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Title

The Goal is the Digital Enterprise:
Professional Digital Representation of
Product Development and Production

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Software has become the most important driver of industrial innovation – and its importance continues to grow with ever-increasing speed. Accounting, Human Resources, Sales and transactional processes within companies are today extensively and systematically supported by business software. In core value creation processes of product R & D, production and aftersales service, however, support through software has up until now generally been rudimentary.

In order to accelerate the value creation processes while at the same time ensuring higher quality, industry has in the meantime also begun to fully support its technical workflows by using software tools. Interaction with those processes on the commercial side already enjoying extensive software support has meant that digital "parallel" companies have arisen in the enterprises concerned. It can be safely assumed that in the foreseeable future all value creation processes involved in the development and bringing to market of a product – including its production – will be able to be completed almost entirely digitally without the involvement of physical processes such as the building of large numbers of prototypes. A company that has made the necessary investment and has also undertaken the required change to its operating processes has, from our perspective, successfully carried out the transformation into a Digital Enterprise.

So-called "early adopters" are already showing that the necessary technologies, even though not yet perfect, are available in sufficiently mature form to be able to be used in practice. The results obtained and the advantages gained are even today so dramatic that we can truly speak of a revolution. The competitiveness of companies will in future mostly be determined by the scope and penetration of these technologies and how professionally they are utilized.

The products of the future can only be successfully developed and economically produced with the aid of digital tools and supporting information technologies. However the same rules that apply to physically realized products and production systems also apply to a digital company. Its development demands the ongoing readiness of all involved to be continually put to the test and, if necessary, a willingness to reinvent themselves. In the innovative and massively software-aided technical work processes of the future, progress in production will for the most part be determined by ongoing development of the software tools used. In such a case, holding back on investment until these tools have matured makes no sense because the software environment itself is continually undergoing further development at great speed. Taking up these technologies at a later point in time will consequently be accompanied by great disadvantages in competitiveness.

The forward-looking Industrie 4.0 project addresses the evolutionary changes that will be brought about by the merging of modern information and software technologies with classic industrial processes and the revolutionary effects that this transformation will have on industry. It is, however, reasonable to suspect that broad penetration of industry with these technologies will, in spite of their revolutionary effects, take a considerable amount of time. This aspect should always be taken into consideration when planning the corresponding investments.

The challenges facing industry can be compared to open heart surgery – many barriers must be eliminated while development and production are still ongoing in order to turn the digital company, with its enormous potential productivity, into reality. The greatest barriers are to be found today between the inconsistent data silos of the technical departments and processes, between the engineering disciplines and between companies on a global scale. Differences between various industries and the reflection of their characteristics in the software platforms on which the digital company is built must of course be taken into account. Moreover, standards and openness are core requirements for viable economic realization. Last but not least, care must be taken that tools and communication structures are prepared that permit the digital company to integrate with the real company or allow a fusion of both.

In this respect, Siemens Industry Automation is both a supplier and a user. The naturally holistic perspective across the entire value creation process that arises from this has, for a company that both develops and produces

products, a decisive influence on the definition and development of the software products that we also offer our customers. For this reason Siemens is doubly interested in the Digital Enterprise quickly turning into practical reality.

7.1 Digital Enterprise platform

Many industrial processes, from development through to production planning, production, commissioning and on to servicing, are today both supported and managed by technical information systems. These operate along the entire value creation chain and across the total product lifecycle. In general, however, the tools for these systems have until now been developed and perfected in a standalone environment. Developers – whether those within the company or those at an IT supplier – have focused on providing the best possible support for the applications concerned. Interaction with other tools or continuity of technical data were in general not in the frame. In spite of this, however, such tools represented a great advance for both processes and products.

This is still far removed from the Digital Enterprise, in which all value creation processes right through to suppliers are represented digitally and in a seamlessly networked manner. The currently emerging requirements for cyber-physical systems (CPS) and the Internet of Things, along with their services, are very difficult to realize with today's technical data infrastructures. A solution oriented towards a broad spectrum of usage (and therefore economically viable) will only become available when a technological platform emerges that permits fast and seamless docking of new tools. Only with the help of such a platform will a broad range of tools or apps covering any kind of specific and differentiated applications be developed and provided by the many interested parties present on the market. Such a platform will not be developed in an ad-hoc manner on the drawing board but will in the coming years emerge as a result of cooperation between providers and users.

