Chapter 3
The Big Picture—Information Technology in Enterprises

Executive Summary

This chapter deals with the following topics:

- information technology and its technological history,
- important evolutions and major milestones of modern information technology (incl. desktop/workstation operating systems and mobile operating systems) and
- the IT setup within enterprise organizations.

Quick Reader Orientation and Motivation

The intention of this chapter is:

- to provide a solid understanding of the roots of modern information technology.
- to describe the technological hardware development from calculation machines up to modern super computer farms.
- to explain the importance of desktop/workstation and mobile operating systems to provide the basis for application-oriented software.
- to gain insight into how the technology and the organization of IT has been developed from middle of the twentieth century until today.
- to comprehend that the execution of information technology has reached meanwhile an (IT) factory level with its own rules and services.
- to gain insight into Industry Senior Manager expert assessments with respect to changes of the future IT landscape.

3.1 Introduction and Basics

The term "information technology" comes with two meanings today: firstly, the original meaning in terms of tools and applications which create, transform or convert sets of electronically storable data and information. The basis for such technology comprises basic computer architecture, binary coding techniques, data models as

R. Stark, *Virtual Product Creation in Industry*,
https://doi.org/10.1007/978-3-662-64301-3_3

well as related software, hardware solutions. Nowadays, the term *ICT (Information and Communication Technology)* is often used for this first meaning and also includes message and network technologies. Secondly, the term *IT (Information Technology)* designates a department or an organization within an enterprise which is held responsible for the operation of computers, servers and related "IT services and solutions". IT as a department or enterprise organization obviously is in charge to coordinate all general aspects of information technology in its original sense. In contrast to the original information technology development role, IT departments nowadays are oftentimes exhausted to put significant focus on policy aspects, user administration, data storage tasks, operational readiness of hard- and software equipment and general help desk services.

The obvious question is why such a difference in using the term IT really exists or what might have changed in the last twenty years of IT perception within the enterprise. The following sections will provide a deeper understanding, starting from the history of information technology up to the current set-ups of IT in modern enterprises and will also come to conclusive statements with respect to Virtual Product Creation.

3.2 History of Information Technology (IT)

Information Technology (IT) is one of the crucial enablers for modern digital engineering which is designated in this book consistently as Virtual Product Creation (VPC). A detail explanation of VPC is given in Chap. 4. To understand IT better, it is necessary to reflect the origin and the different stages of computation and related tools.

3.2.1 Hardware: From Numbering and Mechanics Towards Electronics

The development of the first calculators started with the invention of numbers and numbering systems. Most numbering systems are based on the counting of the fingers of the hands. Therefore, it is not astonishing that the Sumerian, Egyptian and Babylonian numbering systems are based on the number ten. Our decimal system was invented in India and arrived in Europe via the Middle East. But the first known calculation tool is the abacus, dated around 2700–2300 BCE [1]. The abacus was invented in Babylon a city-state of ancient Mesopotamia [2]. The earliest archaeological evidence for the use of an abacus was in Greece and dates to the fifth century BC. Primarily the cultures of the near and far east (Mesopotamia, Egypt, Persia, Greece, Rome, China, India and Russia) made effective use of this first calculation machine, interestingly enough, based on different number systems with base numbers 60, 16, 5 and 10 [3].

From the point of view of motivation, the "mathematical number and calculation machines" started with the need of mankind to use arithmetic calculations for day-to-day activities such as for selling goods on the market or for building complex stone or wood constructions which extended the easy enumeration capabilities of the fingers or the mental memory of human beings.

The next step forward concerning calculation tools was the invention of wooden sticks to enable easy multiplication and division of numbers by the Scottish Lord J. Napier. He developed the sticks around 1600, the user had to cut out paper slips and glue them on wooden sticks. Astonishingly, the paper slips were available until 1920 [1].

In the year 1623 W. Schickard designed a calculating machine (calculating clock) for addition, subtraction, multiplication and division based on sophisticated mechanics (see Fig. 3.1): it is the first mentioned machine with spur gearing. Its special feature was a gear-driven carry mechanism, which aided in multiplication of multi-digit numbers. However, multiplication and division was only possible with the help of the user. During multiplication the user had to determine sub-products with the earlier mentioned sticks from Napier. Afterwards the sub-products are manually added to the six-digit calculation unit to be summarized. The only implemented model got lost during the confusion of the Thirty Years' War. A second model which Schickard asked his friend J. Kepler for construction was destroyed by fire. It took a few centuries until B. v. Freytag-Löringhoff could prove the operational reliability by reconstructing the machine in the years 1957 to 1960 [1].

In 1642 the French Mathematician B. Pascal designed a gear-driven semi-automatic adding machine the "Pascaline", which is the first known full functioning

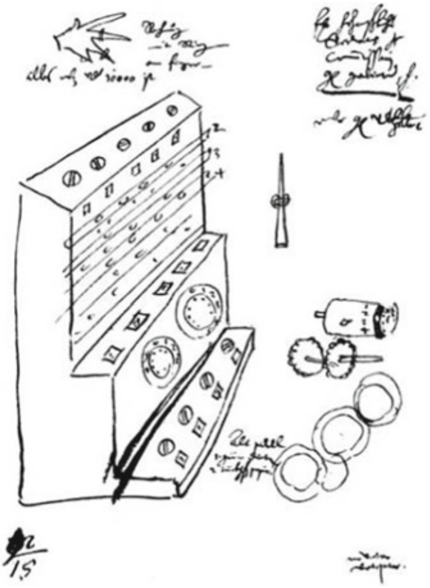

Fig. 3.1 Original drawing by W. Schickard (*Source* Wikipedia)

mechanical adding machine. The goal of Pascal was to relieve the user from the burden of trivial but labor-intensive calculations. Pascal built up to 50 prototypes, but sold just a few due to the cost and complexity of the machine. Furthermore, the Pascaline was difficult to use and could only add and subtract, so that it did not find widespread use [4].

In 1674 Gottfried Leibniz built the "Stepped Reckoner," a calculator using a stepped cylindrical gear (see Fig. 3.2). The Stepped Reckoner was the first machine which could perform all four basic arithmetic operations, addition, subtraction, multiplication and division; it was more complex than the Pascaline. One of his greatest developments was the invention of a binary notation. He even developed a plan for constructing a machine which uses binary arithmetic, but he could never finish it [4].

A further contribution with an enormous impact on the development of computers was the invention of a punch card driven loom around 1801 by J.-M. Jacquard. The loom as illustrated in Fig. 3.3 had to fulfill the task of weaving of patterns and was controlled by a sequence of punch cards.

