Chapter 2
Prologue—Understanding the Difference in Approach

Lisa Weber, Li Wang and Jonathan Lee,[1] three Master Students in Product and Production Systems Engineering (PPSE) within the integrated Global Engineering School that is jointly offered by three leading technical Universities in Europe, USA and Asia are in their final year of graduation. It is the year of 2030 and they have to finish their project assignment within ten working days. This project is part of their interactive exploration curriculum to learn essentials of Virtual Product Creation working patterns and the associated digital transformations. The new way of self-learning comprises the Knowledge and Information Subject Survey (the new KISS[2] approach) by studying, in this particular case, the history of IT (Information Technology) supported digital engineering approaches. Those digital engineering principles should be assessed starting from the 60s and 70s of the twentieth century and the emerging approaches in the first and second decade of the twenty-first century up to the presence in 2030 and beyond.

Lisa Weber, Li Wang and *Jonathan Lee* are all happy that they belong to a privileged generation of students who can use a special configured virtual research assistant. This is a kind of science avatar who actively uses a premium "research search service" for documents, knowledge, best practices and information retrieval and interpretation across all available online databases within the global internet networks (and it could be used within enterprise to interrogate intranet sources and data lakes, if permissions are given!). All three students won the right to use this avatar for one month, as part of an award package by the University consortium due to their excellent research project results from the previous semester. They can use this science avatar exclusively in

[1] All person names formatted in italic format are used to illustrate fundamental scenarios to explain principles and styles of Virtual Product Creation solutions within this book and are entirely fictional with no relation to individuals in present or past reality. Real individuals in presence and past are designated by normal formatting.

[2] In today's industrial application scenarios, complex IT-technologies are confronted with the request to follow the KISS principle, which in the western world is referred to as: *keep it simple and short/stupid*. This requirement expresses the social-organizational desire to keep digital solutions manageable for the majority of users by avoiding difficult and complex case differentiation.

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order to calibrate the community based relevant knowledge it can gain via state-of-the art excessive social engineering wiki networks which were formerly known as web 2.0 technologies.

After two days of refined configured research by their research avatar *Li Wang* and *Jonathan Lee* both feel amazed about the significant difference in executing Virtual Product Creation within the last 50 years. It is similar to what their grandfathers used to tell them about the industrial application scenarios around the significantly evolving manufacturing technology throughout the middle part of the twentieth century. *Jonathan* analyses the first three typical scenarios of Virtual Product Creation analyzed sorted and interpreted by his research avatar, whereas *Li* concentrates at the same time on the use of deep learning methods to predict future perspectives of technology and their applications. *Lisa Weber* holds special knowledge on sustainable engineering approaches: her father, a Professor in Europe, had written several papers on human technical intelligence recognition to ensure true sustainability of products and technical systems. This new engineering intelligence research direction has been started after the machine learning (Artificial Intelligence) hype had left too many disappointments in industry in the first part of the 2020th. The results of their analysis look as follows.

2.1 Pioneering in Self-made Mode by Technical Experts

In the very first beginning of the availability of computing machines in the middle of the twentieth century a relatively small group of Mathematicians and Scientific Engineers had recognized that digitization of calculation did offer new opportunities to assist the execution of tedious scientific and engineering reckoning activities. Due to the fact that the interaction with such computing machines was tedious and error prone—punching cards were to be used as programming interface originally—only the scientific oriented experts were attracted to develop “engineering application programs” such as calculation routines to solve differential equations in the case of dynamic structures.

Based on this mathematical scientific oriented passion the first generation of “0-level digital users” (in the sense of digital calculation and drawing methods) developed their own applications. They used algorithmic methods followed by subsequent coding activities with the help of technical programming languages such as FORTRAN, PASCAL or C. This gene-ration of “Digital Engineers” integrated the role of software developers and application users in one person. It was more or less a club of its own and mainstream Engineers did not get involved at all. They continued to refine traditional physical test and development methods without paying real attention to the new emerging engineering discipline.

2.2 Scaling-Up by Growing Digital Design and Analysis Groups with Customized Solutions

In the end of the 70's large industrial companies and innovative companies with close relationships to universities and research institutes attracted the new generation of pioneering digital experts. Subsequently, those teams began to grow steadily. With the help of the first commercially available CAD/CAM systems[3] growing out of the lab environments of universities and aerospace, aviation and automotive companies a new era started to evolve in the early 80's. Later on, specialized CAD/CAM companies started to offer the first generation of digital engineering tool sets, which were initially tightly linked to the special type of hardware. In the second half of the 80's these new digital capabilities of modeling, designing, drafting, calculating and analyzing mechanical structures hit the arena of mainstream engineering: predominantly young generation designers started to use 2D and first 3D CAD/CAE[4] and CAM-systems for their ordinary engineering work. It was the time of split teams, still significant numbers of drawing board-oriented draftsman and the new generation of "CAD jockeys", young design professionals with profound modeling but limited engineering skills. Due to the rare numbers of specialized computer hardware and vector screens, engineering managers were forced to set up shift systems for the growing number of the CAD design teams. The introduction of UNIX based workstations in the second phase helped to significantly lower cost and to provide workstation usage for every digital engineer.