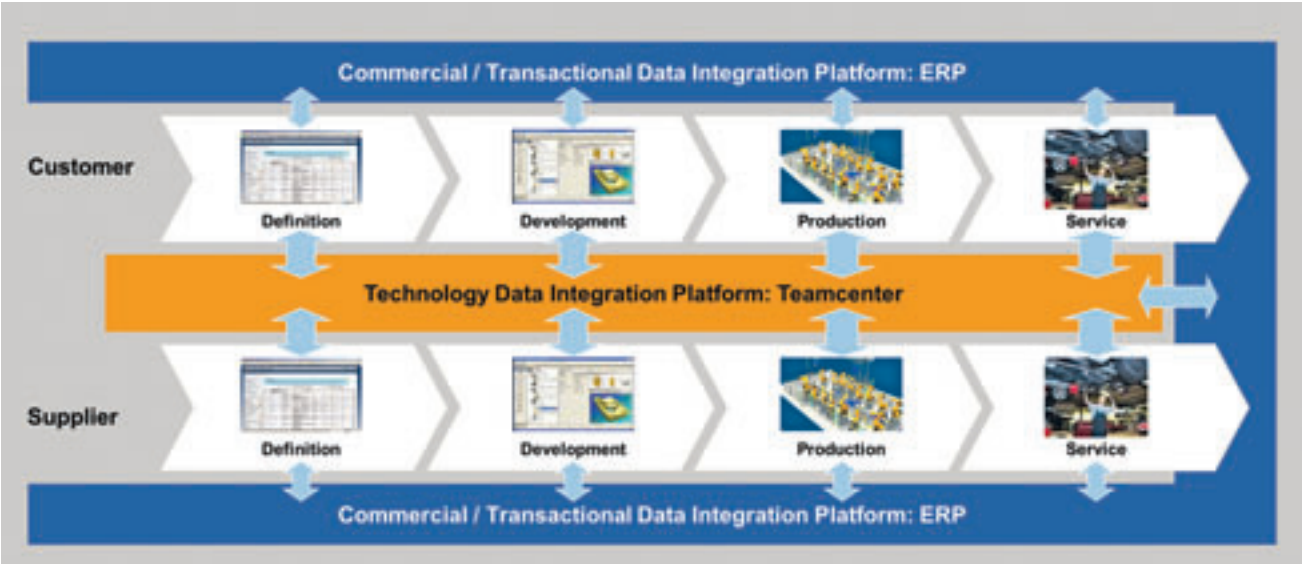

Fig. 7.1 Integration via commercial and technological data platforms (Source: Siemens)

Companies today generate and store an almost completely unmanageable volume of data, but this is only used by a very limited part of the company or in a small section of the value creation chain. The user of the data is mostly the department that generated it. But in the same way that the Internet became enormously important because the information contained therein is available to everyone, the data of the digital company will only be able to be utilized to its full extent when the entire extended company (and to some extent also its customers) can access it.

In addition, in the same way that the Internet can only provide a miniscule number of the functions that can be accessed if just one solution from one single provider is used, one single company cannot provide all of the functions needed for the realization of the Digital Enterprise. Good networking and the best possible integration of all components involved on the basis of recognized standards appears to be – just as in the case of the Internet – the only solution possible.

7.1.1 Globalization, the environment and sustainability call for the Digital Enterprise

This upheaval in industry certainly did not just start today. Indeed industry now finds itself undergoing one of its greatest changes within the last hundred years. Instead of being organized in such a manner that development and planning, tool making and production, overhauling and spare part warehousing takes place under one roof, the modern company is distributed across the globe. Thousands of suppliers and countless number of partners throughout the world are involved when a concern brings a product to market. Even the smallest companies avail themselves of the global offerings from producers and suppliers of services.