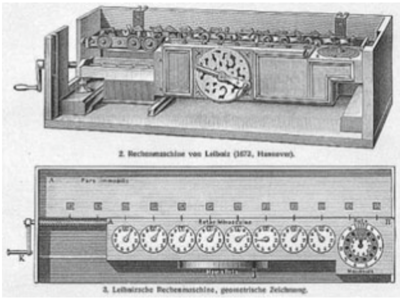

Fig. 3.2 Stepped reckoner from Leibniz (*Source* Meyers Konversations-lexikon, Ed. 6)

Fig. 3.3 Jacquard's loom at Manchester Museum of Science and Industry (*Source* photograph by G. H. Williams)

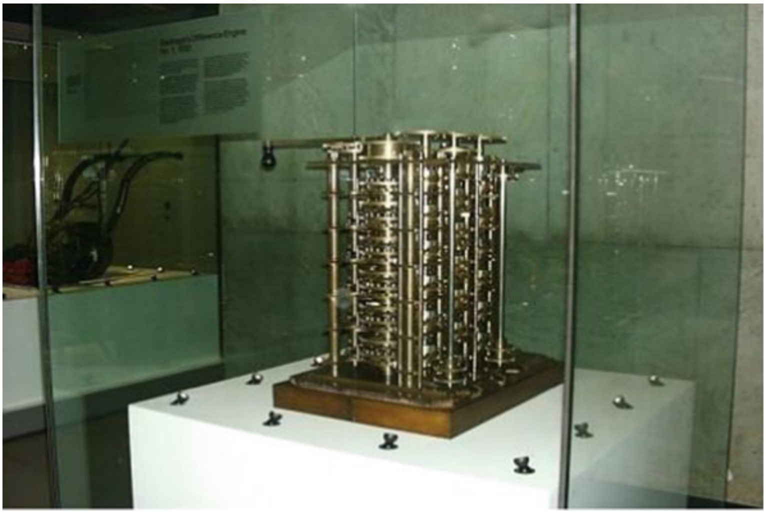

Fig. 3.4 Babbage's analytic engine (The National Museum of Science, London)

The idea of using punch cards to control the pattern and most notably the ability to change the pattern by using different punch cards can be seen as a conceptual pioneer for later computer programs.

The first concept of a modern computer was drafted by the British mathematician C. Babbage in the year 1822 (see Fig. 3.4). He was influenced by Jacuard's loom and planned to use punch cards as storage for his machine. The outline of his Difference Engine already included all important parts of a modern computer, as input devices, memory unit, arithmetic and logic controller unit and output devices.

In the 1880s H. Hollerith developed a calculation machine which could count, compare and sort information on punch cards. The punch card was mechanically scanned, whereas by discovering a hole a circuit was closed. The first usage of the machine was during the census of population in the United States of America. With the help of the machine the time for evaluation could be reduced from 7½ years to just 6 weeks. In 1896 Hollerith founded the *Tabulating Machine Company*», for the construction of similar machines. Later on the name of the company changed to «International Business Machines Corporation (IBM)» in the year 1924. Since then until the late 60s IBM produced punch cards for machines in offices, which found widespread use.

In the year 1919 Eccles and Jordan, both US physicists, invented the flip-flop electronic switching circuit [5]. The invention was critical to high-speed electronic counting systems.

During World War II the building of modern computer was intensified on all sides, since the military was in need of fast ballistic calculation. The British cryptographs needed machines to break the secret code of the Germans.

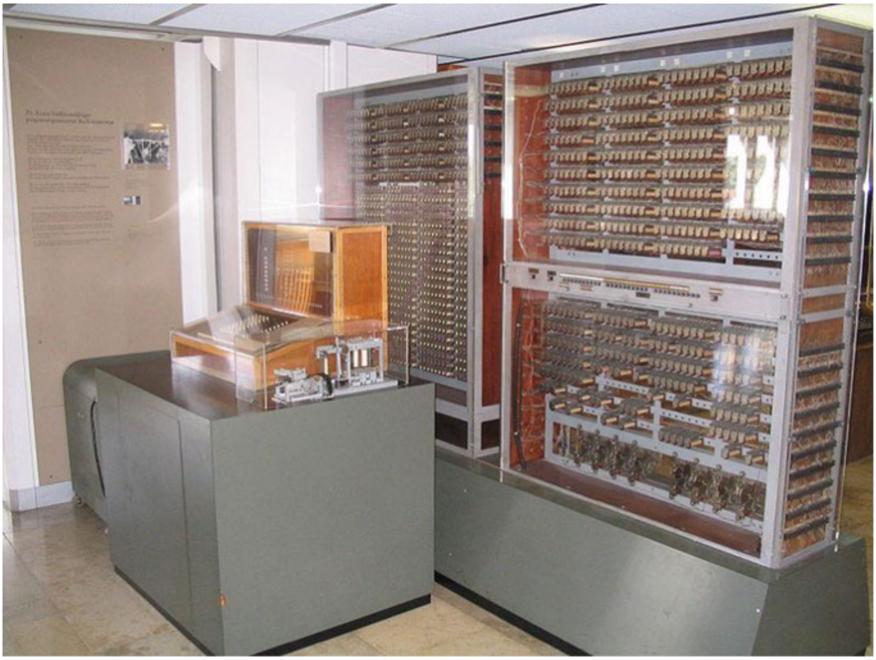

Fig. 3.5 Reconstruction of the Z3 computer of K. Zuse in the Deutsche Museum in Munich

In the year 1941 the German engineer K. Zuse developed an operating computer, which was used in the aircraft industry. The first three models named Z1, Z2 and Z3 were all destroyed during the war. The Z3 was the first fully functional general-purpose computer which was controlled by a program (see Fig. 3.5).

Beside the basic arithmetic operations Z3 could also find square roots. However, the computer never reached its full potential, because of disagreements with the German regime at that time. Z3 counted to the 0 generation of computers [6].

Another development which became operational during World War II (1943) was the Colossus, a British vacuum tube computer. Colossus was designed as part of the British crypto analysis program at Blechly Park for the purpose of deciphering messages from the German Army. It was the first electronic calculation device which was programmable; but it was still not possible to store a program. The first version had 1500 vacuum tubes and was a room filling machine. The second version had 2500 tubes and could process five characters at the same time and can be seen in Fig. 3.6. Astonishingly, the existence of the machine was kept under concealment until 1976 [7].

In 1943 construction on the ENIAC (*Electronic Numerical Integrator and Calculator*) has started, it was the first modern computer for solving general problems (see Fig. 3.7). It filled a 140 m^2 room and was developed by J. W. Mauchly and J. P. Eckert of the University of Pennsylvania, where it was used in 1946. The construction was financed by the US Army during World War II. ENIAC had a weight of 27 t, was

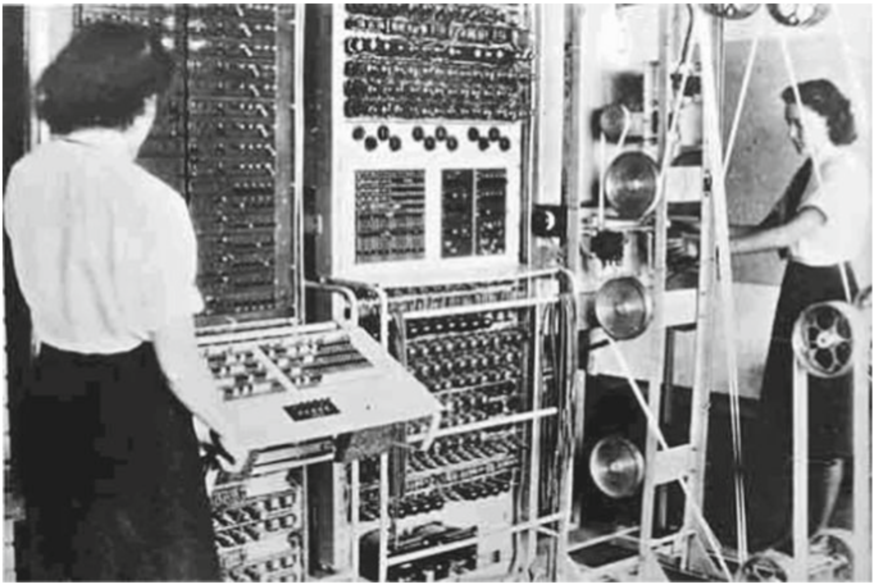

Fig. 3.6 Improved Colossus Mark II (1944)

