Chapter 19
The Role of Digital Technology Vendors

Executive Summary

This chapter deals exclusively with the hidden champions in digitalization, the Digital Technology Vendors (DTV).[1] They act usually in a triple role, first as digital innovators for new VPC capabilities, second as suppliers for PMTI (Process, Methods, Tools and Information Standards) market solutions and third as partners and technology consultants for industry. Their product offerings are oftentimes associated with the following terms:

- *Virtual Product Creation* (VPC) and *Virtual Engineering*,
- *PDM/PLM* (Product Data Management, Product Lifecycle Management) and *ALM* (Application Lifecycle Management),
- *Digital Engineering, Digital Thread, Digital Continuity*, *Digital Factory, Digital Twin*,
- *Computer Aided Design/Engineering/Manufacturing (CAD/CAE/CAM), Virtual Reality (VR), Augmented Reality (AR)*,
- *Modelbased (Systems) Engineering* (MBE, MBSE), *System Design and Simulation*
- *Computational Analytics*, *Data Analytics, Data Contextualization and Semantics, AI based Engineering* and
- Others (e.g. *model/software in the loop, mathematic modeling, collaborative and streaming engineering* etc.).

Digital solution offerings for engineers and their integration into company IT enterprise environments are both essential to enable appropriate digital technology foundations, IT architectures, best suited digital engineering applications as well as process and methods expertise for enterprises and their value creation networks.

[1] The author prefers this term since it is neutral with respect to the offered type of digital technology. DTVs are also known as *PLM or System Vendors*, *CAD/CAM/CAE vendors* and *IT suppliers/companies*. The group of DTVs in this book does not include Internet Service Providers (ISP), Computer & IT infrastructure and equipment vendors or ICT network providers.

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Quick Reader Orientation and Motivation

The intention of this chapter is:

- to explain the principle set-up and competence of Digital Technology Vendors (DTVs),
- to describe the role of DTVs in Virtual Product Creation and the projects to develop, customize, integrate and deploy associated digital technologies,
- to discuss the variance of partnerships between DTVs and industrial companies,
- to forecast likely changes of future DTV directions and associated business models.

19.1 The Set-Up of Digital Technology Vendors

Digital Technology Vendors (DTV) have been emerging from the 80ies of the last century from different technology directions and business backgrounds (please also compare Chap. 5: *The technology history of Virtual Product Creation*):

- Mathematical, geometric and systems modeling
- Computational analytics
- Data management and exchange
- Process modeling and simulation
- Research and innovation
- Technological spin-offs from OEMs in aerospace and automotive.

Therefore, the companies of the DTV group are typically not older than 40 years; the majority might only exist between 10 and 20 years,[2] many new companies emerge every year. Due to capitalization needs, however, many young spin-off or start-up DTVs, which might have been founded based on a new research & innovation idea, get (continuously) acquired by major DTV vendors such as Siemens Digital Industry Software (formerly known as Siemens PLM), Dassault Systèmes, PTC Inc, Autodesk Inc. and others. In some cases, multiple merger and acquisitions have evolved in a period of 10 years or more before such DTVs were finally formed into one legal entity.

The core business of each Digital Technology Vendor is software-based revenue for digital applications in product and manufacturing engineering and planning. In addition, a sub-group of DTVs do also offer digital tools for factory operations, field operations and product maintenance. Over the last years, DTVs have extended their typical PLM-type market penetration from the classical manufacturing industries also into other business sectors such as life science, health & medical, retail, insurance and finance.

[2] One of the best overviews of the spectrum of Digital Technology Vendors (DTV) can be found in the annual report of the prostep ivip associations which publishes all member names under (example 2020): https://prostep.epaper-pro.org/annual-report-2020_english/#6. Approx. 80 DTVs are listed there under the term IT companies (System Vendors).

Typically, DTV consists of the following core functions:

1. Leadership, strategic planning (incl. merger & acquisitions) and finance
2. Research and Development (R&D) with the following principal departments:
   a. Core (internal) research and new technologies (usually just a small core team, ~5%)
   b. Business application knowledge streams (~5%)
   c. Software (SW) development divided into several program lines (50–60% of the R&D headcount and expense)
   d. Test & verification and packaging (30–40%)
3. Technical sales, incl. pre-sales activities and POV (prove of concept work), application engineering, software distribution and customer support
4. Marketing and public affairs.

The following two drivers mainly influence the development of new digital SW applications at Digital Technology Vendors (DTVs):

- General IT technology trends and digital research innovations (mainly from Universities and application-oriented research institutes),
- Needs and demands from industry and other business sectors as well as new legislative requirements with high impact on digital applications.

The longer DTVs exist in the market, the more they usually enlarge their SW application portfolio. This expansion requires additional knowledge in the SW application related business process knowledge and application expertise in order to consult and advise the customer based adequately. The present also applies for the SW applications themselves with respect to the individual functions and features. For the lifecycle of the software application (also known as ALM, Application Lifecycle Management), DTVs need to establish and keep internal efficiencies for ongoing software maintenance. They need to bundle many functionalities originally requested by and co-created with different costumers within a common application architecture. This high number of different software functionalities, however, makes it increasingly difficult for the DTV application experts facing to the customer base to keep abreast about the diversity of the SW functions and features. It remains a constant challenge for DTVs to find a best knowledge fit and balance of the offered SW functions and features to the high number of engineering working scenarios and digital method compliance of their clients, customers and users.

Digital Technology Vendors typically rely on the following three innovation pipelines to drive their strategic future digital capabilities and offerings:

1. *Internally funded new business development projects*: Market observations and business model transformation in different business sectors might be the motivation point for internal product owners of existing SW application portfolios (e.g. data management or product modeling and simulation, business intelligence) to use internally available skills and resources to develop new application prototypes. Such prototyping could be achieved via *user journeys*, *interactive application storyboards*, *conceptual click demonstrators* and *minimal viable (software)*

products. They are intended to be used for internal and external customer focus groups and in clinics and workshops with potential future users. Such internally funded projects are also partially done together with external universities and research institutes and are limited to a period of 3 to 6 months.

2. *Intellectual property (IP) related innovation projects together with trusted partners*: Such partners are typically long-standing customers who seriously geared up to invest together with the DTV into new ideas and applications types including the assessment of business models and internal business case development. In many cases such business-critical topics are based on engagements that run for at least 1 year, in some cases even up to 2 years. It depends on the type of IP contribution and resource working split when the final step is made with respect to a go/no-go decision for further industrialization under different terms. The following options are common:

   a. further co-funded development towards a production ready solution for the IP partner with an exclusive use period of 2–3 years (compare PDM/PLM customization in Chap. 11) or
   b. finalization towards a market ready solution by the DTV including the IP content by the trusted partner (with special conditions for the first years of license use for the trusted partner).

3. *Externally co-funded pre-competitive research and development* with other industrial and university/research institute partners in publicly funded collaborative research projects: There exist different types of such public funded research programs such as *Horizon Europe* in the European Union or various research programs by federal organizations in all major industry countries. In contrast to the other two-preceding innovation schema, the DTVs are obliged in this case—as any other consortium member—to publish major project results (by keeping all rights of using new findings and prototypes for themselves). DTVs usually like such projects since they can be used also as a pre-cursor for standardization work afterwards (together with other industrial companies) and to trigger additional internal development work to accomplish the finalization of market ready architectures and applications.

Some of the Digitial Technology Vendors put a lot of emphasis in collecting and describing best practice process & methods dossiers in order to be better prepared to engage with business partners in Virtual Product Creation pre-sales and solution integration work. Whenever the pre-sales and application engineering workforce conduct workshops with (potential and existing) business customers, research institutes and tech start-ups summarize and compare the findings with their internal intelligence in order to merge new facts, trends, opportunities and engineering methods into their internal knowledge management solutions framework.

The revenue side of Digital Technology Vendors (DTV) differ significantly from the majority of their typical customer base in industry. This fact usually creates a certain degree of churn and unhappiness. It gets usually addressed in special negotiation rounds of IT responsible management and purchase professionals at the industrial company side. The evidence of the intended software usage, however, need to be analyzed, estimated and justified by business and engineering functions of the industrial customers. It helps to compare the situation of the different revenue model types in order to understand the controversial debate around that topic.

Any DTV, from start-up, tech company, or digital business supplier, may operate with multiple revenue sources and, consequently, with different revenue models. Depending on the industry and the product/service type, the revenue model will look differently in order to convince (industrial) companies to accept the inherit rules of the software business.

The group of traditional enterprises in industry is used to transaction-based revenue models. A *transaction-based model* is a classic way business can earn money. The revenue is generated by directly selling an item or a service to a customer. The customer can be another company (B2B) or a consumer (B2C). The price of the product or service constitutes production cost and business margin. Increasing the business margin, the business is able to generate more income from sales but run the risk to become non-competitive. Traditional industries in some sectors like automotive industry have modified this transaction model by adding options of finance leasing or renting models to it. Nevertheless, everything is related still to the product price that provides the framework also for the various financial models. During the 2010th decade industrial companies in the long-term investment sector also introduced industrial product-service systems (IPSS): They combine the provision of products with a certain operation or maintenance service. The business models associated with such type of IPSS also offer new revenue models, which might be linked to delivery-oriented business metrics. Nevertheless, such kind of business models are still rare in traditional industries.

Selling software products or services entails using different pricing tactics. It has to do with the core basic that software (once coded, compiled and implemented as running application) does not follow the principle of "piece price" as any material product has (due to the physical element *material*). However, in many cases certain services of maintenance or update might be included with software and their usage.

Some of the following software related revenue models might be considered as separate ones; however, they also come often used in combined packages. Today, the following revenue models and pricing types are common in software business:

1. **Develop and deliver software based on a fixed or dynamic budget for unlimited use**. Negotiation about SW maintenance is handled separately and might even handed over to other companies. Such as model has been popular by industrial companies in the beginning of Virtual Product Creation in the 70ies and 80ies of last century. This model, however, has been getting more popular again during the last years in large enterprises due to the fact the industrial companies have recognized the importance of specific software packages in the context of their own context and hence have started developing their own software

internally (or together with specific SW coding companies) *without* any DTV engagement again!

2. **Licensing/one-time purchase**. This entails selling a software product by license that can be used by a single user or a group of users. The general idea is to offer a product that requires making only one payment for it, e.g. Microsoft Windows, Apache Server, a majority of video games.
3. **Subscription/recurring payment**. Unlike licensing, a user receives access to the software by paying a subscription fee on a monthly/annual basis, e.g. Netflix, Spotify, Adobe products or Autodesk Fusion.
4. **Pay-per-use**. This pricing tactic is mostly used by different cloud-based products and services that charge you for the computing powers /memory/resources/time used. Examples are Amazon Web Services, and Google Cloud Platform.
5. **Freemium/upselling**. Freemium is a type of app monetization in which a user may access the main product for free, but will be charged for additional functions, services, bonuses, plugins, or extensions, e.g. Skype, Evernote, some video games.
6. **Hybrid pricing**. Sometimes pricing plans are a mixture of more than one. E.g. a *freemium plan* might morph into some form of pay-per-use tiered plan. After passing some limit in computation or resources, a user can be forced or offered to use another type of pricing, for example platforms such as Mailchimp, Amazon Web Services, and SalesForce.