Everyone involved in such an undertaking, however, is confronted with a growing number of regulations and legislative measures formulated around the globe. These have been created to ensure that the products (and the production methods) are useful to humans and do not harm them and that the environment is protected and maintained without damaging it. The number of associated regulations is itself so large that no single company can remain on top of them without being supported by software. The humans involved – for example the development engineers – are even less capable of comprehending the resulting product requirements completely while providing proof that these requirements are met to the full extent necessary, and at the desired quality, without the aid of software solutions. This is, however, what society or even the law today requires of product manufacturers.

The shorter the product lifetimes and the faster the innovation cycles become, the more important is the provision of reliable forecasting and planning. And the larger, more differentiated and thus more confusing the market becomes, the more important it is to involve customers and partners.

All of these aspects can be recorded by a Digital Enterprise, with its information infrastructure and collaborative data platform, more or less in real time and taken into account in its processes and workflow cycles, representing enormous progress compared to the status quo. Once generated, the data is not just available for one purpose but, due to defined data formats, can be accessed at any time and for any purpose. Thus, far removed from the mountains and islands of proprietary data, a well-structured source of information can be created that in turn can be transformed into knowledge.

7.1.2 The Digital Enterprise requires major joint efforts

Unfortunately the technology needed to do this is not available for free, in much the same way as the Internet, which did not suddenly appear for free one day. A technology platform that makes a Digital Enterprise possible will require large investments across many years. Moreover, it cannot be created ad-hoc on the drawing board, but will be developed step-by-step from the contributions of many companies, manufacturers and users.

Suppliers of IT infrastructure components, including the providers of all kinds of software tools, will have to make their tools fit for purpose if they wish to undertake such a collaborative alignment. The way there will lead from monolithic solutions that handle a specific task in a proprietary data environment to solutions whose applications take their data as far as possible from a joint database and make the results available in the agreed form. The data is then of course available for all other applications. The creation of a technical data infrastructure that permits such a way of working will certainly not occur quickly, however. Because the product creation process is one of massive iteration, great care must be taken that the data remains consistent at all times – and that must happen automatically. In particular, collaborative engineering work of the type indispensable to large projects is of great importance. True consideration of this requirement not only affects data formats, interfaces and all of data management but means that the implementation of joint uniform data models will be absolutely necessary in core areas.

In addition, users will themselves not face a small task. They have already invested a great deal in their existing IT environments and have mastered today's development and production at a very high level. And with these IT environments they have created data and generated models that describe their products, their machines and plant and everything else that has to be carried out. But both will have to be fundamentally redesigned in order to realize the next advances in productivity.

On the way to the Digital Enterprise, IT environments will have to be remodeled such that they can meet the requirements of networked "intelligent" development and production. Today's existing data and models of products and production plant will only to a small extent be usable for the factory of the future.

In most cases the second part, the new modeling of products and production systems, will be the most difficult part. Instead of only having to manage the strictly hierarchically organized data volumes for mechanical products defined by geometric aspects, systems of the future will in parallel be confronted by logically structured data volumes necessary for the representation of functional models. This is the only way that system simulation in large-scale systems can handle the differentiation that will be needed to replace time-intensive and expensive prototypes. System simulation will develop into the biggest productivity driver of future industrial value creation.