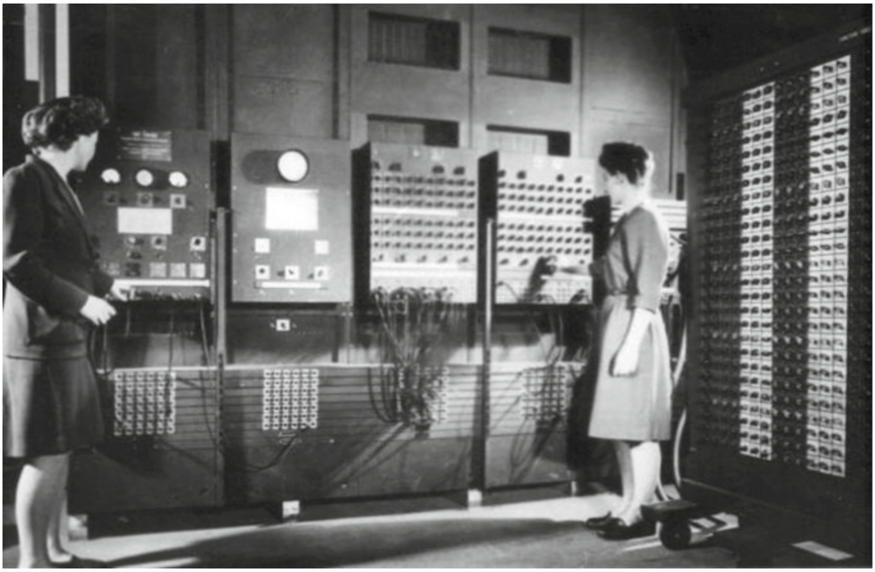

Fig. 3.7 Programmers operate at ENIAC's main control panel (US Army photo from the archives of the ARL Technical Library)

5.5 m in height and 24 m long and contained 17,468 vacuum tubes. ENIAC was able to calculate 100,000 operations/s, the first ones contained calculations to prove the concept of building a hydrogen bomb.

The theory behind general-purpose computer was first drafted by A. Turing with his 1937 published paper "On computable Numbers" which presented the concept of Turing machines. Later on, the theory was extended by J. v. Neumann, he introduced the concept of a storable program in the year 1945. This was one of the major developments towards nowadays computers, which became known as the von Neumann architecture. Data and instructions to manipulate the data could be stored in the same place. This design was inspired by the work of the computer pioneers J. P. Eckert and J. Mauchly and is still the basis for computers today [8].

H. Aiken developed in the year 1944 at Harvard University a calculating machine called "Automatic Sequence Controlled Computer" also known as Mark I, which was a lot bigger than the one from Zuse. It was an electro-mechanical construction based on the ideas of Charles Babbage. The proportion of the machine was astonishing, she was 15 m long, 2.5 m high and was composed of 700,000 individual parts, with 3000 ball bearings and 80 km of line wire. Mark I had the capability to add in 0.3 s, multiply in 6 s and divide in 11 s, wherefore 72 addition counter with 23 decimal places had been used [1].

The first computer with real-time capabilities was developed in 1949 by J. Forrester at MIT and became known as Whirlwind. At that time, it was the largest computer project with an annual budget of $1 million and a team of 175 people working at it. Whirlwind could multiply in twenty seconds and was therefore the fastest computer of the early 1950s. But it was not always reliable as Whirlwind was out of order for a few hours each day. Furthermore, Whirlwind had storage problems, as the storage tubes lasted only one month the costs summarized to an enormous monthly amount [9].

The invention of the first transistor in the year 1947 at the Bell Laboratories resulted in a revolutionary development of computers. The invention was published in a scientific paper that appeared in the Physical Review of 1948 and was announced in a press conference at Bell Laboratories. At that time in history the excitement of the inventors about the transistor was not shared by the public. Not until the end of 1951, the manufacturing of the transistors started. And from there on it still took a long time until hot and unreliable vacuum tubes could be replaced by small transistors. At the end in the year 1972, the three inventors J. Bardeen, W. Brattain and W. Shockley received the Nobel Prize in physics for the transistor [10].

All the new developed machines have to be operated and this opened a new field for inventions. Therefore, on the software side new developments took place. G. Hopper, a professor in mathematics and later on an army admiral, developed the first compiler, named A-0 in the year 1952 for the programming language FLOW-MATIC. The term "debugging" for searching errors in computer programs could also be traced back to her. During her work on Mark I she detected the failure of a relay caused by a moth. Whereupon she stuck the moth in her logbook, see Fig. 3.8, with the accompanying sentence: "First actual case of bug being found."

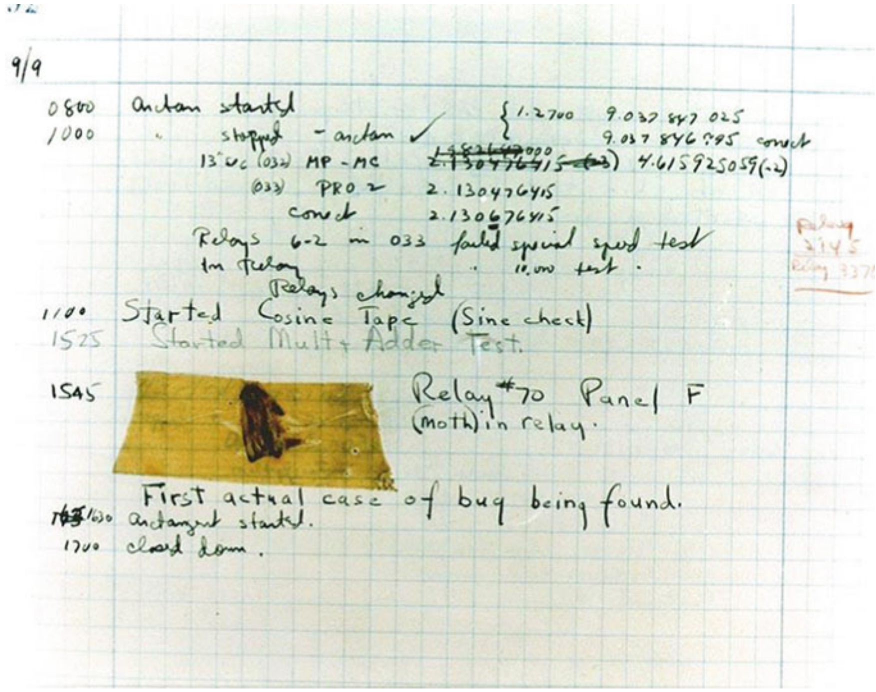

Fig. 3.8 The first "computer bug"; *Source* U.S. Naval Historical Center Online Library Photograph

From there on the term bug was used for software errors and not only by engineers for malfunctions in machines. She developed a lot of software which was still in use in 1999 and a lot of people feared that this software will cause a big disaster, because Hopper reserved only two digits for the date in her Cobol-Libraries [11].

The greatest breakthrough in terms of miniaturization could be reached in 1958 by the production of the first microchip. Whereas the introduction of the first commercial computer with a monitor and keyboard input by DEC is an important milestone in the direction of nowadays computer.