Digital Technology Vendors in the PLM and VPC sector have primarily used the second software revenue model so far and have modified it towards specific customer wants as part of the negotiation rounds. DTVs. Offer the following most popular modifiers of the traditional license deals in the PLM and VPC business (also in custom combinations):

- *Peak license usage*: A certain cap of how many licenses can be used simultaneously in order to limit the number of licenses needed; in such a model, a trusted relation is necessary in order to rely on a robust license count server solution.
- *Named user licenses*: With the introduction of cloud-based Software-as-a-Service (SaaS) platform offerings DTVs have started to charge SW licenses by identifiable users rather than by generic licenses, which do not recognize specific users but only a used license per time slot.
- *Token flex licenies*: With the introduction of cloud-based Software-as-a-Service (SaaS) platform offerings DTVs have also started to offer companies the choice which type of application is selected by individual organizations and users and measure it by different kinds or different numbers of tokens. This provides more flexibility in using new digital applications and follows the thinking of office applications packages (e.g. Mircosoft Office).

For each of the license models the maintenance and update circumstance are added to revenue model. This again is different to the traditional industry business rules where maintenance models are not necessarily constitute a decision point at the point of purchase: DTVs follow the model that customers need to decide on the maintenance conditions upfront for a couple of years. Usually 2–5 years of maintenance contracts are common, but might differ between customers and application types. From 2015 onwards first DTVs have started to offer their VPC and PLM digital application offerings as part of cloud platforms introducing with modified license models (incl. careful extension to revenue models #3, #4 and even #5).

Due to the successful software license revenue model most of the Digital Technology Vendors (DTV) deliver significant higher business margins compared to traditional industrial companies. Successful DTVs easily reach a profit level of 15% in relation to the net revenue, whereas DTV leaders might deliver business margins of 25% and even higher. Questions and doubts, however, get louder whether such "software favorable" situation for DTV has the potential persist and to resist against open and free software in the mid and long-term range. DTVs have meanwhile recognized that they have to invest significant foresight thinking into the fundamental issue which future business conditions will still be supportive to support this traditional software revenue model. Hence, it becomes evident to ask the following question: Will DTV of the future no longer have a chance to survive in its current shape and needs to be adapted to a new sustainable future?

19.2 The Role of Digital Technology Vendors in Virtual Product Creation

Digital Technology Vendors (DTV) meanwhile play a core and crucial role within digitalization of industry. Without the solution offering of DTVs industry could neither introduce, modify, extend and professionalize overall Virtual Product Creation environments nor optimizing, constantly updating and regularly overhauling company specific Digital Engineering and PLM architectures. With the help of their internal functions (compare Sect. 19.1 they host enough internal digital capabilities to tackle a significant range of tasks within the overall spectrum of Virtual Product Creation business, but also have limitations and short falls. This section will explain the strengths and weaknesses of DTVs in Virtual Product Creation.

One of the hidden success factors in Virtual Product Creation business is the ability to establish close and trustful connections to Senior Management of industrial enterprises. This majorly enhances the chances that DTVs are not only treated as a vendor for digital/IT solutions but as a trusted partner to establish new and reliable business and engineering solutions to guarantee today's and future (digital) value creation. Oftentimes, such senior connections are pivotal to enable and support core senior management decisions for or against major digital investment initiatives and programs in industry. Digital Technology Vendors, therefore, put a lot of emphasis to establish solid matching lines of their core leadership personnel with the appropriate levels of enterprise in industry:

- DTV CEO to match with potential industry board members and/or vice president levels of industrial enterprises
- DTV Vice President or director level with influenceable business division leadership and CIO (Chief Information Officer) and/or CDO (Chief Digital Officers) in industrial companies
- DTV regional and key accounting leadership with OEM/supplier digital core initiative and program leaders in IT and in major business functions
- DTV technical architects and research evangelists with technical leadership and specialists as well as IT architects in industrial companies.

DTVs, which follow such a stringent line-up even without having already a solid customer base within specific industrial accounts, will be able to double the chances to be recognized and considered for *future requests for quotation (RfQ)*.[3] The interaction of the appropriate DTV management members with the equivalent management levels of industrial companies are critical to help industry management with their challenges and problems as explained in Chap. 18. However, DTV had to learn appreciating the "hidden role" of senior leaders in VPC research and education (such as directors of chairs and research divisions) who not only deliver the next generation of digital literate employees to industry but also have the advantage to be in a true neutral role regarding digital technologies and working methods. Unlike consulting companies who leverage current know how with best future projections, VPC research leaders have their fingertips constantly (!) on future technologies and overall new digital approaches and ways of working. Consequently, successful DTV run ongoing R&D programs with such VPC research leaders and university institutes driven by senior DTV management.

Moreover, DTV play a major role in transforming current business practices into new future VPC technology options. As explained in Chaps. 7 through 16 in great detail, such evidence has been demonstrated in the last 20 years like in:

- modern and automated CAD and CAE technologies,
- KBE (Knowledge Based Engineering) template approaches,
- new data management capabilities (from vaulting towards full digital configuration spaces for any kind of data, model or information) and
- easy-to use visualization environments (e.g. DMU) and virtual interaction solutions (Virtual/Augmented Reality).

The new challenges ahead in ASE (Advanced Systems Engineering) and MBSE (Model based Systems Engineering) as well as the need for AI (Artifical Intelligence) assisted engineering intelligence will require new ways of DTV solutions deliveries (compare such type of future digital solutions in Chaps. 20 and 21).

[3] A request for quotation (RfQ) in VPC and PLM business is a business process/method companies or public organizations use to request a quote from a supplier (or a preselected group of potential suppliers) for the development and/or purchase of specific digital architectures, applications, products or services. *RfQ* generally means the same thing as *Call for bids (CfB) and Invitation for bid (IfB).*

POC (Prove of Concept) work engagements between DTV and industry represent a typical interaction element of today's VPC innovation streams. DTVs are expected to understand companies needs and to transform it into first workable "digital solution snippets". The following types are common for such POC demonstration environments (usually a mix out of agile working elements and problem/heuristic-based reasoning sessions):

- conference room pilots using brown bag paper and obeya room illustrations with *process cards* and *process run through swim lane type of notations*
- *Design Thinking* type of digital problem structuring and solving sessions allowing explicitly for open and creative rationales
- Highly interactive digital demonstrator environments with clicking type method run-throughs
- Fully equipped digital lab prototypes and minimal viable solution-based exercises even together with process owners and digital project and product owners.

DTVs have earned credentials within the VPC community to serve within an expert technical tole in digital solution customizing and solution integration. Such credentials evolve through constant engagement within company POC, PLM projects and Virtual Product Creation futuring initiatives and are usually not referenceable by official publications and peer-reviews or neutral expert checks like in product homologation in classical industries. This special digital circumstance shows that Digital Technology Vendor business runs in a special mode that is characterized by a reputation mixture out of personal experience and feedback, constant innovation delivery evidence and successful business longevity.

The Virtual Product Creation industrial business often relies on DTVs to take on implicit architecture roles, both on a strategic side and for data model development. This is clear for the DTV own software applications and information models and needs long standing partnerships between DTV and the industrial company if this should be extended to other non DTV-owned information models. In that business, it is even common that senior data professionals acting as freelancer experts execute well-paid data architecture roles in PLM projects. They are frequently contracted by DTVs on a project as needed base and they have to closely work with internal architects belonging to the DTV or industrial company permanent staff.

However, there exist also business areas in Virtual Product Creation and PLM operations where Digital Technology Vendors have only limited expertise and are not accepted as appreciated partners. Due to the unfavorable cost structures of DTV application, engineers compared with digital service agencies and due to limited knowledge of technologies from other DTV competitors, the DTV consulting support accepted and ordered by industry customers has been significantly reduced in the second decade of the twenty-first century. As a subsequent consequence DTV meanwhile have serious difficulties to aquire and keep profound knowledge in industrial digital solution usage and true operational work implementations in industry. Some DTV were really successful in establishing such tight working relations to their customer bases for many years due to solution deployment projects and even in on-the-job implementation work. Such model was especially successful for US based

DTVs. Meanwhile the belief has changed since such high numbers of pre-sales and application resources are often too expensive, according to the internal cost structure, and oftentimes are no longer regarded as critical enough to ensure software revenue as DTV core business. This evolution, however, is somewhat controversially discussed within DTV Senior Management and enlarges the risk of no longer *digital business grounded* enough to understand and reach out to realities of industrial companies.

In looking to new business segments of DTVs, another opportunity crops up and need significant commitment and investment: limited knowledge in engineering model content, collaboration and interpretation and analytics know-how. Traditionally, DTVs concentrated on generic digital model template and structures. Only few DTVs owned core engineering knowledge within their own company and were successful to maintain it. Examples are the LMS knowledge pool within Siemens Digital Industry SW or the recent acquisition of ISKO Engineering by Contact Software. Dassault Systèmes always had the advantage to be an integral part of the overall Dassault Corporation, which has a strong stake in aviation and aerospace industry.

Digital Technology Vendors have no role, no responsibility and no day-to-day working experience in direct product related digital engineering delivery responsibilities, tasks and tactics. This situation makes it difficult, if not impossible, to them to truly understand, support and/or modify the following characteristics of daily Virtual Product Creation work hazzle (compare more detailed explanations in Chaps. 6, 17 and 18):

- The *true level of pain and joy* experienced by ordinary users of their software
- The *business pressure* scenarios under which digital solutions and software do not function or require major work arounds
- The *operational burden* to guarantee error free digital deliveries within the VPC working framework and environment despite of high numbers of software glitches, digital architecture limitations and limited software integration levels into the overall digital solution architecture.

In summary, DTV represents an indispensable pillar of today's and future Virtual Product Creation business solutions. They will most certainly remain in such strong position; however, they have to heavily invest into new core and future service capabilities. Digital Technology Vendors (DTV) most certainly have to change their digital business role and their business directions more significantly compared to the last 20 years. The following section will analyze these scenarios of the future in detail.

19.3 Transformations in Digital Technology Vendor Business

The future of Virtual Product Creation with its future IT technologies and new digital engineering capabilities will be introduced and discussed in the following two Chaps. 20 and 21. However, in order to make already meaningful assumptions within this chapter regarding most likely transformational steps for the group of *Digital Technology Vendors* (DTVs), certain fundamental issues need discussions and elaborations. One fundamental element is indeed related to the base assumptions of software offerings for the various degrees of digital engineering tasks and activities as part of the overall Virtual Product Creation environment.

Unlike the initial days of Virtual Product Creation (see Chaps. 4 and 5), when industrial companies developed their own software applications, nowadays the majority of industrial enterprises do rely on the development and provision of such software by DTVs. Nevertheless, this situation is not necessarily carved in stone for the future. In certain industrial sectors (like automotive and high tech), OEMs and system suppliers as well as private–public partnership organizations (e.g. in aerospace) have already started to return to internally owned VPC software development.

To the same time, there exist significant competition in between the Digital Technology Vendors. Basic VPC and PLM applications such as CAD, CAE or PDM often no longer differ significantly if it comes to basic functional foundations. Therefore, the amount of digital application commodities are growing and will increase the pressure on DTVs to defend their market share with more attractive license and associated service offerings. The situation will be exacerbated quickly once the efforts to migrate and transform today's diverse set of vendor specific models and data types will be significantly reduced. This could happen already mid-term (3–5 years) but most certainly will happen in the end. It will be accelerated, however, if it will be directionally pushed by more stringent measures of openness and standardization by the customer base, i.e. by the industrial companies (compare e.g. the CPO, Code of PLM Openness in Chap. 11 PDM/BOM). Today, DTVs still have the luxury to bond high numbers of legacy customers who do not easily take the effort to migrate to other vendor solutions. They are discouraged by high efforts associated to it. If digital commodity cost pressure and likelihood to migrate existing line-ups of company specific data and models into any other DTV eco system grows, then DTVs will have to be ready for new business models. Those business models will favor different or additional revenue offerings than just selling software licenses for digital tools and applications. DTV, therefore, need to prepare themselves to other and higher degrees of Virtual Product Creation engineering excellence than today.

