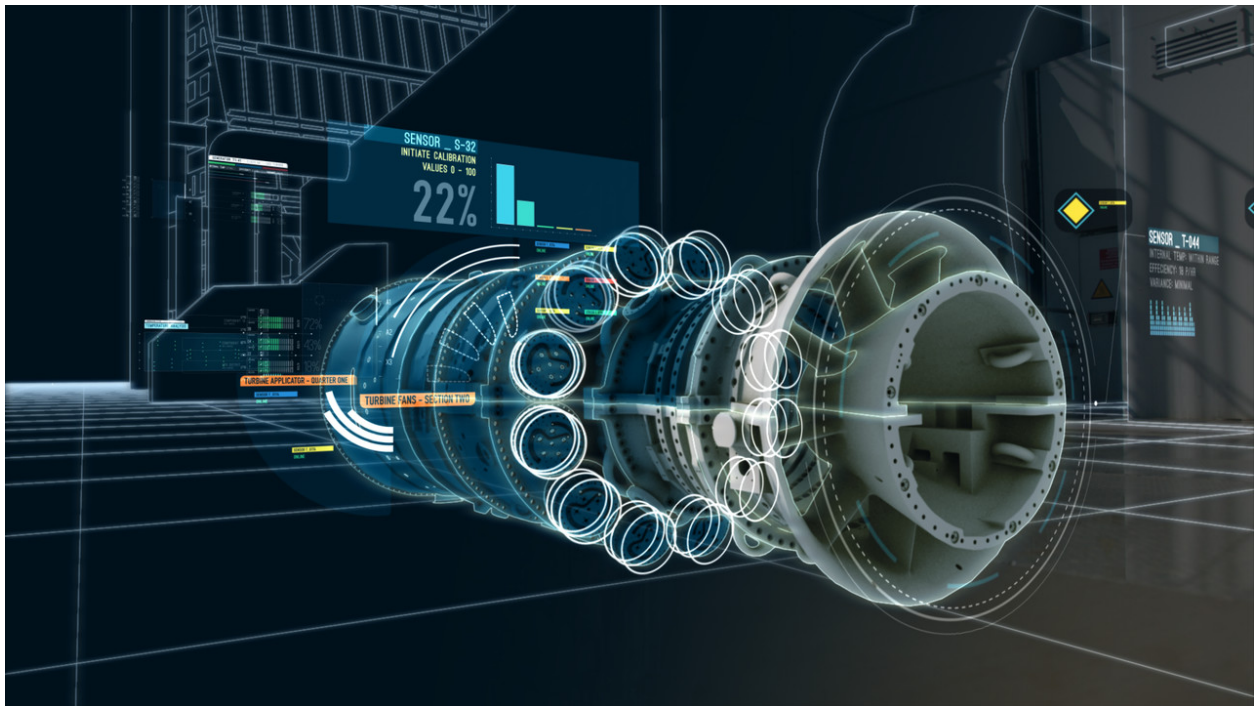

Demystifying Digital Thread and Digital Twin

Every few quarters, we tend to use new words to describe old concepts that are tweaked and update to sounds fresh and...complicated. A few years back, we were talking about Big Data and IOT whereas nowadays we hear about Digital Twin and Digital Thread. In this article, I will try to demystify these two new trends which are based on older models but leveraging state of the art technology and speculate on the difficulties of implementing them. But first, in order to understand where the technology is headed, I will describe where it came from.

In the Beginning, there was CAD...

The beginning of this digital journey started back in the early to mid 90s with the first 3D CAD systems like CATIA V4 and V5, Pro/ENGINEER (Pro/E), MasterSeries, Unigraphics (UG), ComputerVision (CV) and a few others that have disappeared or be absorbed elsewhere. These apps all started on mainframe (CATIA V4) or UNIX workstations (all the rest) and at the time were revolutionary in their ability to allow engineers to create models digitally and start dream of replacing physical prototypes however with limited capabilities of collaboration among engineers. Additionally, the systems were incredibly complex and required an engineering degree to really understand and exploit: a geek's paradise in other words.

I had the privilege of working on the graphics drivers for each of them as we tried to squeeze every ounce of performance out of OpenGL and our device firmware. The market underwent lots

of consolidation leading to the appearance of the modern competitors on the CAD market (all with expanded capabilities of course): Solidworks CATIA **3D**EXPERIENCE from Dassault Systèmes, Creo from PTC, and NX from Siemens-PLM. There are newer entrants such as the cloud-based OnShape, but the lion's share of the manufacturing market uses one of the products I listed above. The focus is primarily on allowing engineers to full model assemblies and products in 3D (now called model-based engineering or MBE) with increased collaboration between simultaneous engineers working from anywhere in the world on the same assembly in real time. I would say that here is one initial form of Digital Twin, the 3D model replicating the future product and behaviors, but more on that later.