In January 1963 I. Sutherland at MIT introduced Sketchpad, the first commercial computer-aided design (CAD) software, developed as part of his Ph.D. thesis. Sketchpad allowed the user to draw directly on the computer screen with the help of a light pen. During this period CAD research started in many European countries. In France, for example, the research in 3-D surface geometry computation was funded by the car companies Citroen and Renault. Before the 60s ended a lot of companies like GM, Ford, Lockheed began to adopt and adapt the new technology. Nowadays it is difficult to imagine a manufacturing firm without CAx-systems and the capability to transfer digital data to CNC machine tools. However, at the beginning it was not easy to accomplish the use of CAx in industry. However, until today there still exist a great gap between the state of the art and the real usage of CAx-systems.

Another important invention was the mouse by D. Engelbart in 1964. Although his invention was not really appreciated at that time, but later on this device has served all kinds of users till today.

The next era (1974–today) is called the microcomputer era and was divided into five periods by Remi et al. [1]. The era is characterized by the application of large-scale integrated circuit (LSI) and very large-scale integration circuits (VLSI). The fundamental technique is used till today, what has changed is the packing density of the circuits. This development from 1971 until 2010 can be seen in Table 3.1.

Period 1 (1974–1982)

In this period hard- and software merged into an entity as well as commercial data processing with manufacturing systems. First local area networks (LAN) were created and first CAD/CAM installations were established in many companies.

In the year 1977 the most important computer companies for end user computers were funded. Steve Jobs and Steve Wozniak corporate Apple Computer, and Bill Gates and Paul Allen found Microsoft. The influence of Microsoft was increased by the decision of IBM to select PC-DOS as operating systems for their new PC. Furthermore, the first Apple was designed, which consisted mostly of a circuit board. In addition, the open-architecture IBM PC was launched in 1981 and started the area for home computers.

Table 3.1 Miniaturization of microchips

Year	Name of the chip	Number of transistors on chip	Size of chip
1971	Intel 8080	2300	10 μm
1974	Intel 8080	4500	6 μm
1978	Intel 8086	29,000	3 μm
1985	Intel 386	275,000	1.5 μm
1995	Intel Pentium Pro	5,500,000	0.6 μm
2002	Intel Itanium	220,000,000	0.13 μm
2006	Quad-Core Intel Xeon	291,000,000	65 nm
2007	Quad-Core Intel extreme (Penryn)	820,000,000	45 nm
2010	Six-core Core i7 (Gulftown)	1,170,000,000	32 nm
2012	Quad-core + GPU Core i7 Ivy Bridge	1,400,000,000	22 nm
2015	Quad-core + GPU GT2 Core i7 Skylake K	1,750,000,000	14 nm
2017	28-core Xeon Platinum 8180	8,000,000,000	14 nm
2018	Apple A12X Bionic (octa-core ARM64 "mobile SoC")	10,000,000,000	7 nm
2019	HiSilicon Kirin 990 5G	10,300,000,000	7 nm
2020	Nvidia's GA100 Ampere	54,000,000,000	7 nm

Source https://en.wikipedia.org/wiki/Transistor_count

Period 2 VLSI, sequential architecture (1982–1990)

In this period the usage of computers for automatization in industry was pronounced. On the software side standard solution for specific classes of problems came into existence. Therewith a new programming paradigm, the modular programming paradigm, came into being. Modules, which could be integrated in existing software solutions, were developed. Later on these developments led to the object oriented paradigm. Using such paradigm, the source code was structured in communicating objects rather than modules. This new paradigm enabled an abstract view on the software development process which facilitated a discussion over software design for a broader group of experts besides software developers. Another invention was the provision of graphical user interfaces for interactive systems, which enormously increased the user friendliness of applications. At the end of this period in the year 1989 Tim Berners-Lee proposed the World Wide Web project during his stay as researcher at CERN (European Council for Nuclear Research).

Period 3 VLSI, parallel architecture (1990–2010)

From 1990 on the PC started to be a mass product in the private and business sector, due to the ease of learning and ease of handling of the new generation of computers. Moreover, the internet started to be a medium for the masses and had more and more impact on the life of everyone. On the hardware and software side the era of parallelization started, Dual und Quad-Core CPU 's were developed at the same time as multithreaded software which could take advantage of the multi cores. Linux-clusters with PCs and Open Source were introduced, which could achieve billions of operations per second. Furthermore, 64-bit architectures were also available on PCs, before this architecture was only used for super computers. The advantage of this architecture is a simpler calculation of big integer values, whereof algorithms like encryption algorithms could benefit from. Moreover, with the new architecture the usage of more than 4 GB main memory was possible. Further milestones in this area were the development of distributed embedded software engineering and the invention of portable computers like laptops and handheld devices like smartphones. Furthermore, a new generation of programmable graphic cards for general purpose programming (GPGPU) on the GPU of the card has been developed. Therewith, for time consuming simulations like physics-based simulations, the calculation time could be massively accelerated.

Future hardware developments

In the future, asynchronous chips could be used to boost operations per second even further. In asynchronous systems the data flow could be controlled by switching networks for local coordination instead of tact cycles. With this concept not only the computation could be accelerated, but also the power consumption could be reduced.

Another new development could be the use of quantum computers. With this new type of computer the dual system will get obsolete, because more than two states can be represented. Once it will be possible to get a quantum computer to work robustly, a range of new applications will emerge. As of today, the quantum computer operation is still not stable. However, hardware lab research in this direction is booming and in computer science the theoretical concept has already reached sophisticated levels.

3.2.2 Software: The Key Role of Operating Systems of Modern Computers

In order to make functional use of computers, it is essential to provide an *operating system* that controls the link between the base resources of modern computer architecture. The operating system serves as control linkage between the various sets of application software (office software, communication software, engineering applications etc.) and the key hardware components of a computer such as

- central processing unit (CPU),
- different types of memory such as cache memory (very fast memory to reduce loading times of operations into the CPU processing routines), RAM (read access memory), ROM (read only memory), disk memory and external drives (incl. USB sticks) etc.
- internal communication bus system and
- external devices such as monitor, mouse, key pad, touch screen, printer, plotter, USB driven devices, network node components such as switches, bridges, hubs, repeater, proxies, router etc.

The evolution of operating systems meanwhile has a history of more than 60 years. The following sub-section gives an exclusive summary of both the "traditional" operating systems for computers (desktop and laptop) and the "new" operating systems for mobile devices.

The timeline of computer operating systems

The era of operating systems started in the 50s, before that time operating systems were unknown, even programming languages did not exist. In Fig. 3.9 the timeline of the main operating systems from the 50s up to the year 2020/1 is shown.

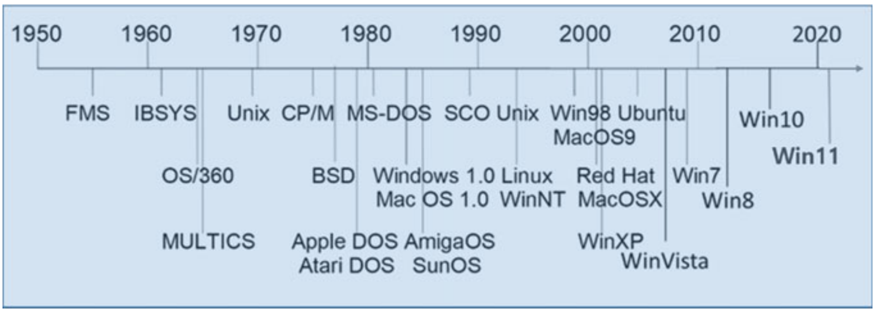

Fig. 3.9 Timeline of operating systems

Operating systems in the 1950s

In the 50s simple batch operating systems-were developed. These operating systems could only run one job at a time. The first operating systems were characterized by their diversity. They were strongly hardware dependent. Even in one firm, there existed different operating systems for different computer architectures. The user known in today's IT operation—mainly a practitioner of applications—was not known at that time: a user was the operator of the system, which would be called today a system admin or super user. Such an operator had to load cards to start a job and unload the card when the job was done. A computer program consisted of a lot of cards. The main one in this era was the Fortran Monitoring System (FMS) for the IBM 709 by North American Aviation [12].