Figure 19.1 shows the one of the author's outlook perspectives on how today's Digital Technology Vendors (DTVs) might transform themselves towards *Digital Engineering Excellence Provider (DEEP)*. DEEP, will represent a new class of *engineering competent digital technology vendors* in the future. The transformation from a pure DTV, i.e. being solely dependent on software centric revenues, towards a full capable DEEP, requires various transformation steps to offer high reliable Virtual Product Creation service levels. Up to a full degree of ownership for full service delivery on digital engineering core elements with high value creation potential and associated service rates. The nature of a DEEP, however, should not be mixed up with typical Digital Engineering Service agencies as known today. DEEP run their own software for future digital engineering work and still will benefit from the software

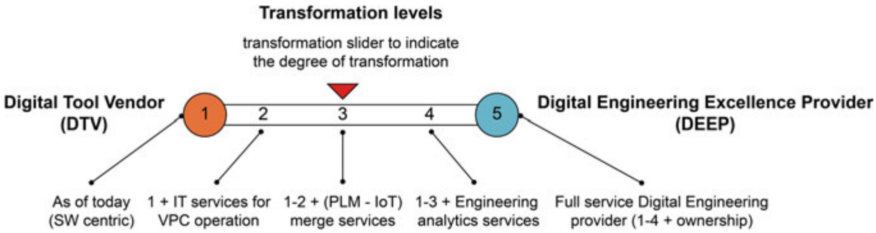

Fig. 19.1 Transformation levels from DTV towards DEEP

revenues of the traditional DTV business. Acquiring new valuable business without losing profitable earnings in the traditional role will be the leadership profile of the future!

At level one, still operating as pure DTV, a couple of business changes are expected and necessary, too. The leadership role of Autodesk Inc. in migrating away from a "*license type*" *software revenue model* to a full "*subscription based*" *software revenue model* has shown major advantages, both, for the customer base and for the DTV itself. Autodesk Inc., e.g., has achieved this type of transition between 2015 and 2019 by converting to almost 5 million subscribers whilst delivering a solid (non-gap) operating margin of 25% via constant and solid subscription earnings and giving the chance for divestment options to profile the future.

According to a specially selected content from the editors from *Catalyst* Autodesk has sponsored a report about their subscription model and the advantages for the customers (subscribers) on the Web[4]; please note the following core characteristics of the Autodesk subscription model (as of May 24th of 2021):

> Subscribing to Autodesk products streamlines the software management workflows, including licensing compliance, software updates, and upgrades. Every subscriber receives direct access to Autodesk support specialists via online chat, by appointment, or through e-mail, as well as direct access to a vast and growing knowledge base of documentation, tutorials, training videos, and community support forums. Remote desktop assistance offers secure hands-on troubleshooting. For collection subscribers, benefits do not end with access to software and support. A subscription license allows home use and use of software on the road. Most products in the collection also include access to prior versions. CAD managers and IT staff can use new administrative tools to simplify managing software licenses and account use. Reporting and analysis tools are available to monitor product use, spending, and productivity, and estimate future needs. Having a collection is much like having Microsoft Office: Not every employee needs Excel or PowerPoint every day, but the software is there when needed, especially as needs change over time. Companies can now reduce operational costs (IT and procurement spend) by standardizing on a collection of technology flexible enough to suit the needs of a majority of users rather than managing unique software deployments for each employee.
>
> In the past, fluctuating staff size could mean companies had to make tough decisions about whether to add or drop software licenses — and if so, how many? Subscribing to a collection, however, makes it much easier to manage such change: Acquiring software for

[4] https://damassets.autodesk.net/content/dam/autodesk/draftr/1759/spotlight-autodesk-collections-final.pdf.

new employees has a lower cost of entry and you have more flexibility around who uses each subscription.

… for cloud-based Autodesk services, including certain rendering and analysis tools in the AEC (Architecture, Engineering & Construction) Collection, users choose whether to store data locally or in the cloud.

Another major transition towards DEEP offerings according to Fig. 19.1 will achieved by the capability to act as *digital platform provider* across all levels. Autodesk Inc. and Dassault Systèmes have been pioneering to *digital platforms* for their product portfolio (partly together with digital platform technology provider such as AWS or Azure): the successful platforms are called *Fusion 360* by Autodesk and *3D Experience* by Dassault Systèmes. In order to provide best services to users on such platforms DTVs have changed the *serial number license* to a *named user license model*. By doing so, each user has a personal login from any capable client. For the DTV it becomes easy to analyze software impact caused by individual users and—to the same time—to consult users more professionally in best software usage questions.

Figure 19.2 explains the first two transition steps of the transformation of DTV on their way to a DEEP (Digital Engineering Excellence Provider). Many Small and Medium (SME) companies in industry have severe difficulties to establish core groups of Virtual Product Creation (VPC) competence, both in IT departments and within engineering and manufacturing functions. SMEs, therefore, will majorly benefit from the stepwise offerings since they can leverage this capability at least

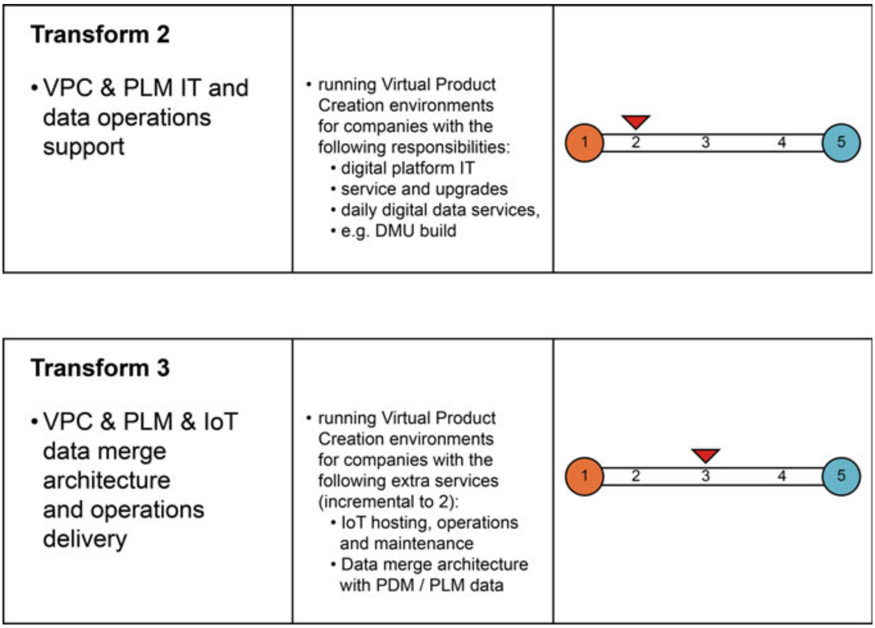

Fig. 19.2 Characteristics of DTV-DEEP transformation levels 2 and 3

in the first years by DEEP service levels. In step 2 they could already leverage the competence of DEEP for a professional set-up of the underlying IT and data operations support for the wide range of VPC solutions. This does include from today's perspective, e.g.,

- operations of special server and services to run DMU clash & clearance detection,
- population and maintenance of voxel-based geometry finder applications such as QPL (Qiuck Part Locator) functions or
- operating robust linking mechanisms for data, document and model traceability across databases including SOA (Service oriented architecture), REST (Representational State Transfer) and graph-based technologies.

Bigger companies already today implicitly rely on such competence by DTV but realize this options trough expert leasing rather than by DEEP service levels.

Step 3 would open the "merge connection" between the IoT (Internet of Things, compare Chap. 20) active data world reaching out to the factory resp. field and the PLM type of engineering backbone models and data. This connection is critical to start establishing pre-requisites for *personalized* or *technical system driven* engineering analytics including Digital Twins (compare Chaps. 20 and 21). Industry would benefit from such offering by robustly realizing new "intelligent data lake" types of information environment providing different degrees of data contextualization. This capability will enable and boost *no-code* and *low-code* development—i.e. without specific computer language knowledge—of specific data analytics applications by engineers. Additionally, such level 3 service would push new robust ways to connect and integrate AI-type of IT services (incl. running special lambda type IT architectures[5]) to support new types of engineering support and intelligence.

Stages 4 and 5 (see Fig. 19.3) represent offerings of digital engineering capabilities for future types of Virtual Product Creation. They are based on IT infrastructure knowledge, IT services capabilities, data structures and network fidelity levels, model content and hierarchies as well as digital application functions.

Digitally assisted Virtual Product Creation does require high robustness of data and model synthesis, analysis and linkage, especially in the context of growing system (or even system-of-system) interactions. Such interactions engage model and data flows between partial technical domain architectures and digital artefact types (such as requirements, functions, system partitions, behaviors, physical structures). The level 4, therefore, does address engineering service capability that delivers meaningful engineering exploration, analysis and synthesis results. Functional engineering activities of industrial companies are the direct recipients for such digital engineering deliveries. DEEP capability does require substantial systems and domain knowledge and competence. Those DTV who retain or have acquired direct engineering knowledge will have an advantage to reach such level. Level 5 constitutes the highest capability in delivering *and* owning digital engineering content with the obligation (and associated highest value proposition) to serve as integral partner

[5] Lambda architecture is a data-processing architecture to process massive quantities of data by leveraging both, batch and stream-processing methods.

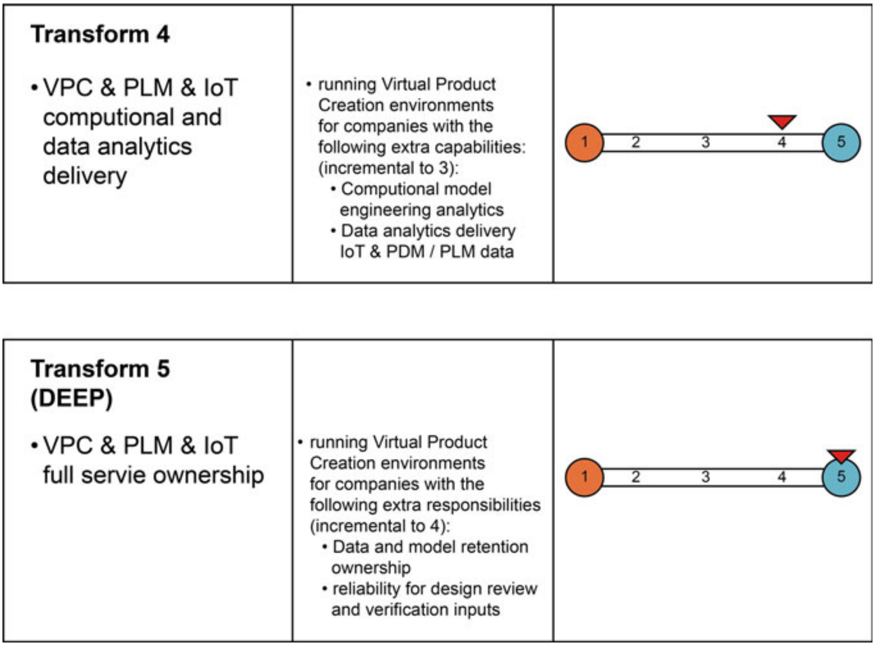

Fig. 19.3 Characteristics of DTV-DEEP transformation levels 4 and 5

in the engineering progression amongst "system/product" owners and stakeholders. Important tasks such as model fusion deliveries with associated predictions and technical assessments are covered by this degree of DEEP capability. DEEP, therefore, no longer sell generic models' types and data analytics as digital templates to industrial customers but actually use them in real project context to deliver engineering reasoning, analysis and model/data content for their industrial customers. This will be digital engineering service levels, which only a few DTV of today would be able to achieve due to missing active operational engineering experience. It will be interesting to see to whether Engineering Service Provider (ESP) might come from the other end to take on work tasks of DEEP level 4 and 5, or whether strategic alliances between DTV and ESP will even accelerate aligned DEEP offerings in the market!