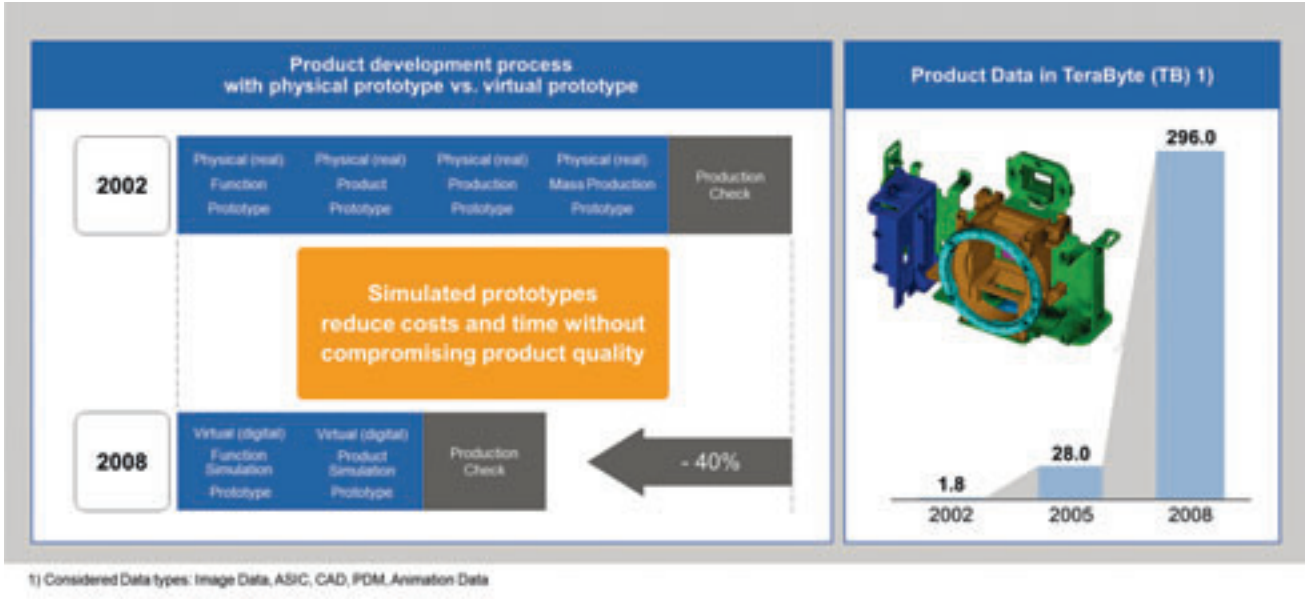

Fig. 7.2 Simulation leads to a dramatic acceleration of development processes (Source: Siemens)

7.2 Surmounting the barriers

It is often the investment needed that prevents many companies becoming early, or even the first, adopters of the new technologies. Sometimes it is the realization that in doing so there are considerable fixed costs, both initially and perhaps later, to be considered, and this is the real reason why such projects are approached very hesitantly. The necessary functionality can in most cases not be subdivided at will to permit these efforts to be easily accommodated within the normal IT investment budget. Moreover a fairly large number of employees must in general be equipped with much of the functionality to achieve any increase in productivity worth talking about. This fact usually leads to the initial investment not meeting the return on investment (ROI) expectations and therefore the entire project being placed on the back burner. Only after installing the critical basic functionality, which takes an over-proportional slice of the infrastructure costs, do incremental investments provide an adequate gain in productivity or ROI.

A further barrier is the fact that these kinds of new solutions must generally be introduced "on the run," i.e. during normal business operations. This means that the staff affected has to perform considerably more work over a relatively long period. If this extra work is not carried out to its full extent, or in the necessary quality, going live can result in massive interruptions to work processes and serious problems in the acceptance of the new solution.

The third problem that must not be underestimated when such systems are introduced is the necessity of defining, introducing and carrying out new process steps. The associated task of having to learn and stabilize the new work processes is usually found by staff to be a deficit of the new solution and often temporarily leads to dissatisfaction and loss of productivity.

For reasons of economy, the new IT support solution should generally, and as far as possible, be realized with so-called "out-of-the-box" software. Customer-specific modifications should be kept to a minimum to reduce the risk of having to undertake complicated and risky global adventures every time a new release is implemented.

7.2.1 Mighty islands of data: PLM, MES, SCM, DF, ERP

If one examines the value creation chain of an industrial company and the processes behind it, the broad palette of acronyms, each one representing a sub-process, already gives a hint of the main problem. The development of products of all types – from the simplest consumer goods up to highly complex automated production lines – is summed up in the term Product Lifecycle Management (PLM). The data generated for this is held in the various databases of the many sub-systems that support the PLM process.

Production planning and control, including the capture and the management of operating data is supported by sub-systems that, depending on individual developments in the individual company, are to be found in part in the Enterprise Resource Planning (ERP) system or in the Manufacturing Execution System (MES). The data needed for this is also to be found in a variety of databases and very often in differing formats. Every transfer of data is generally specially set up for this purpose and is a complicated and fragile process.