Operating systems in the 1960s

In the 60s many companies started to provide their computers with operating systems. The main inventions in this era were the introduction of multiprogramming and time sharing systems. Multiprogramming stands for the capability to load different programs in the main memory of the computer. This enables the execution of more than one program "simultaneously". The simplest multiprogramming systems were so called spooling batch systems. Spooling (Simultaneous Peripheral Operation On-Line) was a technique that enabled the operating system to start a new job if the current running job had been finished.

An operating system developed by IBM for its 7090 and 7094 computer called IBSYS had multiprogramming capabilities. IBSYS was based on the FMS and was used with control cards. The IBM OS/360 enhanced multiprogramming capabilities further by [13].

An operating system with time sharing capabilities allows different users to share time on the same machine during their programs execution. The development of this technique was inspired by the desire to achieve shorter response times.

One of the first timesharing operating systems was the Multiplexed Information and Computing Service (MULTICS). The development of MULTICS was a combined research project by MIT, Bell Labs and General Electric. Apparently, MULTICS was a kind of failure, because of the high expenses during development, which drove Bell Labs to finally withdraw from the project. Nevertheless, it had a high impact on the development of subsequent operating systems, because all important concepts of algorithms had already been tested on the system. MULTICS could support hundreds of simultaneous time-sharing computers. Therefore, the MULTICS developer at Bell Labs started to rewrite MULTICS and called it UNICS and later on UNIX [14].

In early 1969 UNIX was developed by computer scientists at Bell Labs and AT&T. With UNIX a new conceptual view was developed on how operating systems should work. With the appearance of UNIX the era to design a unique operating system for each computer architecture was over. As a consequence, for many firms it was easier and cheaper to adopt UNIX as their "standard" computer architecture rather than continuing to develop their own. UNIX became the dominant time-sharing operating system used on all kinds of computers. Bell Labs licensed the source code of UNIX to Universities almost freely, which is the reason for the quick improvement of UNIX and its' widespread usage. Over the years UNIX developed further and is still used up to now, for example in its Berkeley version BSD (Berkeley Software Distribution) also now known as FreeBSD. UNIX most impact on mainstream computing lies in the 80s. Afterwards UNIX builds the basis for many modern operating systems for PCs like MacOSX, and the Linux-family and for many embedded operating systems like Android and others.

Operating systems in the 1970s

In this era the disk operating systems were developed. The first one was CP/M (Control Program for Microcomputers), developed by Intel and Digital Research as an operating system for microcomputer. In the beginning it was kept very simple. Later on other utilities as editors and debuggers were added. It was a single user system and can be seen as a milestone for the later on coming availability of personal computers. With this invention the era of personal computers has started.

(Other disk operating systems in this era Apple DOS, Atari DOS, PC-DOS).

Operating systems in the 1980s

One operating system which quickly came to dominate the IBM PC market was MS-DOS (Microsoft Disk Operating System). When Bill Gates bought PC-DOS, he asked the developer of the operating system to join his new founded firm Microsoft. Afterwards, he renamed the operating system to MS-DOS and licensed it to IBM. From this point in time all IBM PCs were shipped out with MS-DOS preinstalled.

An important invention in this era was the development of a GUI (Graphical User Interface) by Douglas C. Engelbart at Stanford University. Engelbart also invented the mouse in the year 1963, but at that time without GUIs there was no real usage for it. These ideas were adopted by researchers at Xerox PARC (an innovative "office of the future" laboratory). Steve Jobs, student and hardware developer in the garage of his parents, saw the GUI, while visiting PARC and realized its potential value. Jobs then had the plan to build an Apple with a GUI, which then led to Apple Macintosh. The operating system on the Apple Macintosh was known as the most user-friendly operating system at that time. From then onwards computers came along with an operating system which had not only a GUI but also a new interaction device: the mouse. This was the first computer which could be used by people with no computing background [14].

Microsoft followed shortly after Apple Macintosh by implementing a GUI in their new operating system which was called Windows.

From the mid 80s onwards computer network and distributed operating systems were developed. With a network operating system the computer of one user could be connected to computers of other users. Resources like files and printers could be shared amongst those users. Furthermore, the user could log into remote machines. One of the first network operating systems was Netware, developed by Novell. A distributed operating systems goes one step further, it adds an abstraction layer to the system. Herewith, the operating system and all resources appear to be local for the user. Consequently, the user no longer has to bother with which operating system he/she is connected in a network since he/she has the availability to access all resources in this system [13].

Other popular operating systems in this era were: Commodore DOS, SunOS, and Windows 2.0.

Operating systems in the 1990s

In this era also, Microsoft operating system developed networking capabilities. Windows NT (NT stands for New Technology) describes a new family of operating systems. The first one was released in the year 1993. Newer operating systems from Microsoft such as Windows XP, Windows 7 or Windows Server 2008 also belong to this family of operating systems. They meanwhile have the same capabilities as the UNIX family: multiprogramming, multiuser and processor independencies.

The main invention in this era was the development of PC cluster computing. A computer cluster is a compound of computers linked to each other for example by local area networks.

The first Beowulf-class PC cluster was developed at NASA's Goddard Space Flight Center in 1994 using early releases of the Linux operating system and PVM (Parallel Virtual Machines) running on 16 Intel 100-MHz 80486-based PCs connected by dual 10-Mbps Ethernet LANs. The Beowulf project developed the necessary Ethernet driver software for Linux and additional low-level cluster management tools and demonstrated the performance and cost effectiveness of Beowulf systems for real-world scientific applications. All Linux systems are developed under the GNU General public license (GPL). The acronym GNU is self-referring and stands for "GNU's Not UNIX", implying that GNU software was not developed from UNIX code. The first kernel for a linux operating system was developed by Linus Torvalds.

(Other operating systems in this era: Windows 95, Palm OS, Windows 98).

Operating systems in the 2000s

In the year 2002 Apple started with Mac OS X a new generation of operating systems switching from Motorola CPUs to Intel CPUs. From then onwards Apples operating systems also run on PCs and not only on PowerPC. Apple committed itself to this switch, because of the stagnation in the development of Motorola CPUs. In the beginning, Mac OS X was built with cross-platform capabilities, but from 2009 onwards Motorola CPUs were no longer supported. The transfer to Intel CPUs helped to spread the operating system to new user communities. Meanwhile Mac OS X is the second most used operating system after the Windows family.

In this era one of the major developments were new human computer interaction possibilities without the usage of a mouse. Almost all operating systems meanwhile include support for multi-touch screens. One example is Windows 7, which was released in 2009, resp. Windows 10, which was released in 2015. Other popular operating systems in this era wre: Windows 2000, Windows ME, Red Hat Linux, Solaris, FreeBSD, Suse Linux, Debian, Novell Netware, Ubuntu, Windows Vista.

In Table 3.2 the usage of operating systems for PCs in January 2020 is shown.