From technology point of view, Digital Technology Vendors have to heavily invest into cross model and cross digital architecture solutions to be able to fulfil the needs of industry regarding networked technical systems and IoT based intelligences. Democratization trends of model and data usage will force DTVs into easy to use data environments based on IT micro-service architectures. To the same time, however, the desperate need for new extended information models across all disciplines and lifecycle areas will demand new ways of highly standardized but flexible data elements or information objects. Those new levels might even include self organization of information objects (which does not exist yet)!

Today's mostly transactional oriented database schema are no longer capable enough to support the automated engineering reasoning of data and models. IT technologies of today cannot deliver on data semantics. DTV need to become much more active on the data and model side, both in terms of semantic standards and with respect to open their own data and model architectures for flexible exchange mechanism. The future will put much higher emphasis on the value of data and model. Such massive change in value understanding in industry will boost the acceptance of today's DTV to develop themselves toward the revenue models according to new DEEP responsibilities.

The following new scenarios need serious attention by Digital Technology Vendors (DTV) in the future to be able to survive and play a successful business role in Virtual Product Creation of "tomorrow". Those scenarios become true in certain industries, but not in all. DTV no longer can afford the one and only revenue model of the past. The pressure to act rises!

Scenario 1 (Likelihood: High)

- Software feature & function differentiation for basic digital engineering applications no longer plays a decisive role due to high similarities amongst DTV offerings
- DTV face severe risks of declining digital commodity business
- Competition from open source digital engineering apps increase steadily and does erode classical software revenues
- Differentiation to cloud offerings from digital platform providers as part of SaaS, PaaS or IaaS set-ups becomes increasingly difficult; pure cloud provider become too powerful to accept high license, maintenance and subscriptions fees from DTVs
- DTV need to increase their footprint in high value DEEP business

Scenario 2 (Likelihood: Medium)

- Industry has fully picked up on MBE (Model based Engineering) and on MBSE (Model-based Systems Engineering) due to immense societal and political pressure caused by error prone and non-reliable verification and homologation of highly networked products and technical systems in the field
- Industry has, therefore, recognized that reliable digital models and data become the prime asset in Virtual Product Creation of "tomorrow", a major shift away from the SW tool and application-oriented asset viewpoint of the first 20 years of the millennium
- Such change triggers heavy investments and new revenue models (incl. leasing) for digital engineering data and model generation incl. contracts of co-ownership of engineering content deliveries
- The new business roles "engineering solution provider" emerges with core method competence in certain engineering disciplines and engineering methods; DTV see the value of transforming to DEEP
- Competition from open source digital engineering apps increase with the growth of the model market

Scenario 3 (Likelihood: Medium)

- Industrial companies steadily increase their investment into internal software development and are no longer or only partially dependent on DTV competences and offerings
- Such new digital competencies and model-based software development capabilities in industry allow agile development approaches for engineers to compose their own digital development and validation environments
- VPC data and models are highly standardized; VPC, therefore, follows the software engineering approach (high reuse of software code) to guarantee high degrees of model and data reuse
- Such new sets-up make it possible to offer easy *configurable no/low code* digital application which becomes a must for DTV of the future

These potential new scenarios show that DTVs might undergo through substantial if not disruptive or even radical transformations. Therefore, it is important to have a closer look how today's Digital Technology Vendors (DTV) asses their own position in the market and their roles to drive the future of Virtual Product Creation. The following section will provide a positional overview giving by six Digital Technology Vendors that are competitors to each other but also offer complementary software applications. In their presentations, they explain their self-understanding, their focal points moving into the future with their technical solutions and the challenges ahead in term of driving innovation forward.

19.4 Perspectives by Digital Technology Vendors

To be able to describe the strategic positioning of Digital Technology Vendors (DTV) today and for the future the author of this book has asked several well established and long-standing digital technology companies as well as one start-up to lay out their own views on the following five questions:

1. How do we describe ourselves?
2. What is our role as Digital Technology Vendor (DTV)?
3. What is our vision to drive the future digital technology portfolio?
4. What are our biggest challenges being a digital technology vendor?
5. Which inhibitors exist for robust integration of our digital capabilities in industry? Why?

Please follow their valuable statements and views in alphabetic order of their company names.

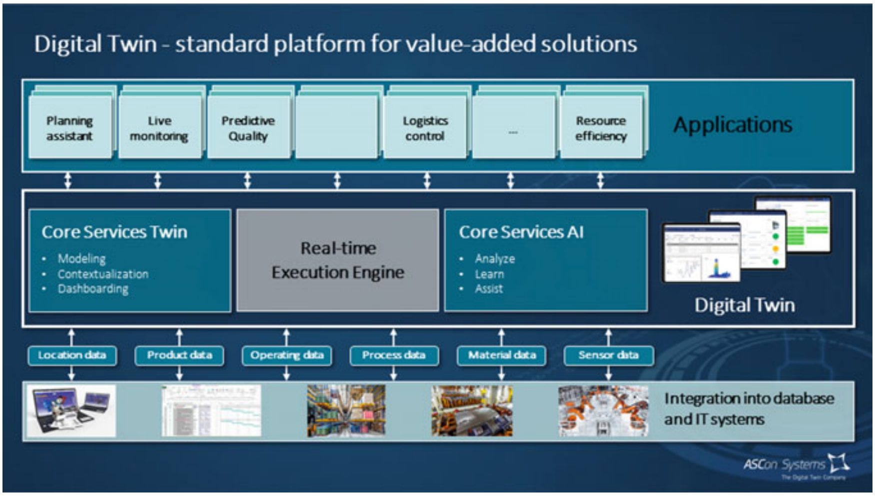

Fig. 19.4 Real-time execution engine as core block of the ASCon digital twin platform (*Source* ASCon system GmbH)

ASCon Systems GmbH—The Digital Twin Company[6]

How do We Describe Ourselves?

ASCon Systems is a provider of real-time, context-based digital twins for manufacturing. The high-tech start-up was founded in January 2017 and employs over 90 people at four locations. Its unique selling point is a real-time kernel for continuous data acquisition directly in a context-based behavioral model for the synchronization of product development, planning and production as the basis of a twin platform and building innovative solutions. The ASCon Digital Twin closes the gap between PLM (product development, planning and virtual commissioning), analytics (Big Data/AI) and the real production world.

What is Our Role as Digital Technology Vendor (DTV)?

Our role as Digital Technology Vendor is focused on the implementation of digital twin-based solutions for the industry.

The ASCon Digital Twin is based at its core on a, in Europe, the USA and Japan patented, real-time, discrete-event, non-time-clocked process execution engine, which is called *IoT Execution Engine*. This is the core of a general-purpose platform that also includes modeling and direct signal coupling. This integrated overall environment allows control processes to be defined and executed without having to program for them (no-code), from modeling to connectivity to execution in the execution engine. The platform approach is shown in Fig. 19.4.

[6] The *ASCon System* technical contribution has been created and delivered by Prof. Dr.-Ing. Uwe Winkelhake and Mathias Stach.

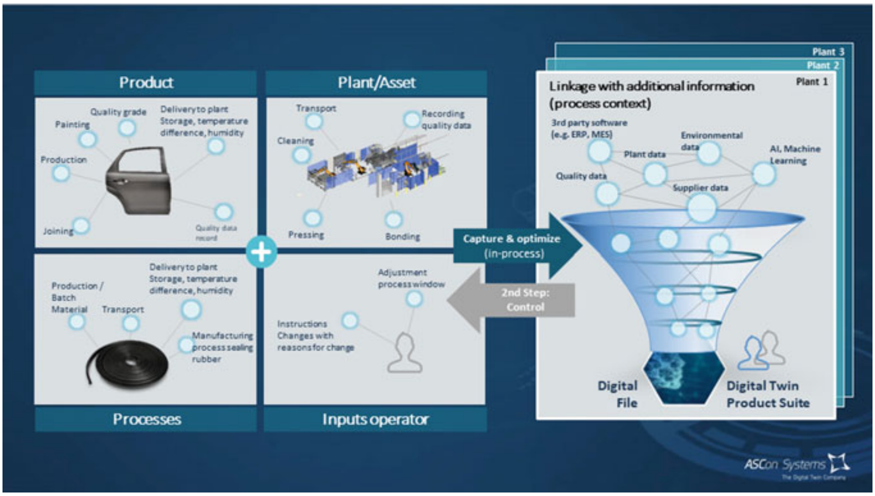

Fig. 19.5 Reference project: rolling head plant (*Source* ASCon systems GmbH)

The Digital Twin platform is based on solution modules that enable AI-based optimization in the virtual model. A typical application example is shown in Fig. 19.5, which deals with the operational optimization of a door rubber assembly line in the final assembly area of an automobile manufacturer. Six industrial robots work together to automatically install the foam rubber seal in the door areas of the vehicle bodies.

The task is to collect a large amount of data in real time and to continuously incorporate it into the virtual plant model. The plant model has been configured in a no-coding approach on modular elements and the control level has been connected via an ASCon device level. Based on the ongoing situation analysis, the digital twin-based solution continuously provides operating instructions and shows the key figures of the overall plant. By using the solution, it was possible to significantly reduce the operating effort of the plant and, by implementing preventive measures, to reduce downtimes and thus increase output. Overall, this project has a very short payback period of less than 10 months. Currently, the rollout of the standard solution in other plants and an adaptation to further plants is planned.

What is Our Vision to Drive the Future Digital Technology Portfolio?

ASCon Systems GmbH was founded with the ambitious goal of revolutionizing the way of planning and manufacturing in the future.

With our digital services, we monitor, analyze and control production and create an efficient ecosystem of modular, powerful and connected solution modules for assisted production. In this way, we are already laying the foundation for future autonomous production.

In the future, factories will be able to efficiently manufacture highly individualized products in very small batches. They will control themselves, anticipate malfunctions in automated equipment and in the operational process, and initiate AI-based measures to avoid failures. These smart factories are adaptable and can also respond immediately to changes in production and products. Digital Twin solutions offer great potential for the planning and operation of such factories [1].

In analogy to the established vehicle navigation, test drives in virtual images of plants or planning projects are made possible. Similar to the navigation systems used in cars, advice is given on how to avoid traffic jams and bottlenecks on the route and thus arrive safely and predictably at the destination. Similarly, there are hints for plant operation or even the automatic implementation of planning measures [2]. Good overviews of reference projects, research projects and also providers are available for this topic area, for example, in [3, 4].

The vision of ASCon is shown in Fig. 19.6. Today, the projects are about supporting the users. Concrete measures for improvement are proposed during plant operation or even line planning. In the future, these optimizations will be autonomously incorporated directly into the control systems, thus achieving continuous improvements automatically.

What are Our Biggest Challenges Being a DTV?