Control of the entire supply chain in the development and manufacturing operations is handled by Supply Chain Management (SCM) tools, while the planning and development of manufacturing processes and production plant is supported by manufacturing preparation or industrial engineering solutions that will in future form part of the so-called Digital Factory (DF). Transaction software, usually to be found in the ERP system, handles purchasing and procurement organization, order processing and company logistics.

This short list only refers to the central building blocks of the IT environment. Many other sub-systems such as field trials, fault testing, ergonomics design or the innumerable kinds of calculation, simulation and analysis used by a successful company for specific purposes during the product creation and production operations (and therefore essential) are not even taken into account here.

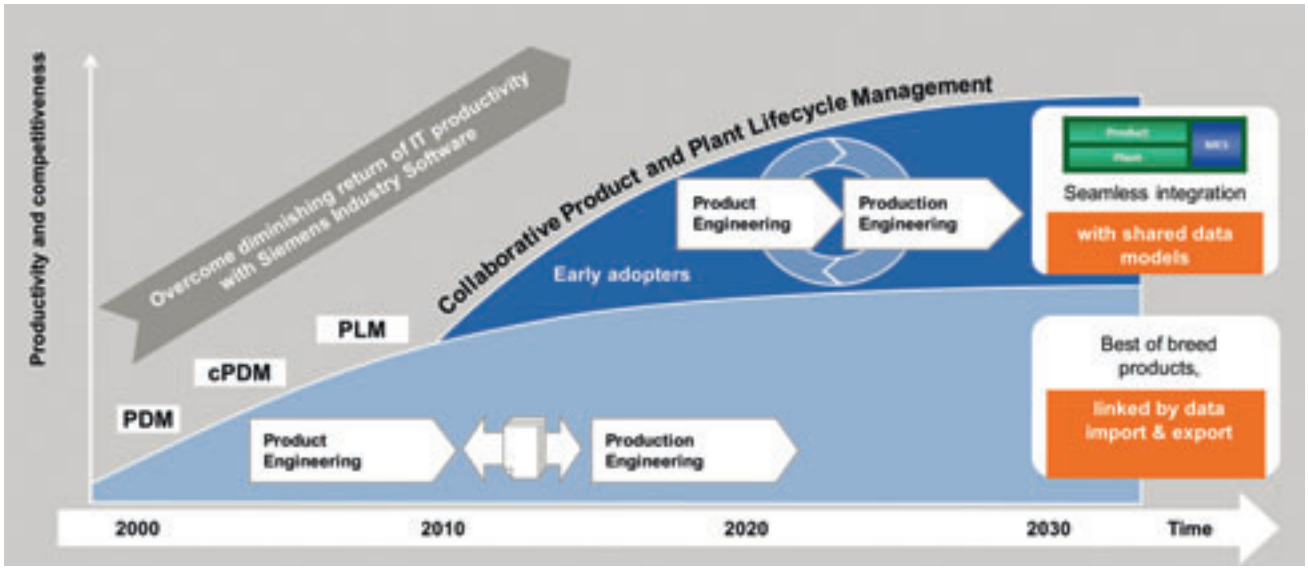

Fig. 7.3 The next productivity stage requires ongoing lifecycle management (Source: Siemens)

If there are any links at all between the differing large amounts of data stored, the necessary interfaces are usually complicated to maintain and make the entire solution very prone to errors. Even by updating the version of a software component involved – and numerous components come from many different companies – it is easy to overlook a change, with far-reaching consequences.

Product development and product care are massively iterative processes in which change can be more or less a daily occurrence. The data import and export processes practiced today over defined interfaces are not only very time-consuming but are also a barrier to any kind of automated data consistency assurance.

It can be confidently predicted that in future the integrity and the seamless integration of data across the entire value creation chain will play an even greater role for a commercially successful industrial company. These factors will make a considerable contribution to the increase in productivity needed for international competition.

7.2.2 Merging engineering disciplines

Simulation of the product and the associated production processes will not only provide the greatest productivity gains in the future for the manufacturing of physical goods of all kinds, but will also make a major contribution to the sustainability of product and production.

Mechatronic elements are components consisting of mechanical parts, hydraulics, electronics and software that are described at the digital level by means of so-called “Systems Engineering” that often permits highly complex interactions to be represented and investigated using system simulation.