Table 3.2 Usage of desktop operating systems according to statista https://www.statista.com/statistics/218089/global-market-share-of-windows-7/

Windows	MacOS X	Linux	Chrome OS	Others/unknown
77.7%	17.04%	1.9%	0.5%	1.83%

Table 3.3 Distribution of the 500 most powerful supercomputers worldwide from 2017 to 2020, by operating system (June 2020) https://www.statista.com/statistics/565080/distribution-of-leading-supercomputers-worldwide-by-operating-system-family/

Linux	CentOS	Cray Linux Environment	bullx SCS	Redhat Enterprise Linux	Others
54.2%	23.6%	6.8%	3.4%	1.8%	10.2%

In the area of supercomputer, however, it is Linux the commonly used operating system (see Table 3.3). Linux holds a market share comprising the top 500 supercomputers worldwide of 54.2% in June 2020, whereas Windows is not relevant anymore in this sector. Even Microsoft started to use Linux on its own Azure Cloud Services (https://www.cybersecurity-insiders.com/microsoft-uses-linux-instead-of-windows-for-its-azure-sphere/).

After the introduction of operating systems on PCs, it has to be mentioned that approximately 90% of CPUs are meanwhile used within embedded systems. Embedded systems represent algorithmic processing units and are built in mobile phones, digital cameras, DVD recorders, cars, washing machines, exercise machines, television sets etc. With the help of embedded systems such devices, products and machines are enabled to follow intelligent functional or control behaviours. Most of these modern devices, products and machines use a 32-Bit- or 64-Bit-operating system [14]. One of the most widespread operating system used on these devices is Symbian OS, which runs also on a lot of smartphones.

Hereinafter, this chapter of the book concentrates on operating systems for mobile communication inasmuch as those are one of the inventions with enormous impact on mankind with relation to future business operation and communication within society networks.

Mobile operating systems

A mobile operating system is an operating system that controls a mobile device. Typical examples are smartphones, personal digital assistance (PDAs) and tablet computers. Nowadays the operating systems running on smartphones are the same as on PDAs and tablet computers. Today, smartphones include the capabilities of PDAs and tablet computers.

First generation mobile operating systems (1992–2006)

This first generation of mobile operating systems was dominated by Symbian OS, Blackberrry RIM and Windows Mobile.

The first actual smartphone was developed by IBM in the year 1992. It was called Simon, had a touchscreen, mail, calendar, address book and a sketch pad. The operating system running on Simon was Zaurus OS. Since then operating systems for smartphones evolved rapidly.

In the year 2000 Microsoft released its Pocket PC 2000 with Windows CE 3.0 running on it. It offered applications like Pocket Office, which included trimmed-down versions of Word, Excel and Outlook. The successor of Windows CE was Windows Mobile 2003 with also supported add-on keyboards and Bluetooth connections to other devices.

Already two years before, in 1998, the three-telecommunication companies Ericsson, Motorola and Nokia founded the new company called Symbian LTD. Under this new umbrella, the formerly known mobile operating system prototype EPOC32 was relabelled to Symbian. Between 1998 and 2006 the use of the Symbian operating system was growing up to 67% market share amongst the first generation smart phones (Palm OS and Windows CE were trailering significantly behind). However, it was the reputation of Symbian that was difficult to be software coded. In June 2008, Nokia announced the take-over of the Symbian LTD and at the same time to establish a Symbian Foundation in order to provide an open platform for all companies with respect to develop their mobile operating system derivatives. Finally, the Symbian Foundation was established in April 2009 and the availability of the Symbian platform could be realized in February 2010 (with a remaining part of close sourced components under the ownership of Symbinan LTD).

During the peak usage periods of Symbian in Q1 of 2007 almost 16 million smart phones were equipped with this operating system. Overall, more than 126 million smart phones were sold with Symbian OS. As lessons learned it became clear that the number of Symbian OS developer was by far exceeding the opportunity to recruit them from the job market. Consequently, the community thinking was the right one, but came 3 years too late in order to catch up with the growing role of the second generation mobile operating systems (see next section).

Finally, Nokia closed all activities in Symbian development in January 2014 after several years of constant decline in overall mobile phone business. Meanwhile Nokia has started to concentrate on Google Android operating system as part of their re-entering to the market after some experimentation with the latest Windows Phone mobile operating system.

Similar to the technology history of Symbian, the operating system of RIM (originally owned by Research in Motion Limited and later known as BlackBerry Operating System (OS) had its major starting point in the late 90s. RIM itself existed already since 1985 as part of a technological cooperation with Ericsson in order to develop a two-way paging service and new wireless networking capabilities. BlackBerry OS was specializing in secure communications and mobile productivity. Nevertheless, the peak of BlackBerry OS was in 2008 and declined with the Lehmann Brother crisis and the emergence of Android. Similar to Nokia, also BlackBerry used for several years (2010–2015) another operating system kernel—QNX a commercial Unix-like real-time operating system, originally aimed at the embedded systems market and originally developed in the early 1980s by Canadian company Quantum Software Systems—before moving to the Android platform (see next section).

Second generation mobile operating systems (2007–2018)

The second generation became highly influenced by Google Android and Apples iOS. The starting point of the second generation was the release of the first iPhone by Apple. It offered as main innovation multi-touch capabilities. But the main invention was the speed of its internet browser, Safari provided by the operating system. Currently Safari still is the fastest browsers on smartphones.

One year after Android another operating system was released. It has been developed by the Open Handset Alliance under the supervision of Google. The Open Handset Alliance is a consortium of different firms like Intel, HTC, Samsung, ARM and so on. Dissimilar to the trend in operating systems for computers the number of operating systems for mobile communication devices still grows and many smartphone and tablet vendors even create their own add-ons to the base operating system architectures.

A new paradigm has been created by Apple and Google by providing standards for the global developer community to develop applications based on their mobile communication operating systems. Those applications are simply called “Apps”. The apps technology has the high potential significantly penetrate into the future business and engineering world and to revolutionize the interaction with information. Enterprises will face the challenge with the young generation of employees to satisfy their expectations to handle official company information as easy as it is enabled by the *“apps-based”* smart phone generation.

3.3 The Set-Up of IT in Industrial Companies

In order to understand today’s set-up of IT in industrial companies a dedicated section will provide a quick historic analysis of the main drivers for the different technical and organizational foundations. Subsequently the state of the art of today’s IT factory set-up will be briefly discussed as well as the resulting problems and limitations which are subject for major changes in the future.

3.3.1 History of IT Technical and Organizational Drivers in the Twentieth and Twenty-First Century

Information technology started out as a research activity at several universities and research institutes in the mid of the twentieth century, predominantly in the US, in England, in France and in Germany. It took until the 60s in the twentieth century before the new information technology could be used within enterprises in a wider sense: it was necessary that generalized hardware became available to enable the execution of “custom” oriented calculation applications.

The first official set-ups of Information Technology departments in industrial enterprises occurred more consistently after the Second World War, however, not before the second part of the 50s. Around that time the rather small, central IT groups were located high up in the organization, close to the company owner or president. As seen earlier in IT history (compare the section before) it was necessary that business drivers were found in industry to promote the use of "calculation machines": in the early days of IT in enterprises in the mid of the twentieth century it was the need for better organizational, sales, marketing and accounting work execution which served as catalyst for calculator machines and computers. Especially sales revenue and related tax calculations in the financial sector of big enterprises were traditionally established close to Senior Management offices in order to guarantee close loop and secret interaction between the small dedicated groups of analysis experts and the cadence of leadership meetings. Quick turnover of calculation tasks no longer could be ensured efficiently and precisely enough by manual reckoning methods and activities. Consequently, the business and accounting tasks did drive the innovation, set-up and usage of calculation and computer machines within first "unofficial central" IT departments as illustrated in Fig. 3.10.