As an innovative and disruptive company, ASCon Systems GmbH faces the challenge of penetrating existing and established market structures. Furthermore, it is necessary to break up grown organizational structures. The responsibilities for planning, controlling and operational execution often lie in different areas of the companies. With the integrated twin platform of ASCon, these areas grow together and new processes have to be adopted. To achieve these changes, not only the technology

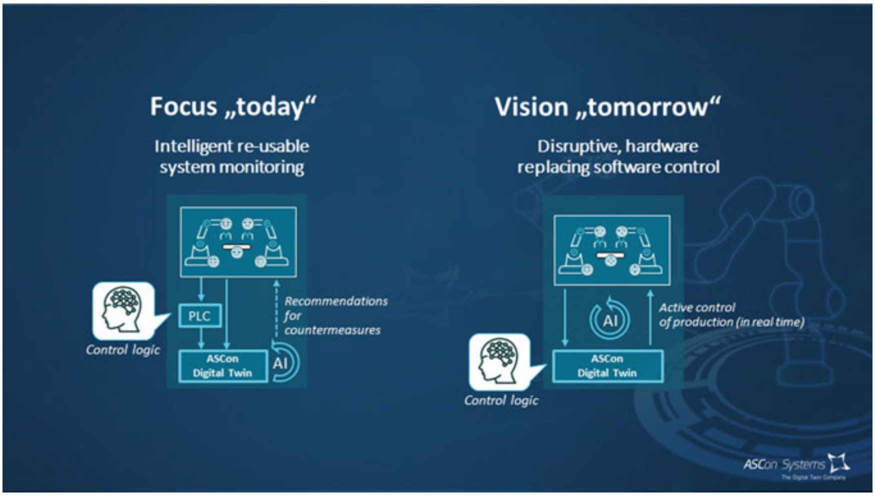

Fig. 19.6 ASCon vision of future production (*Source* ASCon systems GmbH)

must be convincing, but also the general approach to concrete projects. Integrated control and optimization on the basis of a digital twin is still in its infancy today with initial pilot projects. There is a lack of overarching, platform-oriented solutions for which basic requirements are named in the implementation recommendation on Industry 4.0 [5]. According to this, it is necessary to address the entire value chain across all company organizations and also across company boundaries in horizontal integration, to enable a dialog between the company control level and individual machines in vertical integration, and to continue to establish digital continuity and continuous integration of engineering across the entire product life cycle and production system. This is where the unique ASCon solutions are positioned. Based on the real-time kernel or the twin platform, further solution modules and fields of application will be quickly established and thus inspire existing as well as new customers and partners with innovative solutions.

Which Inhibitors Exist for Robust Integration of our Digital Capabilities in Industry? Why?

The prerequisite for powerful digital twins is the near-real-time recording of all relevant information. On the one hand, these are plant signals from a wide variety of sources, such as actuators, sensors and controllers, and on the other hand, product and process information as well as data from the factory environment, such as quality, weather and logistics information. This information is often not directly usable data, but only context-free measured values. All this information must be captured and assigned to a logical context. For this purpose, ASCon Systems has developed a unique technology, the real-time kernel, which enables the construction of powerful digital twins (compare Fig. 19.7).

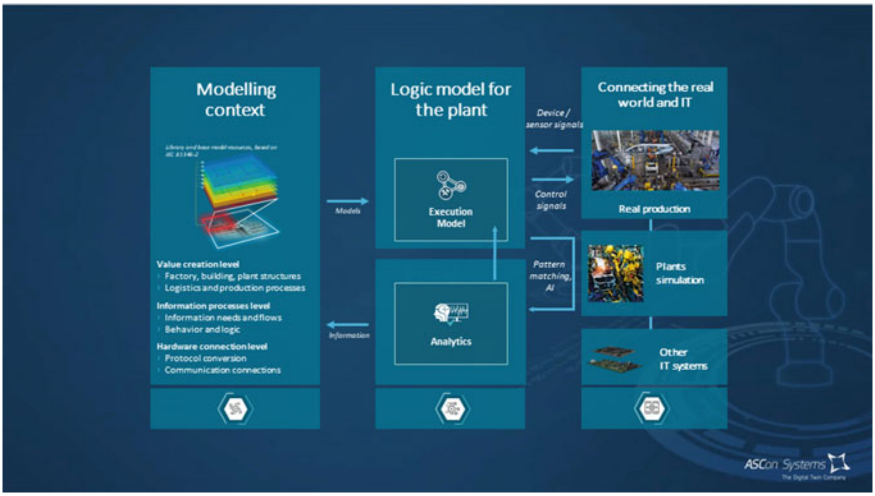

Fig. 19.7 Emergence process digital TWIN (*Source* ASCon systems GmbH)

For the implementation process, it must also be ensured that the necessary data for the digital twin in operation can be mapped by appropriate sensors and processed at near-real-time speed. For larger data volumes, it may be necessary to supplement existing database systems or to replace them with an edge computing approach, for example. ASCon Systems has the corresponding process knowledge and the resources to solve these challenges through its constantly growing partner network.

What is Our Way for Successful Partnership with Research and Industry?

ASCon Systems has a number of cooperation with universities. Thereby, we focus on the use of state-of-the-art technologies and their application possibilities in the industrial environment. In addition, we participate in research projects to bring innovations to industrial maturity together with the participating companies and universities. Development partnerships with strategic customers complement our approach of bringing state-of-the-art technologies to market in a very agile manner.

CONTACT Software[7]

How do We Describe Ourselves?

CONTACT Software is a software vendor offering a portfolio of information management and collaboration solutions for industrial and enterprise customers. Operating mostly out of Germany, with subsidiaries and offices in several European countries, customers all over the world are served through a network of partners in the Americas and Asia. CONTACT and its partners complement the software products with implementation and consulting services.

Our approach is based on our scalable low-code platform *CONTACT Elements* and a range of composable application building blocks ("apps") running on top of that platform. Application modules are either off-the-shelf standard software provided by CONTACT and third parties, or customers and service providers can additionally build custom apps on top of *Elements*.

The portfolio of 100 + ready-made apps covers a broad range of functional areas, from PLM core activities like CAx data management, bill of material, variant and requirements management, to traditional and agile project and process management, to IoT and manufacturing execution. The platform includes means for efficient global operations through data replication, and aims for market-leading user experience to improve user acceptance and facilitate process improvements (see Figs. 19.8 and 19.9).

The *Elements* platform is also marketed to other software vendors that re-brand the technology and build their own software products on top of it. OEM customers include global vendors of industrial software.

CONTACT itself is bundling its platform into differently branded offerings: *CIM Database*, a comprehensive PLM system, *Project Office*, a collaborative project management software, *CONTACT Elements for IoT*, targeting the industrial IoT, manufacturing operations and maintenance processes, and *Collaboration Hub*,

[7] The *CONTACT Software* technical contribution has been created and delivered by Frank Patz-Brockmann.

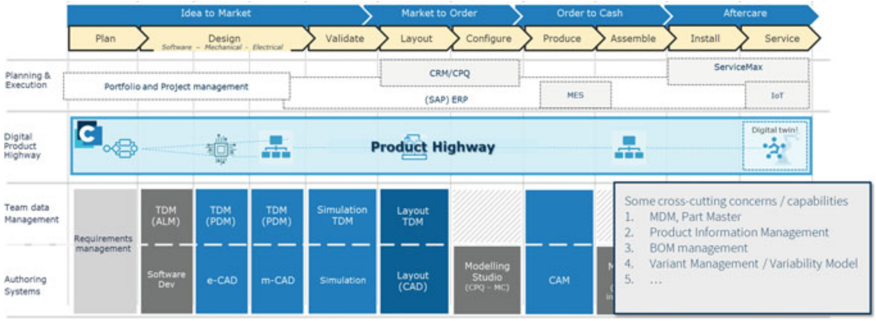

Fig. 19.8 A customer scenario of the system landscape for the digital thread' (*Source* CONTACT software)

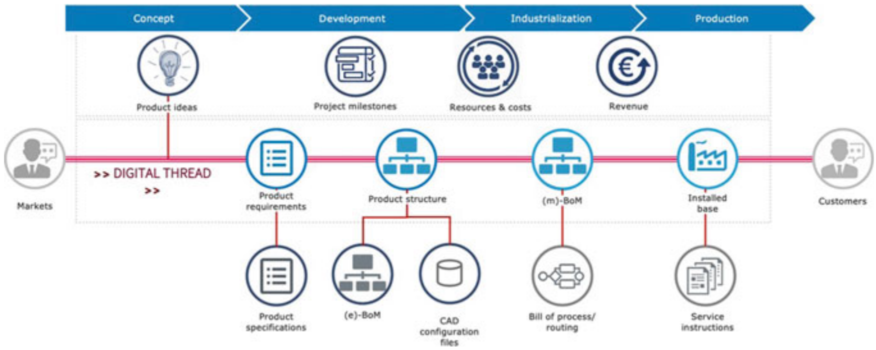

Fig. 19.9 Key information models involved in the digital value chain (*Source* CONTACT software)

supporting cross-company collaboration in engineering supply chains. The "apps" are available in either offering, and can be freely combined to build a targeted solution.

CONTACT *Elements* solutions can be run on-premises or in software-as-a-service (SaaS) and platform-as-a-service (PaasS) models.

What is Our Role as Digital Technology Vendor (DTV)?

Following our vision of "energizing great minds", we aim to be an enabler for digital value chains inside and beyond the boundaries of the enterprise. As a partner for our customers, we want to understand the customer's challenges and goals, and contribute our software products and industry knowledge to build solutions that put the customer in the best position possible. Although we believe that every company eventually requires "digital" skills, it is our role to be our customer's specialist partner for lifecycle software and digitalization. Through our standard software offerings and the tailor-made solutions augmenting it, we enable customers to build efficient digital processes, that seamlessly integrate with other software tools and the broader "digital environment" of connected devices and the internet.

What is Our Vision to Drive the Future Digital Technology Portfolio?

Processes for designing, manufacturing and operating products supporting certain business models vary widely in their underlying patterns—from engineer-to-order to configure-to-order, from large-series to single-item manufacturing. In addition, products are designed and realized using technologies and materials as diverse as those products' purposes—ranging from airplanes and smart phones to steel mills. To satisfy the need to differentiate itself in the market place, nearly every company's lifecycle processes have unique properties not found elsewhere—not accidentally but deliberately and necessarily. On the other hand, many abstractions and paradigms are similar or the same and can be handled by standardized software if it is sufficiently flexible.

It is our vision to build a software portfolio for supporting lifecycle processes with information technology that embraces the diversity of users, methods and tools in use. Business models, the resulting processes, and therefore the landscape of methods and tools are subject to an ongoing discourse in any organization and are ever changing, raising the need to constantly re-organize software systems. We want to ensure the digital sovereignty through a holistic combination of customizable standard software and effective consulting.

What are Our Biggest Challenges Being a Digital Technology Vendor?

The biggest challenges in being a digital technology vendor revolve around making customer success sustainable. Against the backdrop of trends like the opportunities of digital business and the risks of being outpaced by competitors that embrace digital business models, customers more than ever need consultative approaches from vendors: we increasingly have to help customers discovering their needs. Once a project is in place, it is in some situations challenging to maintain the motivation for continuous improvement and moderate the definition of meaningful priorities.

We see a growing gap in the market place between leaders and laggards in digitalization. Supporting organizations from both ends of the spectrum requires a vendor to support both, stability and a higher cadence of innovations.

Which Inhibitors Exist for Robust Integration of our Digital Capabilities in Industry? Why?

A major inhibitor for lifecycle digitalization initiatives, specifically where those aim to close loops between design, manufacturing and operations, is the inability of organizations to untangle and resolve the inherent complexities. This applies to complexities in business requirements, changing established processes, but also in reconfiguring and changing existing IT systems and adopting new digital technologies like Artificial Intelligence. Software vendors and service providers need partners on the side of the customer at equal footing to align potentials and expectations, and build and evolve the system landscape.

Finally, as competition is intense, and although every vendor is claiming the opposite, some vendors try to force customers into lock-in situations by inhibiting interoperability like imposing contractual restriction or concealing information in proprietary data formats (e.g. CAD).

Occasionally, product lifecycle initiatives lack top-management support, resulting in missing strategic momentum, inappropriate priorities or insufficient funding. A significant number of industrial companies is not aware of the risks of being marginalized by digital leaders or becoming locked-in by less well-intended vendors—to gain digital autonomy it is essential to properly understand and manage risks and opportunities and not just "buy the necessary tools".

What is Our Way for Successful Partnership with Research and Industry?