At the end of this phase (up to the early 90s) the clear set-up of separation between software developers and "ordinary technology applying" CAD designers was finally established in industry. In the CAE and CAM area, however, application experts and analysts still developed major parts of their own tool sets and they continued software maintenance and improvement. The new era of specialized CAD service providers started to evolve.

2.3 Desire to Restrict—The Dilemma of Limited Understanding of the Role of Virtual Product Creation

From the early 90s onwards, organizational changes and the introduction of project management approaches were necessary to put in place simultaneous and concurrent working principles in industrial companies. As consequence of *time to market* reduction needs, the digital workforce was asked to deliver more design and analysis models in shorter times. The number of digital models was growing fast enough to convince companies and solution providers to put more efforts into data management

[3] CAD: Computer Aided Design (initially Computer Aided Drafting); CAM: Computer Aided Manufacturing (initially dedicated to computer assisted generation of numeric controls for tooling machines).

[4] CAE: Computer Aided Engineering, special tool sets to calculate and analyze product properties.

solutions such as EDM and PDM.[5] Within the companies themselves, it was no longer sufficient just to use CAD, CAE and CAM as individual tool sets. Data exchange solutions between the individual CA-applications as well as more powerful collaboration and information management environments became the bottleneck. Significant investments were made to introduce the next level of virtual product creation tools sets.

It took until the millennium before leading companies in virtual product creation operation recognized that digital processes and methods represent the real competence that needs to be established in engineering instead of digital tool functionality alone. In this phase of entering the "adult status of virtual product creation" most of the development projects were still led through ordinary physical artifacts driven business managers. This generation of business managers still could afford—according to the company's internal reward and recognition values—to keep their digital knowledge limited. However, they were unable to control and correct fundamental flaws in digital processes and methods and, therefore, had to rely on a new generation of digital experts.

Those groups of digital process and method experts were partly organized in backbone engineering organizations or still in "process IT" organizations. Those technical competent experts and managers usually were limited in political power unless they were made responsible also for operational engineering working teams (which did not happen often at that time).

The gap between ordinary engineers and managers who constantly asked for digital solution simplifications and evidence of verification prove-outs, and the new group of "full digitally convinced" engineers became bigger from year to year. A crisis in form of missing operational robustness in digital engineering did occur in many organizations, especially in those where research and development expenses for virtual product creation was cut significantly, although new challenges in mechatronic system development, e.g., did ask for significant new investments towards new PLM-based (Model-based) Systems Engineering. Prove out of improved solutions no longer could take place and necessary research actions to integrate digital solutions (process, method, tools and information standards) were scaled down as soon as economic downturns occurred.

The era of traditional business case driven IT enabled engineering started to decline. Consequently, limiting and restricting virtual product creation to enabling technologies only had failed. The PLM vendor landscape to the same time was reduced to an oligopoly scenario: 2–3 major PLM vendors controlled technological innovation and all associated digital business matters.

[5] EDM: Engineering Data Management; PDM: Product Data Management.

2.4 The New Digital Presence—Living a New Understanding of Information Based Value Creation

During the financial crisis and more than 10 years later during the pandemic crisis driven business recession again in the beginning of the third decade of the twenty-first century a group of experienced Virtual Product Creation researches and PLM and industry experts started to define staggered plans how new alliances between research, industry and PLM vendors could be shaped up. New business models, engineering principals and engineering execution models (such as model-based systems engineering) put *Information Activity* (IA) and the related neutral process and method solutions into the focus of digital value creation. Gradually, however, it became also evident that new harmonization efforts were necessary in industry to meaningfully steer innovations in

- *Information Technology* (IT) leveraging smart infrastructures as well as information backbone technologies and networks
- *Data platforms and data values* to offer data contextualization and training pools for machine learning support and new data driven smart services
- *Information Logistics* (IL), the new discipline to exchange and transfer information objects to the entry points of engineers' needs, engineering process activities and model based engineering execution points.

These efforts aim at reducing the drastically increased risks of "information outages" and "information tsunamis" in global engineering operations and business collaborations.

From 2015 onwards, it became possible to introduce the capabilities of the matured WEB 2.0 technologies into the new day-to-day digital engineering task execution within a systematic approach—IT departments reverted their development approach to integrated "agile" development and operations (DevOps) progression. Social network capabilities could be made available within the new digital engineering work pattern, mash-up technologies started to help providing new intuitive interfaces in order to improve comprehending complex product and lifecycle views as well as delivering intelligence of visual analytics to decision makers. The dream of involving all partners of product creation within the virtual process became true and the dominance of a PLM vendor oligopoly had vanished naturally. New start-ups, inspired from new the WEB 2.0 and Apple/Android apps technology opportunities (leveraging the new hyped approach of "microservices), as well as business professionals from the Business Intelligence and Big Data expert groups started to create new paradigms of digital engineering. Within such new innovative solutions it became possible to dynamically offer task oriented engineering apps based on online search engines, not only screening classically structured data but also the vast majority of unstructured data within and across companies. Google, Baidu and other IT and Web intelligence companies all over the world started to inspire the new generation of start-up companies, digital lab providers, Digital Life Cycle Engineers and Cross Innovation Managers. A new idea about the "future PLM" was born, the real starting

point of true Virtual Product Creation for all engineers, planers, managers, users and interested customers.