Technical computation activities initially started in the 50s of the twentieth century due to the first digital control driven milling as well as other manufacturing, drafting and calculation machines [15]. From then onwards, more and more engineering functions in product development and in manufacturing were built up on calculation machines (compare more details in the Chap. 5 "Technology History"). New critical skill sets were provided by engineers and mathematicians who tried to help themselves in resolving tedious calculation problems to analyze test results, determining

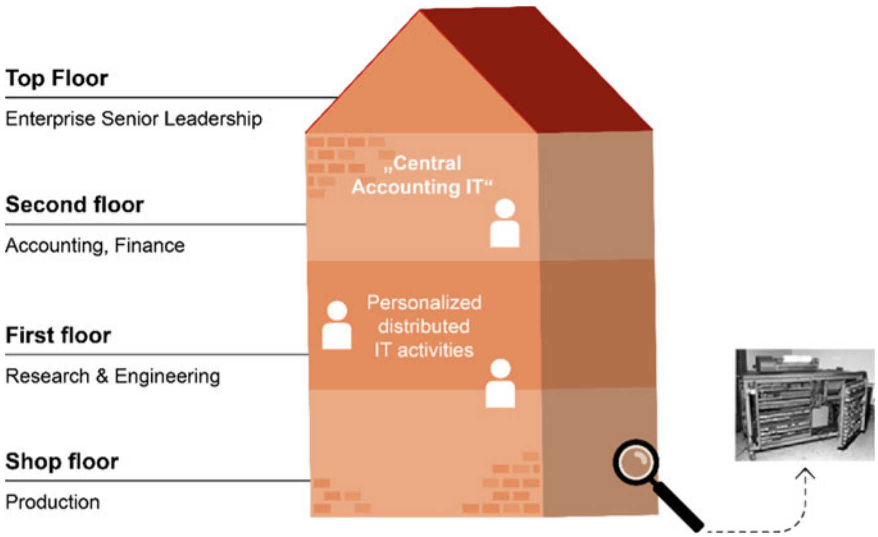

Fig. 3.10 Early organizational/local IT set-up within industrial enterprises (end of 1960s to the beginning of the 1970s)

mechanical structures or dynamic problems as well as time and quality measurements in manufacturing.

During the initial times of setting up IT departments there was no special architectural preparation of building space and offices to accommodate for these new calculation machines. Initially no special IT infrastructure drivers existed. Nevertheless, over the first ten years of industrial use it was also recognized that the enormous amount of space to install bigger computation machines such as already known from military and research center installation would need special space and utility preparations (electric power, cooling) within the old, traditional office and factory buildings.

Traditionally, the ground floor areas and later on also locations near elevators on higher floors of newer buildings were chosen to provide space for mainframe computational hardware. Special purpose and centrally set-up main computer facilities were operated by special technical staff with special skill sets to maintain and repair the still rather fragile hardware (relays, transistors etc.).

As shown in Fig. 3.11 new layouts of office and workshop/manufacturing buildings in the second phase of IT organizations in industrial companies did lend themselves to a natural separation of different IT sections each of which belonged an individual finance, engineering and manufacturing department. In addition, a first kind of "central", general IT laboratory was established to host general purpose compute power in form of mainframe and workstation clusters.

Between the early 70s and the mid 90s of the last century step by step a growing need to connect terminals to mainframe and workstations to compute clusters was

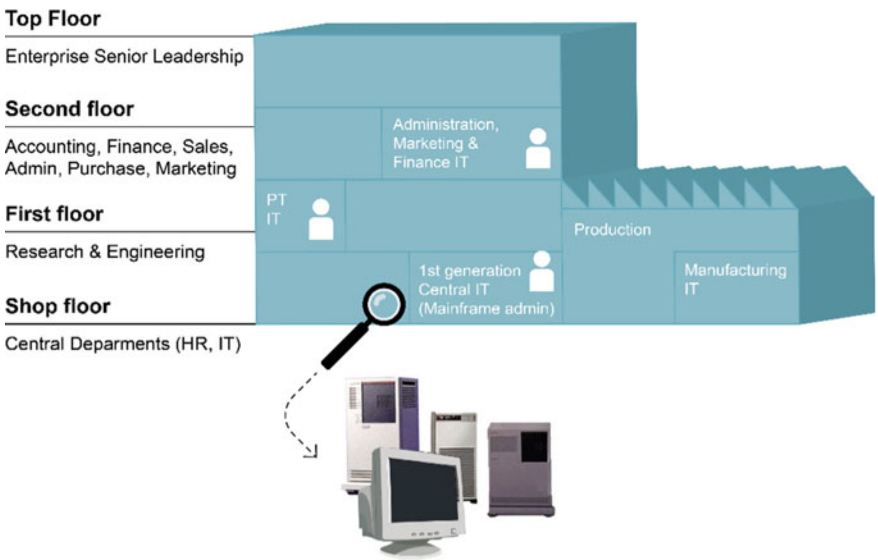

Fig. 3.11 The 2nd phase of IT organization in enterprises—the majority as local set-up belonging to functional organizations (mid-1970s to mid-1990s)

recognized. At that time, however, this trend was mainly driven to better utilize hardware for individual computation tasks.

Starting in the 70s and then sharply increasing during the 80s of the last century professional IT experts were established in big enterprises with the sole responsibility to set-up, install, maintain and improve computer installations. Small and Medium Enterprises (SME) could not yet afford those experts and waited in many cases until the mid-nineties to allow a full set-up of those IT departments with the right skill mix of hardware set-up and maintenance, software installation, database technology, network and related infrastructure, data center and store operation and customer support resp. help desk execution. In line with the sharply increasing number of users, IT applications and required skill sets to run an IT operation it became necessary for enterprise IT organizations to grow, both in size and individual array of skills.

During the 20 years between 1980 and the millennium, industrial companies could benefit from the first wave of young professionals with university degrees: those IT literate experts brought fresh information technology knowledge from university majors such as computer science, informatics and computational engineering into the so far “IT on the job self-learning” community of engineers, physicians and mathematicians.

With the evolving network technology and cross enterprise engineering and production evolution big sized enterprises and subsequently also SME had to establish in addition to their local (building-to-building) IT set-up also regional (city-to-city) IT set-ups and cross-regional and global IT set-up (see Fig. 3.12).

Information technology became a critical enabler for global economy operation. It evolved from a supporting equipment industry to an own mainstream business sector by providing bundled services out of hard- and software, telecommunication, mobile and cloud computing, IT operations and helpdesk service as well as associated policies and compliances. Despite the .com hype and crash right after the millennium all enterprises did accelerate their infrastructural IT set-up and prepared themselves for a location independent IT service provision from anywhere in the world. Therefore, the effective control over shared internet networks, related bandwidth and latency characteristics, secure virtual private network connections and most efficient software license utilization over the enterprise network has become a major business operation in industry. Those operations are executed more and more by contractually time-bonded IT-departments inside and outside the actual enterprise. Low cost country sourcing in India, China and other countries in Eastern Europe, South East Asia and Africa is still one of the major answers to a year-over-year cost saving task which many of the IT executives have to deliver as part of the yearly commitments to company’s profits. From this standpoint Information Technology has been established as commodity.