Regarding research, we are maintaining a structured research roadmap, that is informed by a "trend radar" aligned with our strategic goals. Our in-house consulting staff is well connected in industry and academia, and a competent dialog partner for the research community. Actual projects are put to work with the support of a network of research partners. Strategic research partners in Germany and Asia are funded directly through long-term agreements. The *Elements* development platform is a powerful enabler for research prototypes and demonstrators, and also facilitates efficient exploitation.

CONTACT maintains a dedicated team for acquiring and governing alliances and industry partners. We are participating in partner programs of all major players in our market. Strategic alliances are in place with globally acting companies like Mitsubishi.

Dassault Systèmes[8]

How do We Describe Ourselves?

Dassault Systèmes, the 3D EXPERIENCE Company, is a catalyst for human progress. We provide business and people with collaborative 3D virtual environments to imagine sustainable innovations. By creating virtual twin experiences of the real world with our 3D EXPERIENCE platform portfolio, our customers push the boundaries of innovation, learning and production. As of 2021, Dassault Systèmes brings value to more than 290,000 customers of all sizes, in all industries, in more than 140 countries.

For more information, visit www.3ds.com.

What is Our Role as Digital Technology Vendor (DTV)?

Dassault Systèmes has already led the charge in transforming how products are designed, developed and supported, with 40 years of digital technology innovation. The accelerated pace of innovation required in the three sectors of the global economy we are serving, Manufacturing, Life Sciences & Healthcare, and Infrastructure & Cities, can only be achieved by the continued platformization of industries, where companies can leverage the social enterprise to support their innovation

[8] The *Dassault Systèmes* technical contribution has been created and delivered by Philippe Laufer.

processes throughout their value chain and across all disciplines, to drive successful end-customer experiences (see Fig. 19.10).

Today, consumers (whether a corporation, small company, individuals or government entity such as a city), make purchase and usage decisions, not based on the product or service itself, but on their experience with it. Our objective is to help our clients create, test and evaluate these experiences to make sure they are rewarding for their users, ensure that the product manufactured or the service provided meets expectations, and use this information to drive further improvements in the end-user experience.

Our 3D EXPERIENCE platform, which pioneered the category of „business experience platform", provides a collaborative environment that empowers businesses and people to innovate in entirely new ways and create these products and services using the virtual world. We are positioned to help customers become platform-driven through:

Fig. 19.10 Experience in the context of human, nature and technologies (*Source* Dassault systèmes)

– **A system of operations** coupling Modeling & Simulation (Mod-Sim) with extensive data capabilities
– **A business model** acting as a marketplace or trading platform that connects service providers and buyers

The 3D EXPERIENCE platform enables customers to reveal real-world data, from many disparate sources, elevated to a consistent, actionable semantic, and activate them into virtual twin experiences of the products, manufacturing facilities, or even enterprises themselves. The offer is built on a rich portfolio of data-driven industry processes and roles, spanning a wide spectrum of domains from high fidelity modeling and scientific simulation to production and logistics optimization. It is applicable in sectors such as natural resources, cities, transportation, buildings, smart products, consumer goods, as well as biological systems and chemistry.

This strategy focuses on *Human Industry Experiences*:

- **Human**: centers on online, mobile and ease-of-use, for collaborative innovation and for bringing 3D to consumers. For example, our HomeByMe solution helps millions of people all over the world imagine, easily create and place furniture in rooms, and experience them in virtual reality.
- **Industry**: centers on creating the knowledge and know-how needed to ensure that our solutions match closely the needs of the industries we address. Large clients have a strong focus on deep transformations to adapt to the respective challenges of their industries. In all these industries, new entrants have appeared with small teams focusing on sub-segments of their markets and proposing high-value experiences with products. Our solutions appeal to industry leaders and startups, both of which are shaking up industries.
- **Experiences**: Being able to model experiences is how companies can innovate and create new categories of products and solutions that will drive new, better experiences for their consumers. But this use isn't limited to companies. Our work with cities demonstrates that we can do this at the most demanding level thanks to the 3D EXPERIENCE platform's capabilities to model city experiences to improve the lives of citizens.

What is Our Vision to Drive the Future Digital Technology Portfolio?

Dassault Systèmes 'key driver is *sustainability*. Today, we are supporting the United Nations Sustainable Development Group (UNSDG) and its 17 Sustainable Development Goals such as Industry, Innovation and Infrastructure, Good Health and Well-Being, and Responsible Consumption and Production, through our purpose to provide virtual universes to businesses and people to imagine sustainable innovations that can harmonize product, nature and life.

To do this, we provide industry with the technological capabilities to create real-time virtual representations of a product, platform or ecosystem. These virtual twins can be used to model, visualize, predict and provide feedback on properties and performance, reduce operational costs, and drive end-to-end disruption in value chains, making them a key enabler of disruptive and sustainable innovation as well as more circular business models that would be prohibitively expensive, risky, and complex to develop and test in the physical world.

A virtual twin is not only defined by its physical representation, but also by its operational, functional and logical representation, hence the importance of the objects dictionary (Requirements, Functions, Logical items, Physical items, Processes, Resources, Models, Scenario, Scenes, Results, etc.) provided by the platform and all related services such as Lifecycle, configuration, change, … Dassault Systèmes is the only company delivering these unified services.

Today, many of the items people use on a daily basis—from a shampoo bottle to a car—have been designed, engineered, improved and developed using virtual twin technology. The technology has enabled disruptive solutions that can positively impact society, from smart city initiatives and driverless vehicles, to record-breaking solar-powered aviation, hydropower plants and wind turbines.

The next frontier of virtual twin technology involves healthcare, which is why, as a company, we have expanded our focus „*From Things to Life*".

What is the difference between things and life? Life is not made of parts: the human body is one piece and hyper connected. Life doesn't do standardization: it's personalized design, production and usage. And life isn't "used" but lived. Life is an experience. Therefore, to improve life, we have to invent new ways of representing reality. We have to invent the virtual twin experience of life**.**

A virtual twin experience of the human body with the 3D EXPERIENCE platform integrates modeling, simulation, information intelligence and collaboration (see Fig. 19.11). It brings together biosciences, material sciences and information sciences to project the data from an object into a complete living virtual model that can be fully configured and simulated. By combining art, science and technology, it makes it possible to understand the invisible to represent the visible. Industry, researchers, physicians and even patients can visualize, test, understand and predict what cannot be seen—from the way drugs affect a disease to surgical outcomes—before a patient is treated.

Fig. 19.11 The evolution from *3D design* to *virtual twin experience of humans* (*Source* dassault systèmes)

What are Our Biggest Challenges Being a Digital Technology Vendor?

Accelerating the understanding and implementation of virtual twin experience concepts, and making them inclusive for everyone in a company, whatever its size, are some of the key challenges Dassault Systèmes is addressing and meeting everyday.

Global GHG emissions are projected to reach around twice the *IPCC*- and *UN*-recommended CO2e target by 2030 in order to limit global warming to 1.5 °C by the end of the century. Achieving a carbon-free, circular economy in which waste is eliminated and resources are continuously used cannot be done incrementally and requires radically disruptive innovations by industry that are only possible through a molecular-level understanding of each product, material or process through its end-of-life.

Virtual twin technology is a non-negligible opportunity to stay within the recommended global carbon budget. Yet the technology has only been adopted by 10% of the companies that should be using it due to a number of barriers such a limited understanding of technology use cases and benefits. This requires advancing the thinking on the potential for virtual twin technology to accelerate this sustainable transformation towards a more circular economy.

Which Inhibitors Exist for Robust Integration of Our Digital Capabilities in Industry? Why?

Dassault Systèmes is already working with disruptive startups that are using the 3D EXPERIENCE platform to invent new industries. We‘re helping to facilitate the transformation of global OEMs into leaders of what we call the *„Industry Renaissance",* a digital revolution that is transforming every aspect of industrial business: how product experiences are conceived, developed, tested, made, sold and serviced; how supply chains form, operate and braid themselves between industries; how consumers and manufacturers interact; how the real and virtual worlds inform and reinforce one another; how value is created; how the workforce is trained; and the very nature of work itself.

But the *Industry Renaissance* is powerful, and its transformations occur fast. Companies must either embrace it today or disappear tomorrow. This was further revealed during the pandemic, when companies needed to continue to work with their data and maintain business, operational and digital continuity. This was possible only by extending their communities, project management and business to a virtual environment on the cloud.

Cloud adoption, although now accelerating, is key for robust integration of "out of the box" solutions to implement virtual twin experience concepts. It eliminates costly and unuseful customizations that systematically hinder inclusive usage, through normalized processes and data.

Lastly, digital platforms, intelligent 3D models that embed knowledge and know-how in context, and digital marketplaces that can transform traditional supply chains into value-creation networks are critical components of success, but are not yet widely integrated in the standard thinking and decision process in industry.

What is Our Way for Successful Partnership with Research and Industry?

Dassault Systèmes has embarked on many initiatives to put our technology and knowledge at the service of research, education, culture, and artistic creation, as well as to drive our commitment to sustainability.

We advance our purpose through collaborations with larger, leading companies in key industries that have given us the means to solidify our pioneering position, as well as with the „movers and shakers" that are catalyzing the creation of new categories of products and reinventing industries.

Our research and development is conducted in close cooperation with users and customers to develop a deeper understanding of the unique 'To be' business processes of their industries and their future product/experiences directions and requirements.

We also have long-standing scientific and technical collaborations with key partners to maximize the benefits from available technology and increase the value for our shared customers. These alliances are established with three objectives: to cover end-to-end solutions with holistic offerings; to participate in shaping the future structure of industries; and to integrate the most advanced features of these technologies into our solutions. Dassault Systèmes participates in several hundred public–private projects including ones with the FDA, with prestigious universities such as Harvard, MIT, or Berlin University of Technology (TU Berlin), and with world-leading institutes such as INRIA, INSERM, and Fraunhofer Institutes. We also collaborate with renowned scientists including Nobel Prize winners.

We are also working very closely with innovators within the 3D EXPERIENCE Lab. This open innovation laboratory and startup accelerator program was created to foster entrepreneurship and strengthen society's future of creation. First established in France and now located in the U.S. and India, it has yielded successful projects aligned with the UN SDGs, including large-scale additive construction using robots, 3D printing of personalized organs for simulation of surgery, and unmanned long-range solar drones. The Lab has grown to include more than 25 incubators, accelerator, educational, entrepreneurial, technology and fab lab partners worldwide, 1200 mentors, and collaborations with multinational companies on co-accelerating promising projects in specific industries.

La Fondation Dassault Systèmes is dedicated to transforming the future of education and research through 3D technology and virtual universes. The foundation provides grants, digital content and skillsets in virtual technologies to education and research initiatives at academic institutions, research institutes, museums, associations, cultural centers and other general interest organizations throughout the European Union, the U.S. and India. In 2019, La Fondation supported 35 projects across these regions.

In education, Dassault Systèmes partners with institutions worldwide such as Berlin University of Technology (TU Berlin) closely with Prof. Dr.-Ing Rainer Stark, to jointly develop enhanced teaching methods that help transform science, technology, engineering and mathematics (STEM) education, and to define and implement policies and initiatives that contribute to preparing the workforce of the future. It is one of the founders of key academic associations such as the Global & European

Engineering Deans Councils, the International Federation of Engineering Education Societies, and the Cartagena Network of Engineering. It also organizes and supports competitions for science and technology students worldwide, to get young generations interested in the domains, anticipate and meet skills requirements, and boost their employability.

The strength of Dassault Systèmes lies in its inclusiveness, and its ability to reach all audiences and offer specific solutions to fulfill each need.

MathWorks[9]

How do We Describe Ourselves?