A new generation of virtual service providers in close cooperation with a wide group of digital service developers had grown up until 2030 in addition to the "classical" PLM vendors. From then onwards a new virtual eco system was formed which consists of this new group of digital economy business partners, neutral modern virtual product creation research institutions, the "transformed" PLM vendors, meanwhile nameplated as Digital Technology Vendors (DTV), and the industrial partners themselves. From then onwards, all four partners were equal in importance and well connected in order to design and set up virtual product creation solutions in the industry. Closed shop virtual product creation was successfully transformed into an open, trust and competence oriented digital business. This was possible due to the introduced value and price system for data, information sets and digital models which was invented in Europe based on the desire to extend the classical production factors *land, work and capital funds.* The thinking of data souverenity had started around 2020.

Almost in parallel a growing number of researchers, engineers and computational experts did develop new ways of engineering by introducing the 2nd generation of digital models for the description of technical system core modules (beyond the traditional first generation geometric based CAD, CAE and DMU models). Those 2nd generation models did evolve from an initial set of models, which were only used for control problems. The new generation of model-based (systems') engineering tools and methods allowed to co-simulate and to integrate various perspectives of the technical system model: mechanical behavior, control behavior, functional and logic behavior as well as time- and state based dynamic model transitions and interaction up to human machine interactions (including cognitive elements). Towards the end of the third decade of the twenty-first century, it became possible to use real-time full digital model-in-the-loop validation of technical systems. Engineers needed to get a skill set-up update every 2 years in order to keep in synchronization with the exploding world of system modeling opportunities! Organizations, however, were not in the position to integrate such new working methods quickly enough, which resulted in a growing number of technical system modeling experts working for projects rather than companies on a pure contractual base.

It had therefore taken approx. 70 years to close the circle back to where the digital innovation had started: engineering competence uses technological commodity in a robust and innovative style. In 2030, however, it is the *IX-technology* (*Information Authoring, Information Logistics, Information Learning, Information Technology, Information Retrieval, Information Mash-Up, Information Models* etc.) which is the base for virtual product creation and PLM based systems engineering instead of the physical tool shop that used to be the base for component and prototype engineering in the middle of the twentieth century.

Jonathan Lee is intrigued by the results of the research avatar. For him it is amazing to understand the difficult way of virtual product creation from initial invention of basic IT technology up to the deep immersion of digital engineering solutions into almost every angle of (virtual) product value creation. He halts for a couple of seconds

of wondering and then switches back on to his real assignment: picking a 2–3 year period between 1960 and 2030 and explaining virtual product creation in industry from the understanding out of this period. He remembers the time frame when he left kinder garden and all of a sudden became aware of new digital computing possibilities in school: it was the time frame around 2011/2012, the time right after the major finance turbulence in the world. This would be a good period, he thinks. His research avatar—unfortunately the older software load still limits the search retrieval and interpretation capability to information and knowledge in English language only—suggests an interesting book for further study on this subject: *Virtual Product Creation in Industry—the difficult transformation from IT enabler technology to core engineering competence.* The book you are currently reading …

Li Wang meanwhile got many attractive job offers out of his project assignment since he was able to demonstrate and showcase in a set of global digital pitches the application of new sets of artificial intelligence methods to assemble a perfect mix of digital models and methods for any engineering task. Li Wang will be on world tour for the next two weeks to decide whether he wants to work in Asia, Australia, Europe, Africa or America. Due to new super-fast networks and emerging digital technologies it is no longer necessary to be physically present for personal interaction with teams and technology. *Li Wang* will be part of the first generation digital entrepreneur, Chief Digital Engineer and University Professor in one person – a total new career opportunity of the digital future!

Lisa Weber has started first steps of her new career to become the Deputy Governor of the EU (European Union) *digital sustainability program* that is central part of the *Green Deal Act* in Europe. The avatar analysis results were not yet sufficient for her to directly derive the new sustainable business and technology value elements of the future. However, it helped her significantly to recognize shortfalls and to deduct clear conclusions how to accelerate open digital data business to offer circular economy solutions as basis for any 2050 business model. Digitalization to drive sustainability started to become the new critical political and technological power in the world, perfect for Lisa in her future role as Deputy Gonvernor.

Lisa, Li and Jonathan continue to stay connected with each other through their personal digital avatars. Their personal avatars remind all three of them not only to stay interested in the individual achievements (as it was popular in social networks already before…) but also to learn from their individual shortfalls. All three agreed to use the *sustainability mode* of their avatars alerting them mutually if they do not leverage the new digital opportunities of Virtual Product Creation hard enough to drive for the new sustainable balance of industry/technology/business, society/humans and ecology.