Efficient handling of such complex elements requires a very close interdisciplinary cooperation of all staff involved in the product and its production. To achieve this it is however necessary that all involved can store the results in a joint database that not only permits hundreds of engineers to simultaneously work on a project, but also ensures that the data is at all times up to date and consistent.

This is no easy task and many companies have not yet succeeded in changing over the development methodologies of the many departments involved in order to meet this challenge. The effort this demands is often not justified by the competitive situation and also has a negative effect on profitability.

Many of the difficulties found out are due to the differing cultures and languages of the participating engineers and educational establishments. This is to some extent to be expected because the engineers generally come from university faculties whose highly specialized education in fact is their own specific form of branding. In future, however, it will also be a specific task for such universities not only to educate specialists but to concentrate more on interdisciplinary research and teaching in order to promote the emergence of generalists.

One of the prerequisites of the Digital Enterprise is to ensure that such discipline- or faculty-specific barriers are eliminated. All modules whose data link to one another must be represented digitally in such a way that all participants can use them to fulfill their tasks without having to undertake complicated real-time transformations.

7.3 Differences between industries

It almost seems as if some parts of industry have been hoping for years that they will remain unaffected by the continually increasing and more and more difficult to manage complexity and dynamics of the cyber-physical systems and the associated digital revolution. But the technology of the World Wide Web, the absolutely unlimited (because increasingly inexpensive) storage capacity of semiconductor memories and availability of sensors and actuators available at a low price, to name just a few factors, now permit such a degree of miniaturization, precision and efficiency in products that they have become highly attractive to customers. This in its turn has led to the development of very large markets. For many companies, it would be a sentence of death if they were unable or unwilling to participate in this business. But in so doing they are overtaken by all the requirements that the technology and the new business models bring with them.

In this regard, it should not be forgotten that the tendencies to ever-stronger global regulation and the associated proof of conformity have developed into an enormous driver of complexity. Although it was originally the process industries that were particularly affected by regulation, the discrete industries, driven by sustainability and health aspects (and also product liability) have very strongly caught up.

The broad field of energy generation and distribution through to the management of carbon dioxide emissions will also contribute in a big way to a further increase in the complexity of products and production plant.

7.3.1 Mass production

What started over 100 years ago with Henry Ford's production line has now reached an almost unbelievable degree of perfection. The capability to produce millions upon millions of the same product at a constant high quality is today no longer anything special.

But even here, development has not reached its limits. The manufacture of customer-specific or customized products is a matter of course even for such complex constructs as an automobile. However even although automobile manufacturers are already in the position of being able to produce several hundred thousand variants of a vehicle with the desired special equipment and accessories, modern PLM solutions can make much greater degrees of differentiation possible. The main barriers to be overcome that stand in the way of such commercialization are today's software applications for ordering, production planning and production itself. Upgrading these to handle the new complexity (at manufacturers and suppliers) is currently the big challenge. Insiders know, however, that while this is a Herculean task, it is today well into the realm of the possible.

Delivering just-in-time customer-specific products to the consumer market is not only interesting but, due to reasons of sustainability, will become a mandatory requirement in coming years. Overproduction, wastage and the destruction of valuable raw materials and energy will become absolutely unacceptable given the quickly growing numbers of humans on the planet and their continually increasing standard of living.

The Digital Enterprise, as roughly sketched out at the beginning of this dissertation, represents an excellent solution platform for all coming tasks and problems associated with product creation and maintenance.

But it is not only the manufacture of automobiles that is a mass production sector highly relevant to raw materials and energy consumption, the electronics industry in its broadest sense must also be included. The quality aspect "first time right" is given special attention because of the immense number of units that can be produced in a very short time.