MathWorks is the leading developer of mathematical computing software for technical computing and system development. Founded in 1984, MathWorks is a privately held company with a staff of over 5000 people in 34 offices around the world. Millions of engineers and scientists worldwide rely on its products to accelerate the pace of their discovery, innovation, and development. MATLAB, the language of engineers and scientists, is a programming environment for algorithm development, data analysis, visualization, and numeric computation. Simulink is a block diagram environment for simulation and Model-Based Design of multidomain and embedded engineering systems.

Building on those two platforms, the company produces over 100 additional products for diverse applications such as signal processing, control system development, machine learning and deep learning, optimization, automatic code generation for production use, communication systems design, and computer vision.

What is Our Role as Digital Technology Vendor (DTV)?

Our role spans three key areas: education, research, and industrial applications.

In education, our tools enable students to learn and master engineering and scientific concepts, by applying them in real-world applications and problems. More than 6500 colleges and universities around the world use MATLAB and Simulink for teaching and research in a broad range of engineering and science disciplines. Our tools integrate with learning management systems, can be leveraged for massive open online courses (MOOCs), and work with more than 2000 textbooks that present theory, real-world examples, and exercises in engineering, science, finance, and mathematics.

In research, the open-system architecture of MATLAB and Simulink enables researchers to create and share leading-edge techniques as community toolboxes, built on the impeccable MATLAB numeric foundation and the ability to integrate with a broad range of professional toolboxes developed by MathWorks. Researchers can also integrate with techniques and libraries created in other languages such as C/C++, Java, and Python.

In industry, MATLAB and Simulink are used throughout the automotive, aerospace, communications, electronics, and industrial automation industries as

[9] The *MathWorks* technical contribution has been created and deliveredby Jim Tung.

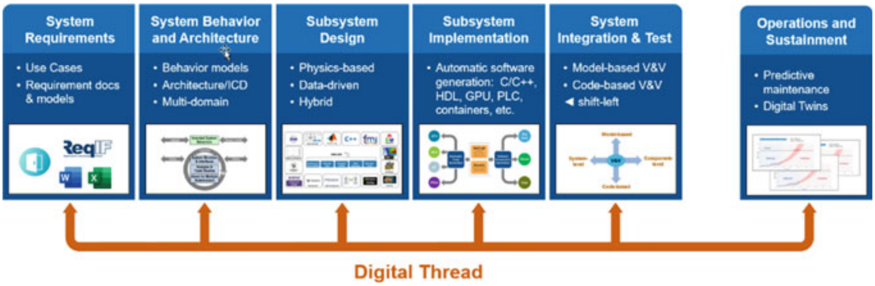

Fig. 19.12 MathWorks solutions along the digital thread (*Source* MathWorks)

fundamental tools for research and development. They are also used for modeling and simulation in increasingly technical fields, such as financial services and computational biology. Our capabilities span the system development lifecycle, from requirements management, to system architecture, multi-domain modeling and design, code generation, model-based/code-based verification and validation, and the use of models as a digital twin (compare Fig. 19.12). Our capabilities also enable powerful data analytics, with the ability to deploy to embedded devices, edge systems, on-prem/HPC, and cloud.

MATLAB and Simulink are designed to interoperate with other aspects of the digital ecosystem, including traditional PLM systems, modern systems such as Jira and Git, more than 100 other modeling tools and languages, CI/CD (continuous integration and continuous delivery), and enterprise systems based on Spark, Hadoop, and other Big Data frameworks.

Our tools support most popular development approaches, including the traditional V-model, Agile, and DevOps (compare Figs. 19.13 and 19.14).

What is Our Vision to Drive the Future Digital Technology Portfolio?

Our vision is to enable the systematic use of data and models so organizations can create and deliver superior value to their customers throughout the entire product/service lifecycle. The data include experimental data, production data, test data, and operational data. The models include dynamical and physics-based models, AI models, and other data-driven models. Value is obtained by enabling decisions in the asset, at the edge, on-premises, and in the cloud.

What are Our Biggest Challenges Being a Digital Technology Vendor?

In companies across all the industries that we serve, "digital transformation" initiatives are dramatically changing their strategies, workflows, people, and systems. In some cases that creates uncertainty, and sometimes conflict, between engineering groups who want to use model-based approaches and digital/software groups who want to use data-driven approaches. A key challenge—and major opportunity—is to work with those groups to define synergistic approaches that leverage the strengths of both perspectives.

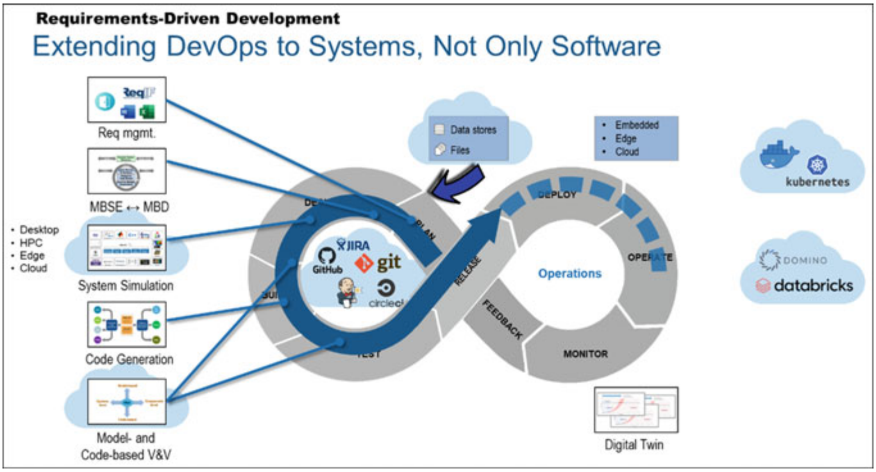

Fig. 19.13 *Requirements* driven DevOps to (technical) systems (*Source* MathWorks)

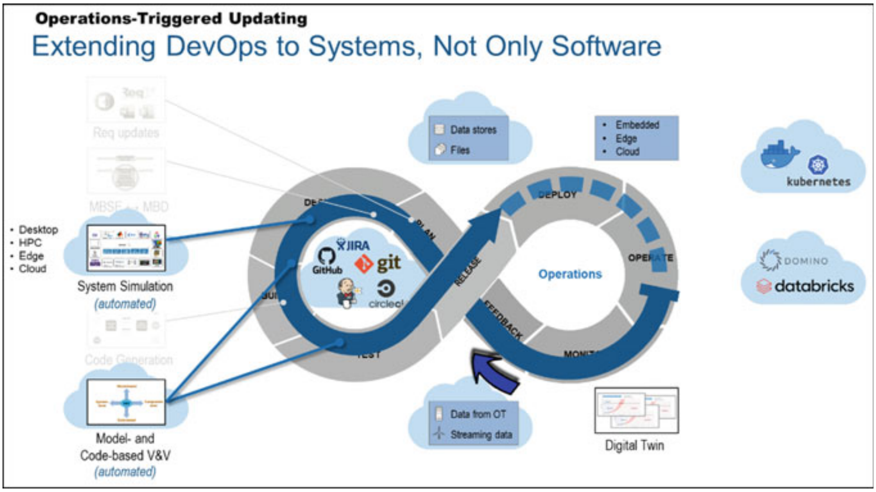

Fig. 19.14 *Operations triggered update* driven DevsOps to (technical) systems (*Source* MathWorks)

Which Inhibitors Exist for Robust Integration of our Digital Capabilities in Industry? Why?

In general, MathWorks has a proven track record enabling robust integration of our capabilities with other tools. We do that by carefully designing APIs (application programming interfaces) in our products, then documenting, supporting, and maintaining them as features of our products. We rely on well-proven protocols and standards for the given workflow, such as COM, .NET, and DDS.

An inhibitor can exist when a standard is not well proven or lacks rigor needed for a particular workflow. One example is the XMI interchange specification in SysML, which is not able to support rapid exchange and roundtrip workflows due to the specification and SysML tools' support for it.

What is our Way for Successful Partnership with Research and Industry?

The MathWorks approach for successful partnership with research and industry relies on our robust, performant, and flexible technology foundation. With that in place, we can enable research and industry customers to self-serve their way to success, and we can also define ways to partner, extending and customizing our capabilities when appropriate.

PTC Inc.[10]

How do we Describe Ourselves?

PTC Inc. (formerly Parametric Technology Corporation) is an American computer software and services company founded in 1985 and headquartered in Boston, Massachusetts. The global technology company has over 6000 employees across 80 offices in 30 countries, 1,150 technology partners and over $1bn in revenue.

The Company offers a portfolio including.

- IoT products, such as ThingWorx, KEPServerEX,
- PLM products, such as Windchill, Integrity, Navigate, Creo View and Arena,
- CAD products, such as Creo and Mathcad and Onshape,
- AR/VR products, such as Vuforia and Vuforia Studio.

What is our Role as Digital Technology Vendor (DTV)?

IT is now playing a more prominent role in organizations' decisions to adopt Industrial IoT platforms as part of broader digital transformation initiatives [6]. Importantly, IT's involvement is being met with enthusiasm from OT groups at the organization. The historic divide between IT and OT has been well documented, but as the Industrial IoT platform market has matured, so has the concept of IT-OT convergence. Platforms continue to be the dominant option for Industrial IoT functionality, but CIOs should also be aware of the emerging selection of Industrial IoT solutions that address specific use cases. Together, a platform and a solution built on that platform are a compelling option for digital transformation projects [7].

In this context, PTC has consistently been named a leader in Industrial IoT by all major industry analyst firms, e.g. [8], over the last several years, see Fig. 19.15. PTC can deploy its Industrial IoT offerings on-premises, in the cloud, or in a hybrid environment. PTC has developed a broad partner ecosystem in the Industrial IoT space, including strategic partners, global and regional systems integrators, and technology partners.

[10] The *PTC Inc.* technical contribution has been created and delivered by Dominik Rüchardt and Dr. Erik Rieger.

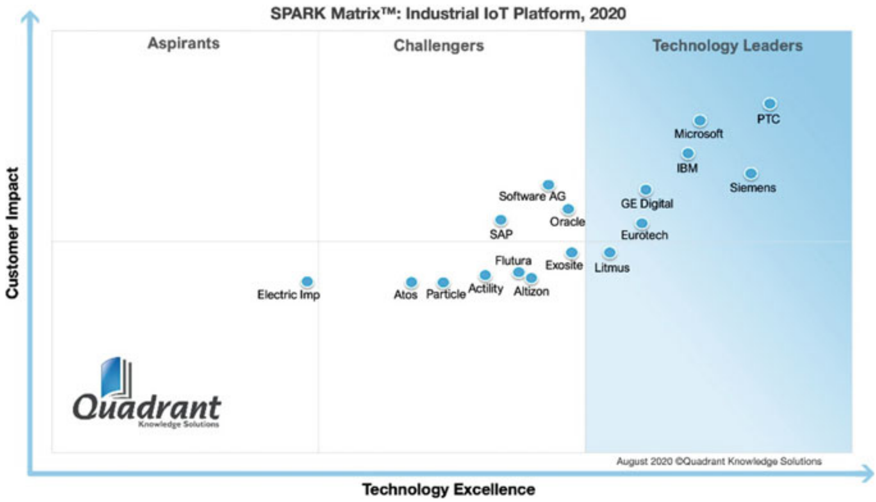

Fig. 19.15 Quadrant of IIoT leaders [7]

PTC brings its industrial IoT offerings to market through this partner ecosystem, a growing channel network, and a global direct salesforce. Complementing core IIoT functionality like application enablement, analytics, and device management, PTC offers a range of device connectivity offerings, including some of the broadest support for industrial protocols and drivers. Moving forward, PTC will offer more of its Industrial IoT functionality in a pure software as a service (SaaS) model.

What is our Vision to Drive the Future Digital Technology Portfolio?

