not sufficient to be able to control the manufacturing floor. An OWC capability needs to consider all the Virtual Twins on the factory floor and understand the factory operations, within a single site and across all sites, so that humans can step in and provide control capabilities if the MOM system sees a lack of digital continuity.

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[2] While the Disney animated version in Fantasia may be what comes to mind, this originated in a poem of the same name by Goethe in 1797.

Factory Replication

This idea of a virtual representation of the factory floor was contained in a previous white paper on Factory Replication[3]. Factory Replication proposed to repurpose the factory simulation that had been prepared to understand how the factory would operate and drive the planning simulation, not from assumptions, but from the actual MOM data coming off the factory floor in real time. Factory Replication would visually show what was happening on the factory floor at all times.

While Factory Replication would show what is actually occurring on the factory floor, we would want to take this one step further in the situation where we have manufacturing equipment communicating with each other and adjusting the manufacturing processes in real time. What we would propose as a next step is what is called "Front Running Simulations."

Front Running Simulations

Instead of simply a factory replication showing what is currently occurring on the factory floor, we would run simulations of the next few seconds, few minutes, and/or few hours. We would utilize the current state of the factory data at any specific point in time and simulate from that point on a continuous basis.

This means that the simulation would run in front of the actual factory, providing a window on what would happen to the factory in the immediate future. Using this front running simulation, we could provide OverWatch of the factory and step in to adjust or even shut down intelligent equipment if the simulations indicated a potential problem developing.

This would not only allow us to see what actually is occurring on the factory floor at all points in time, but predict problems in the future based on the current and actual states of the factory floor.

Front running would be especially useful during the manufacturing ramp up of a new product. Production could be simulated forward from each step of the Bill of Process (BoP) utilizing actual information from the steps already performed. When the front running simulation showed that the future processes were not going to produce the product as desired, the BoP could be adjusted right then and there. This would reduce the number of bad builds and compress the time to move through ramp up to full quality production. This is just one example of digital continuity between Product Engineering, Industrial Engineering and Manufacturing Operations.

This integration of virtual and physical activities requires complete fidelity and timelessness of digital continuity. Having machines communicate with each other and having humans work alongside robots, i.e., cobotics, requires this kind of digital continuity. IIoT on the factory floor cannot safely exist without this capability.

Threats to Digital Continuity

Digital continuity is far easier to describe than it is to implement. There are numerous threats to a successful implementation of digital continuity. We

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[3] See Virtual Twin: Manufacturing Excellence through Factory Replication, available at: http://www.apriso.com/library/Whitepaper_Dr_Grieves_VirtualTwin_ManufacturingExcellence.php

will highlight two major ones: one internal and one external.

The internal threat is information silos. What this means is that there is little digital continuity, and that each functional area creates its own version of the information that it needs to perform its functions.

A prime example of this is the engineering to manufacturing interface where manufacturing receives very little information from the engineering group. Manufacturing creates its BoP, defining how the product is to be manufactured, recreating information that is available in engineering. In many cases, information is lost as 3D engineering models are dumbed down into 2D blueprints for manufacturing.

In many organizations, engineering does manufacturing engineering, creating BoPs, and sends it to manufacturing. Manufacturing completely disregards engineering’s BoPs and creates its own. This obviously creates huge discontinuities of information. It also raises the costs of this information both in the duplicative effort itself, but also in that creating information downstream from where it should normally be captured is always much, much more expensive.

The external threat is cyber and cyber physical security. Cybersecurity, that is securing an organization’s information from outside hacking, has been and continues to be a major and serious problem. However, this type of hacking has been passive in nature. The information is stolen, but there is no impact to the organization's use of that information.

When we start to discuss intelligent manufacturing equipment, the opportunity for causing catastrophic problems on the factory floor becomes a real possibility. Active hacking, where information is either corrupted or incorrect or where inaccurate information is transmitted to equipment, is a real possibility. This would cause equipment to perform dangerous activities or even act as weapons on a factory floor.

Securing this intelligent equipment from active hacking and penetration is the number one issue that will prevent IIoT from being a reality. An intelligent machine sending and receiving only accurate and authorized information must be a core and inviolable requirement for digital continuity.

These two threats come together when suppliers are taken into consideration. Siloing is not simply an intra-company issue. Siloing impacts suppliers who now are involved in all phases of the product lifecycle. Siloing information from suppliers impacts digital continuity. However, sharing information with suppliers increases cyber security risks.

There are many other threats to digital continuity, but these are two of the major ones that organizations need to address if there is to be digital continuity.

Conclusion

The movement of product information to the digital domain in the 21st century has meant that we do not have physical items, like pieces of paper, which we can authenticate as being reliable information for decision making.

Digital continuity is meant to remedy shortcomings of the digital environment by ensuring that information is unique, authoritative, current, and consistent, or more simply, has the characteristic of singularity. This ability to rely on information is necessary both within and across the different phases of the product lifecycle.

Digital continuity also means that the same information is available instantaneously and simultaneously to anyone anywhere with the proper authorization.

Digital continuity has its representation in the Virtual Twin which is the digital or information version of the physical product and processes.

Digital continuity is especially important in the manufacturing phase, because we are beginning to remove the human as the interface between machines and rely on machines communicating among themselves. With this new model, it is imperative that we have two aspects of digital continuity, a Virtual Twin of all the equipment so that we know what the machines are doing any point in time and OverWatch capabilities, which is the ability for humans to step in when we see issues arising in machine to machine communications.

On the positive side, once we have these digital continuity capabilities, we can drive our factory simulations with actual data from the factory floor and create a factory replication that will show what the factory is doing down to the machine level at each instance in time. We can also simulate through front running what will happen from that point forward in seconds, minutes, hours, or even days.

There are many threats to this model. Two that were highlighted here are the internal threat of information silos and the external threat of a lack of cyber physical security.

Digital continuity is the core characteristic that we need for the 21st century digital world. This paper introduces a brief explanation of digital continuity and the opportunities and threats that it faces.

About Dr. Michael Grieves

Dr. Michael Grieves is a world-renowned authority on Product Lifecycle Management (PLM). Dr. Grieves has written and lectured extensively on the topic and is a frequent keynote speaker on PLM. Dr. Grieves' works include the seminal work on PLM, Product Lifecycle Management: Driving the Next Generation of Lean Thinking (McGraw-Hill, 2006) and Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management (SCP, 2010)

Dr. Grieves is the Executive Director for the Center of Advanced Manufacturing and Innovative Design (CAMID) at the Florida Institute of Technology and a University Research Professor.

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Dr. Grieves has over forty-five years' experience in the computer and data communications industry. He has been a senior executive at both Fortune 1000 companies and entrepreneurial organizations during his career.

Dr. Grieves has a BSCE from Michigan State University and an MBA from Oakland University. He received his doctorate from the Case Western Reserve University Weatherhead School of Management.

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