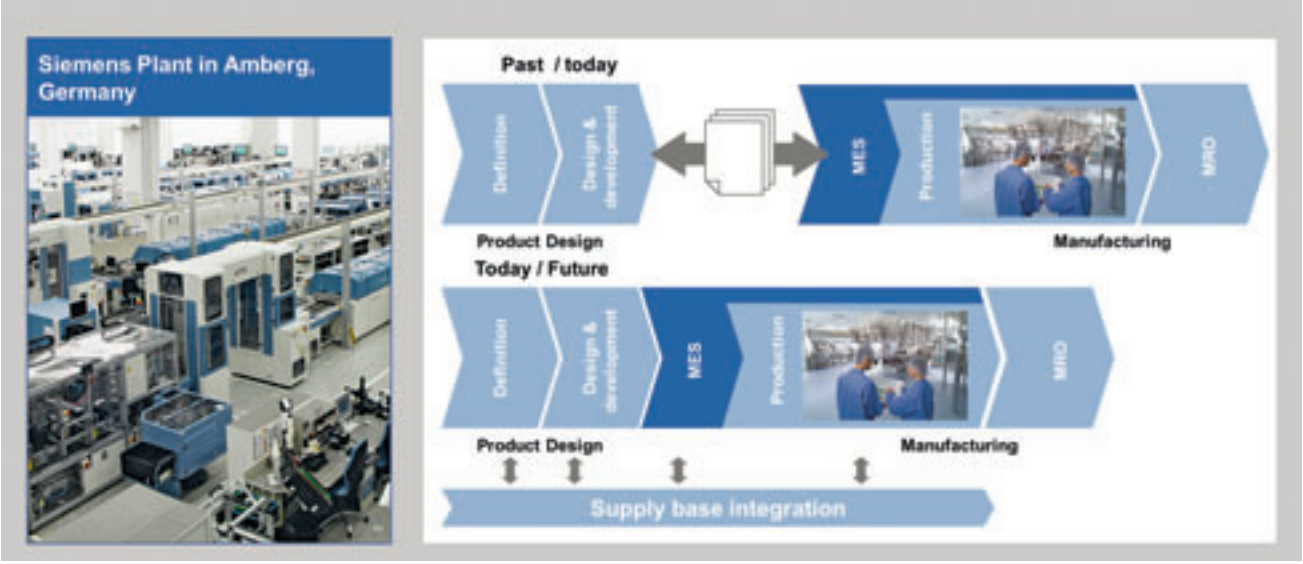

Fig. 7.4 Results of integrating the data flows in the Amberg electronics facility (Source: Siemens)

In its Amberg electronics facility, Siemens has put in place the necessary preconditions to achieve the very highest quality standards in the production of more than 380,000 SIMATIC HMI units and more than three million S7 controllers a year. From the '24 defects per million devices produced' result that was achieved in 2007, the value sank to 15 per million in 2011. This is a record value across the entire industry.

On the way to this result, all involved experienced up close just how much optimization can be achieved in this apparently simple case. The complete assemblies exist as full CAD models. Every employee has, as an accompaniment to the real product as it moves through the entire production line, an exact representation of the assembly in the form of the original CAD data available on a monitor. Photographs and drawings, which were always troublesome to keep up to date, now belong to the past.

Conversely, production managers can feed back manufacturing problems or deviations from the design to the appropriate worker by attaching a description of the fault directly to the original data. No longer do both sides have to conduct a search, the necessary data accompanies the assemblies through all stages of production. Moreover, the new technology enables employees to remedy the fault immediately, permanently and in a documented manner instead of having to spend a great amount of time generating and interpreting fault statistics.

7.3.2 Make-to-order manufacturing

The other extreme is make-to-order or small batch manufacturing, for example in the production of special machines, one-off vehicles or in specialized shipbuilding. There is here no clear separation between disciplines and development and production preparation and production do not necessarily follow one another in that order – a great deal happens in parallel. In such projects, quasi-parallel cooperation between the many specialized disciplines and a large number of suppliers and partners must be organized.

Without the integration of all of the core systems involved, no "digital" future is in view. The data from the many solutions must be capable of being called up or input, and in particular visualized, not only at any workplace within the company but also at suppliers workplaces – and here these are increasingly mobile workplaces.

Especially in these industries, however, the attitude brought about by long-outmoded technology is widespread: "Our projects are too complex to be organized and supported by standard IT." And it is exactly here, where integrated IT support could give particularly large benefits, that skepticism regarding digital work processes continues to prevail.