...and shortly thereafter PDM

Initially, these systems were rudimentary graphics models that were either direct modeling (CATIA V4 and V5 and MasterSeries) or parametric (Pro/E) and generated lots of data files that had to be managed. Product Data Management (PDM) was born from this need in the late 90s early 2000s and two philosophies were taken: (1) immersive management of product data such as VPM V4 for CATIA V4 and iMan for Unigraphics or (2) file-based management of CAD data such as in in Pro/INTRALINK for Pro/E. The former approach had the strength of understanding the relationships inherent in the CAD model between its components and was closely tied to the CAD data model whereas the latter was easier to deploy being and integrate into other systems since it was less tied to the geometry of the data within the files.

Here comes PLM

Somewhat in parallel to these movements concerning CAD data, the enterprise processes for managing BOMs, Changes, Supplier Management, connection to ERP among others necessitated the birth of another class of software for managing the lifecycle of these various items during the product's lifetime, and Product Lifecycle Management (PLM) was born. The first really successful systems of this type were SDRC Metaphase and MatrixOne.

Consolidation in the PDM Market leading to PLM

Several guys left Metaphase, whose code was written in C/C++, to write a version in Java that they called "Windchill" and which was used by ComputerVision (CV). Both CV and Windchill were acquired by PTC in 1998 and PDMLink was born. The capabilities of Pro/INTRALINK were moved into PDMLink so PTC's approach was still loosely-coupled CAD file management. However, they made a series of acquisitions to broader their portfolio and encompass more business processes under the Windchill brand. In 2013, PTC acquired ThingWorx bringing them into the IOT world.

As for the original Metaphase code, it was sold to Unigraphics and renamed TeamCenter Enterprise (iMan having become TeamCenter Engineering) before Unigraphics became UGS in 2001 and was sold to Siemens-PLM (SPLM) in 2007. An effort was started to merge the capabilities of TeamCenter Engineering on top of the TeamCenter Enterprise foundation called TeamCenter Unified which is now the primary product line for PLM products from SPLM.

In 2006, Dassault Systèmes (DS) acquired MatrixOne (M1) and started the process of putting their VPM backbone on top of the enterprise foundation of MatrixOne which eventually saw light as V6 in 2008. After a series of acquisitions and rebranding exercises, Dassault launched **3D**EXPERIENCE in 2014 featuring the unified V6 platform improved and expanded to include Social Collaboration, Dashboarding, Searching, and many other processes based on one of the 12 targeted industries.

I was lucky enough to be present a through many of these transformations and to witness the sea changes happening in each of these products because I worked for both IBM and Hewlett-Packard (HP) on site at ComputerVision, Unigraphics, Windchill, and Dassault Systèmes and I worked on Windchill via HP or directly for PTC for nearly ten years from 1998-2008 and then for IBM and Dassault Systèmes from 2008 to 2017.

The Digital Twin

OK, enough background, so what is Digital Twin? Well, digital twin is really in many ways just an expansion of the 3D CAD world I mentioned, but now expanded to include manufacturing data. Put another way, we used to create new models in CAD and then push them to manufacturing. One of the ideas in digital twin is to go the other way: create 3D models of EXISTING products and systems in the field and import them into the CAD systems. Add to that, the use of data from sensors and such into Virtual Reality (VR) or Augmented Reality (AR) environments and you too can walk around with a pair of funky glasses and - while looking at a physical object - see its digital twin in your glasses with popup indicators from realtime sensor readings. That is really what folks mean today by digital twin.

The Digital Twin, then, exists in modern PLM systems already and is just waiting to be exploited further via these new VR/AR technologies. Some of the challenges companies will face include: (1) filtering through the volumes of data that are produced by IOT and thus an efficient and sufficiently fast integration of this data into the reference PLM system, (2) the kludginess of the current VR/AR systems which require expensive and physically impractical in an industrial setting and (3) the cost of re-engineering existing systems and software to account for the technology and terminology which is evolving at a quicker pace than the systems in use today. However, these challenges can be overcome leading to reduced cost via (1) virtual prototyping replacing or complimenting expensive physical prototypes, (2) increased product reliability and predictive maintenance by using field-generated data in real time in the design process and design data on the manufacturing floor, and (3) reduced training cost as the systems' usability approaches consumer-level technology rather than complex interfaces only exploitable by experts.