The increasing capabilitites of smart connected products not only reshape competition within industries but expand industry boundaries. This occurs as the basis of competition shifts from discrete products, to product systems consisting of closely related products, to systems of systems that link an array of product systems together [9]. Also, in contrast to traditional product development, in the future product development is expected to continue along its entire life cycle [10].

Industrial value creation will benefit from a convergency of the physical and the digital world which creates powerful new capabilities as Digital Twins, Augmented Reality based interactions, any many more.

The fundamental step to these capabilities is the digital thread—the seamless connectivity along the lifecyle an cross all functions and views in connection to industrial products and services (Fig. 19.16).

The Digital Thread is the logical next step coming from PLM and Systems engineering. An open digital architecture connecting things and software systems along the value chain and supporting applications and solutions for the business-oriented interaction. One is the digital twin concept which becomes key for managing products in the future. The management of the digital version of the real product instance is basis for leveraging the benefits of the digital transformation such as

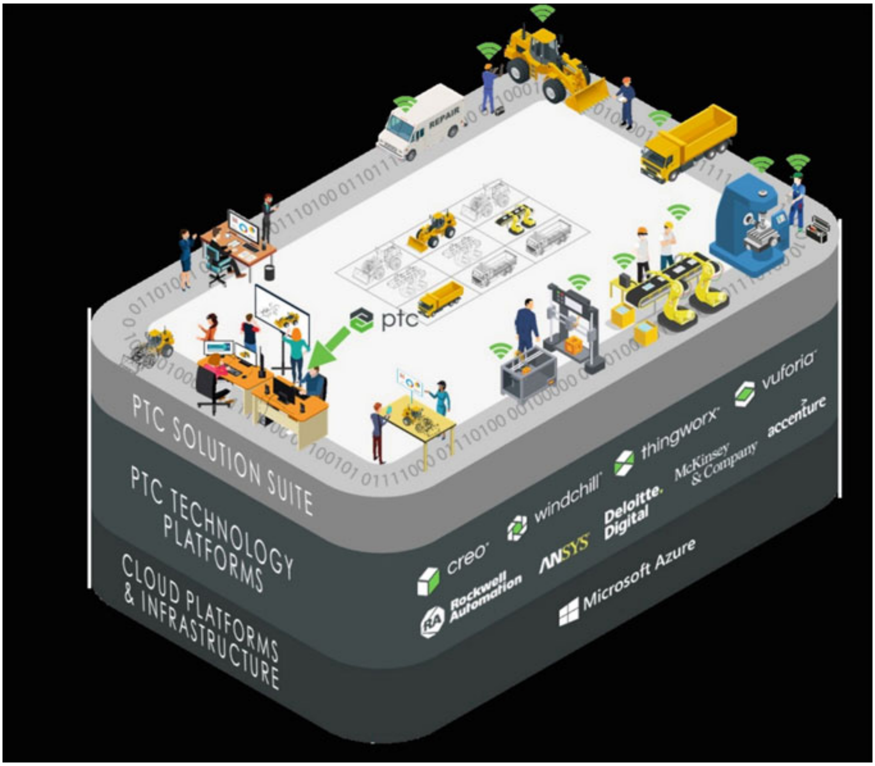

Fig. 19.16 The digital thread connects the entire lifecycle and is the prerequisite for the realization of connected business models and digital twins (*Source* PTC Inc.)

remote product management, performance control, failure prediction, continuous improvement, 'Product as a Service' offers and flexible recomposition.

This comes together with an evolving IT focus on moving IT infrastructure into the cloud, but also leveraging SAAS models. Product related data is now available across the entire cycle from all locations. Data is gathered from different systems, but also along operations (SCO) and directly picked up from the product, while it is in use or in maintenance (SCP).

The comprehensive data is used to establish the digital twin and thus forms as basis for AR and VR embedding. It opens up multiple differentiation paths. It can create companion experiences that expand the capabilities of products, give customers more information, and increase product loyalty. PTC supports all pathes based on the described technology offerings together with the experience and vision as leader in the magic quadrant.

What are Your Biggest Challenges as a Digital Technology Vendor?

With the increasing degree of connectivity value creation shifts more and more from a well fenced product- or user group to distributed user groups and processes across functions and enterprises. The traditional “Customer-Vendor” relation tranforms in that context into a partnership which inludes many stakeolders contributing to the final value add. Vendors have to deliver into complex value networks which continuously change.

At the same time new business models like SAAS (software as a service) and cloud operations change the way of payment, the way of evolution of vendor-customer relations, the way of maintaining software and the way of supporting user communities.

Which Inhibitors Exist for the Robust Integration of our Digital Capabilities in Industry? Why?

A digital transformation investment of a customer is much more than buying software. It includes changes of behavior and the need to integrate with all interfaces along value chains. A digital strategy which includes business and stakeholder evolution is absolutely necessary for short- and long-term success. In addition, standardization and orientation on industrial reference architectures is key to benefit from the fast ecolution of digital capabilities.

How do You Achieve Successful Partnerships Between Research and Industry?

Research need shifts from technology to the question how to apply technology in a given or changing business context. Research results in reference models and processes. As a large vendor of commercial software for the industry the highest responsibility is in ensuring the robustness and long-term reliability of the software. Research consortiums should be reshaped in that sense and follow long term architecture concepts.

Following these principles PTC partners successfully with many universities with a special academic program and runs a large industrial experience center in the RWTH Aachen Business Campus. PTC also supports public funded research in a broad manner with technology and advisory. PTC is active member in asssiciations as OMG, ProStep iVIP, Bitkom, Plattform Industry 4.0 and many more and supports initiatives and consortiums for sustainable business innovation.

Siemens Digital Industries Software[11]

How do we Describe Ourselves?

Siemens Digital Industries Software is world’s leader in industrial software. We offer an integrated portfolio of software, services, and collaboration across a broad spectrum of engineering domains called *Xcelerator*. Xcelerator accelerates digital transformation for companies of all sizes and in all industries. The Xcelerator portfolio supports three key facets of the digital enterprise: the comprehensive *digital twin*, p*ersonalized, adaptable solutions*, and an *open, modern ecosystem* (see Fig. 19.17).

[11] The *Siemens Digital Industries Software* technical contribution has been created and delivered by Brenda Discher.

Fig. 19.17 The Xcelerator portfolio to accelerate digital transformation (*Source* siemens digital industries software)

What is our Role as Digital Technology Vendor (DTV)?

Siemens uniquely enables customers to create a better future with state-of-the-art technology so that anyone can turn today's ideas into tomorrow's products and experiences. By providing all the tools to connect the virtual and real worlds of product development and production processes, it creates a closed-loop environment leading to continuous optimization possibilities.

What is Our Vision to Drive the Future Digital Technology Portfolio?

1. *Comprehensive Digital Twin* (compare Fig. 19.18)

Merging the virtual and physical worlds with a complete digital representation of the product and its creation process allows engineers, designers, production engineers and even end users to experience every facet of a product or system long before a prototype is available, a chip is manufactured, or a factory is built.

The Digital Twin enables integration of the entire product lifecycle with the factory and plant lifecycle, along with performance data. Siemens is the only DTV whose Digital Twin concept encompasses the integrated circuit, embedded software, electronics, electrical systems, mechanical design, physics, and the actual system in operation. Given that the worlds of integrated circuits and systems and products are converging more and more—with automakers, aerospace companies and other manufacturer starting to design their own specialized chips—this ability is becoming increasingly important.

Fig. 19.18 The comprehensive digital twin (*Source* siemens digital industries software)

2. *Personalized and Flexible*

We believe all users of software will require personalization. This means the users will also define the development of the application to their individual needs. IT systems should assist the designer/engineer, customer workflows, digital threads, and industry specific customer solutions. Flexibility means the ability to work across engineering domains and across design, manufacturing, utilization allowing for ubiquitous engineering 24/7, from any device and ramping up new engineering capabilities on demand. Siemens acquired Mendix in 2018, allowing business users to create and tailor our software applications without having to be software developers.

3. *Open Ecosystem*

In the complex product lifecycle world, it is important to have an open architecture so our customers can allow data to easily flow into existing third-party applications. By securing collaboration and sharing data and IP with partners, suppliers, or developers, an open ecosystem enables innovation with low-code and cross-platform compatibility. Siemens enables over 4 million users to leverage its 3D modelling engine Parasolid, and over 130 members utilize our visualization tools. In addition, customers can choose from a strong low-code community of over 190,000 developers[12] to help them. This creates an industrial network effect to speed up innovation, enhance customization efforts and promote partnerships across the supply chain.

[12] All data as of April 2021.

What are our Biggest Challenges Being a Digital Technology Vendor?

The top challenges are:

1. to support our customer's transition into new business models; the disruption happening across most industries,
2. to enable digitalization in the face of a significant skills gap. Currently, design, engineering and manufacturing jobs worldwide go unfilled due to the growing gap between the skills employers need and those recent graduates have.

Meanwhile, digitalization changes constantly and Industry 4.0 drives the need for skilled workers that understand data-driven, AI-powered, connected design and manufacturing. As the industry landscape evolves, the need for highly skilled technologists has never been greater.

How do you democratize and knowledge and experience? We believe digital technologies are already starting to play a major role in accomplishing this goal. Siemens' low code platform Mendix helps to "encode" knowledge and experience within apps, leveraging and exposing the capabilities of the whole Xcelerator portfolio for commercial users as well as for academic institutions. Xcelerator provides the bridge across engineering disciplines to enable more cross/inter-disciplinary collaboration which supports new business models that rely on the combination of sophisticated technologies, services and monetization models.

Which Inhibitors Exist for Robust Integration of our Digital Capabilities in Industry? Why?

Those reluctant to change will point to many factors preventing them from embracing digital transformation. A company's existing investments in technology, regardless of its potential pitfalls and perceived or past successes, may be setting back innovation. Having already invested has translated into a refusal to evolve.

We see that investment in digitalization separates the winners from the laggards, especially as startups enter established industries. Other factors that drop barriers to innovation include the democratization of design and supply chains and the lower thresholds of infrastructure cost fueled by cloud technology.

Most progressive companies in terms of digital transformation initiatives see the highest levels of return. But they must be all-in. We have seen the biggest gains come from customers who have leveraged technology to have different disciplines working in a more united way. An example of a company embracing digitalization and being able to pivot is VinFast. VinFast wanted to be competitive in Vietnam and globally right from the beginning, so the company relied on Siemens' expertise to utilize the latest technology. This resulted in a closed-loop manufacturing system, which uses digital twins of the products, the production, and the performance of production and product. The fully digital factory was built in 21 months, 50% faster than usual, and is designed to be easily scalable for future expansions.

What is our Way for Successful Partnership with Research and Industry?

For Siemens, research and industry cooperation is essential. The company's R&D expenditures reached €4.6 billion in fiscal year 2020 and issued 2493 patent applications with more than 25% of the patents related to "Industrie 4.0" and digital technologies.

Proven and new forms of bilateral partnership allow for the greatest possible sharing of knowledge, which is why Siemens partners with academia on several levels. These partnerships include supplying of our products and solutions for education, free training, certifications, and modular curricula content for educators as well as joint research and development projects. Siemens works closely with universities and research institutions on many research and innovation projects.

The dialog with university students includes idea competitions and hackathons, industry-sponsored doctorates for graduates at Siemens, and university teaching by Siemens employees. Siemens also serves on various academic bodies, where we seek to better fuse industrial and academic requirements.

Research "co-locations" and "living labs" allow professors, Siemens experts, and students to collaborate intensively. Siemens shares its industry expertise and its knowledge of industry needs in the development of new curricula in the emerging technologies of artificial intelligence, digital twin, additive manufacturing as well as model-based systems engineering. Siemens is also actively driving new partnerships with academic incubators.

Siemens serves an ecosystem of 4000 + schools and 1,500,000 + students, as well as over 4000 technology partners.

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