7.4 Data integration requires standards and open, mobile systems

Company processes are an important differentiation factor in international competition. Those companies who run the development in this field in a systematic, innovative and consistent manner create advantages for themselves that cannot in the short term be equaled by their competitors. This has much to do with the necessary learning processes and buildup of experience in employees and within organizations, a process that can only be accelerated in a very limited way. It also depends on the fact that, in principle, processes can be kept confidential more simply and for longer because, in contrast to the products that they are used to generate, they do not appear on the market and are therefore not able to be subjected to quick analysis.

For the foreseeable future, competitive company processes will not be able to be acquired through the use of standardized software products. Future software and communications systems used to build the Digital Enterprise must, and will, have sufficient flexibility to make specific modification (configuration) and ongoing improvement possible. Expensive customer-specific modifications and special developments must be avoided as much as possible since these are not constructive. The necessary flexibility must, if it is to remain affordable, be built-in with the aid of standards, particularly in the provision of data and in the interaction mechanisms of software modules and tools.

Industrie 4.0 also presupposes a far-reaching standardization of digital industrial communication. Only when it is clear to all participants what the rules are for individual solutions providing or receiving data can companies carry out innovation independently of one another while still being certain that their components can be integrated into a joint platform and used in every way desired. An interesting development path could be today's widespread apps technology for smartphones.

This means above all that existing standards such as HTML, XML, UML or SysML must be utilized. Where necessary, industry must quickly agree on standards that are not yet in place. Siemens recently made a major contribution to this by providing its JT 3D visualization format. This data format has been available to all interested users since the end of November 2012 as an ISO norm.

The openness of each individual solution is also a core element of the Digital Enterprise platform. There will in future be no reason acceptable to the market why the

usage of data should be limited to the system which generated it. Only when all data can be accessed by any third-party solution without needing the source system can it be used in the sense meant by a truly integrated data chain.

What must be clear to all involved is that the question of data security again becomes of prime importance. The more that standard software also becomes the norm for industry, the more will secure access regulation increase in importance. This is no longer just about protection against theft or unauthorized use of data; it is about how company-critical processes controlled by software can be made secure. One of the most important measures in this respect is a growing awareness by the user himself of the danger posed by the asked-for openness. This will not be an easy task given the ingeniously devised phishing attempts – to name just one problem area. It is an enormous challenge, particularly for large companies, to keep all staff at a corresponding level of attention at all times, but one that must be mastered in order to be able to fight off such attempts without damage to the company.

In the end, a Digital Enterprise platform can only really be used for the entire lifecycle of future products when data and models are open to mobile access. This is immediately obvious for those working in a shipyard or in the globally operating aircraft construction industry. But in Industrie 4.0 the supplier of electronic sensors, for example, is also an important part of the extended company model. The competitiveness of company processes, for example the development and production processes, will in future also be measured against how well they have been freed from the constraints of location, time and end device through mobile IT support. And as already stated for the previous point, the more mobile the software becomes, the more important securing it against unauthorized or undesired usage will also become.

7.5 Siemens offers infrastructure and tools

Since its acquisition of UGS, completed in 2007, Siemens Automatisierungstechnik has developed into a widely respected supplier of software. The extension of its automation offerings with software products that support the entire PLM process, such as product definition, development and maintenance is bundled with strong CNC technology capabilities and general production automation up to and including MES software. This has made the Company an extraordinarily sought-after partner for the production industry.

The fact that Siemens is one of the largest engineering and production companies in the world, and thus in this respect has a holistic view of technical and value creation, naturally has a considerable effect on the development orientation of the associated software products on offer. These are of course also used within the Company, where they are exposed to critical assessment by tens of thousands of users – the resulting experience flows into the ongoing development of the products.

In this Chapter, Siemens presents its views of, and insight into, the current challenges brought about by the digital revolution, and also possible answers to these challenges. The motive is self-evident and has already been explained in the text: the Digital Enterprise and its platform can only be turned into reality together with users and customers. For this purpose, Siemens seeks an open exchange of views and intensive discussions in which the “chaff” of many ideas, however innovative, is separated from the “wheat” of the digital platform that is now needed.

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