If that still sounds complicated, think of the ideas that William Gibson predicted in Neuromancer and which the Wachowski brothers brought to screen in The Matrix. In these works of science fiction, an alternate digital reality is built on objective reality. Of course, these were both dystopian views of how Digital Twins in the digital universe (The Matrix) are merged with Artificial Intelligence (AI) and serve as warnings to us as the technology evolves in the 21st century - hopefully life will not imitate art.

The Digital Thread

The digital thread is even more closely bound to the origins of PLM than Digital Twin is to CAD data. In other words, the promise of Digital Thread is identical to that of all the PLM systems: how do I maintain a single version of the truth about my CAD systems and ensure consistence of that data across upstream marketing systems like CRM and downstream manufacturing systems like ERP without losing information, diffusing obsolete information, or duplicating information - in other words, how to do this cheaper and more efficiently. Digital Twin encompasses this idea in newer terms.

The concepts of Digital Thread are then already present in the three major PLM systems we have discussed. In fact, you could just take the basic idea of Product Lifecycle Management as being the maintenance of the Digital Thread from conception through manufacturing.

For the SPLM world, the integration of Tecnomatix manufacturing into the TeamCenter Unified portfolio enables them to cover the full breadth of conception of the Digital Twin which is held consistent in each of the phases of the product lifecycle without really expanding the portfolio or changing their key messages. Their solution, however, seems to have remained built around creating objects in the CAD system pushing data down to manufacturing with a feedback loop back into engineering for defect correction and design improvements.

In the PTC world, the acquisition of ThingWorx was a sea change bringing them an industry-leading IOT platform. They seem to attack the PLM market now from the downstream manufactured product and its associated data as acquired by IOT in ThingWorx and pushing that data back up into the Windchill system for modeling and engineering. The Digital Thread is maintained across the ThingWorx and Windchill systems with Windchill managing the master data.

The DS approach to Digital Thread is at the core of their **3D**EXPERIENCE messaging. Using 3DSpace (ex-ENOVIA V6) as the master data management repository, additional social collaboration on the data in 3DSwym, easy to digest performance indicators in 3DDashboard widgets, quick access to data via 6WTagging and 3DSearch, and democratic visualization with 3DPlay, DS enables companies to maintain their digital thread across all the brands whose solutions are built on the foundation of **3D**EXPERIENCE: modeling in CATIA and Solidworks, simulation in SIMULIA, manufacturing in DELMIA, and PLM in ENOVIA. This allows the Digital Thread to be consistently stored in the platform and accessed securely using the 3DPassport whether the data is On Cloud or On Premises. The IOT part of the story is covered by 3rd parties whose data can be consolidated (after filtering) into EXALEAD (the 3DSearch backbone) and then fed to various apps where required. OptimData is one company helping with this particular dynamic.

Some of the challenges facing companies wishing to implement the Digital Thread include (1) consolidation of existing PLM systems into a single, unified instance, (2) the increasing necessity for extreme robustness of this consolidated PLM system as it becomes central to data management across the extended enterprise and involved in more critical business processes, (3) resistance to technology adoption by users that wish to continue to jealously guard their data

inside an Excel spreadsheet. Once these barriers are overcome, the benefits of a Digital Thread would include (1) reduced time to market as more voices are involved in the design process and redundant reviews and work are eliminated, (2) increased product competitiveness as more marketing-generated requirements are turned into product features, and (3) increased profit as wasteful duplication of data is eliminated and less time is wasted working on outdated copies of data.

For an example from science fiction to further illustrate this, I would cite the Philip K Dick story and Tom Cruise movie adaptation The Minority Report. The computer systems used in the story and film for crime fighting are an example of a Digital Thread pulling data from all law enforcement agencies and displayed in beautiful augmented reality displays which show consistent information in any system that the protagonist accesses anywhere he goes. Once again, the movie deals with a dystopian future where free choice is undermined by the erosion of privacy by technological advances and serves as a warning to us in moving forward.

Conclusions

It is relatively rare that concepts appear out of nowhere without any precedent. In the case of Digital Twin and Digital Thread, they have their origins in CAD and PLM respectively. These technologies had multiple vendors and face multiple challenges, but the benefits are particularly attractive leading many companies to invest in moving forward. There are, of course, dangers associated with losing the human elements in all of these transformations about which science fiction has tended to be quite prescient. In all, we are at a fascinating cross-roads as many of these nascent and mature technologies are coming together and giving us powerful new tools for improving products and ultimately life itself.

Pitch Alert! I created Finocchiaro Consulting, LLC and TransformIT Consulting, SAS to help companies in the Dassault Systèmes universe along in their journey to Digital Thread and Digital Twin. Please contact me at Michael@Finocchiaro.Consulting or Fino@TransformIT-Consulting.com if you have further questions or feel free to comment if you agree or disagree with my analysis and/or conclusions.