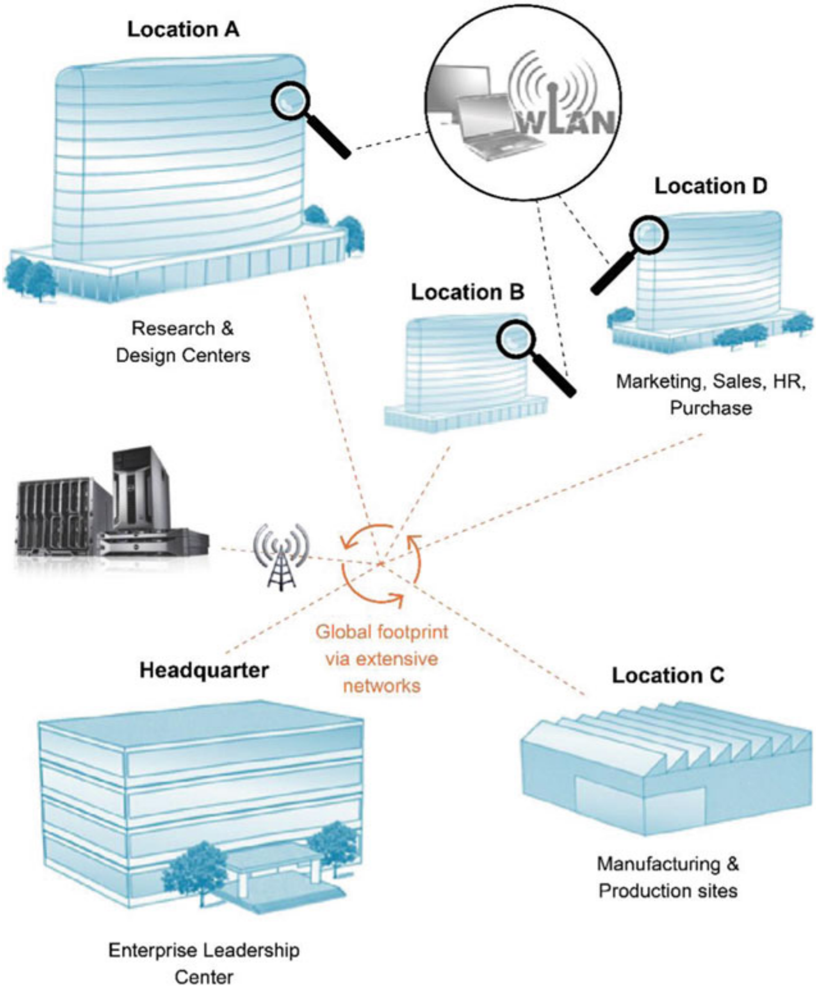

Fig. 3.12 The 3rd phase of IT organization in enterprises—global services and policies + outsourced operation (mid of 1990s to 2010+)

3.3.2 Today's IT Factory Set-Up and Future Business Concepts

Meanwhile each single work place in administration, accounting, product planning, project management, marketing and sales, research and development, manufacturing engineering and production control is dependent on the network connected computational intelligence with the help of hardware such as desktop computers, workstations as well as mobile connecting and computing devices and with the help of task dependent software applications. For each of these "digital value creation activities", however, it is necessary to make investments upfront to be able to make effective use of the IT tools and applications. The investments need to be divided into two parts, the obvious part, i.e. the direct IT related investment, and the non-obvious part, i.e. the "hidden" business and work competence related investment:

Information Technology Investment (ITI)

Obvious direct IT related investment to provide the base working system:

- IT architecture planning, application architecture integration
- Data model development and data base configuration and customization
- Computer Hardware and software purchase
- Network infrastructure and data center equipment (e.g. back-ups and storage)
- System administrator/user help desk training.

Business practice investment (BPI)

Non-obvious, "hidden" business and work competence related investment to establish the working capability for IT enabled value creation:

- Active support in the process of determining *enterprise key business processes* driven and actively steered by Business Senior Management in order to drive commitment and alignment of the type and degree of information technologies; such key processes are e.g.:
  - Product Process (lifecycle such as planning, engineering, manufacturing, logistic, production, use, recycle, reuse etc., compare [16])
  - Costumer Order Process (offer, order, build, delivery etc.)
  - Sales, Service and Maintenance Process
  - Key Support Processes (finance, procurement, marketing etc.)
- Research and analysis to determine the *core IT enabled and supported value creation work packages* within those *enterprise key business processes* (see above under a), such as information and digital model authoring, storage, retrieval, distribution, routing and delivery, visualization, analysis, synthesis build etc.
- Development of effective and efficient *key information process logic* to ensure robust execution of the above determined *key IT enabled and supported value creation packages*. Such logic determines the process for individuals and clarifies how often these individuals should be delivered with up-to-date information and related data or whether they should be automatically triggered by specific digital model update status. This clarification becomes increasingly important within business operations since the timely delivery of information and data sets come with effort, cost and infrastructure impact.
- Modification of traditional working practices and behaviors in order to match them with the business affordable *key information process logic*. It might well be that turn-around cycles of 24 h which might be desirable for quick engineering progress are not affordable and engineers need to find different ways of interaction and reasoning.

- Engineering of suitable conceptual data models, business/IT application methods, use cases and templates in order to realize *efficient information logistics* (data transport, distribution and information flow) and *information intelligence* (analysis of existing and synthesis of new information objects)
- Piloting of and educating the new business (process/method) approach in a phased manner—this investment needs to include testing of the corresponding IT application developments in order to finally justify and confirm the direct IT investment.

Whereas the first type of investment (ITI) is an accepted—but very controversially discussed—investment schema in enterprises the second one (BPI) is merely established as a fundamental, regular investment schema. As Information Technology can no longer provide business value without this second type of investment (BPI) most companies are in a crisis towards business operation innovation.

From this standpoint, Information Technology is only in the beginning to get fully established as a key competence and indispensable skill set in professional life, especially for engineers in Virtual Product Creation. Industrial enterprises in today's world have not yet sufficiently understood how to establish an investment schema to guarantee the Business Practice Investment (BPI), which constitutes the sufficient condition to guarantee robust digital/IT related value creation. The reason for this "currently increasing lack" is twofold:

- The non-existence of a digital value creation model and consequently the limitation of today's business controller models to only accept ITI funding.
- Limited sensitivity and knowledge of enterprise leadership management on/about the critical dependency between business and collaboration competencies and information technology.

A written survey/telephone interviews based on 16 key questions/assessments conducted in the first half of 2011 amongst more than 10 senior IT business managers in automotive (BMW, Daimler, Ford, Mazda, Continental, both headquarter and within the regions) and technology (energy) industry (Siemens) as well as additional single expert interviews within the mechanical engineering, railway and aviation/aerospace industry (experts from Airbus, Bombardier, MAN, Rolls-Royce) have revealed the following interesting set of characteristics:

The top three IT budget spending line items relate to:

- Operational business support such as executing data centers, help desks, data base administration etc. together with dedicated projects:
- to reduce the number of IT applications (*IT consolidation*) and hence to realize a scalable reduction of license cost;
- to use similar or even the same IT applications and server installations where possible (*IT harmonization*);
- to restructure IT "back-office" functions by building up scalable "enterprise architecture integration" (EAI) solutions by introducing SOA (service-oriented

architecture) interfaces between individual business process critical business IT applications and the enterprise digital backbone (web service platform);
- to reduce license cost, improve compliance and policy control and streamline internal operational footprint by outsourcing ITIL based services to special IT companies.

The top three business tasks of the internal IT organization in terms of effective use of internal IT headcount relate to:

- Acting as "IT front office" in terms of:
- Following strategic decision by Senior Management on business processes and organization as well as consulting Senior Business Management on IT solutions as part of future business strategies and
- on specific IT enabled business functions with regard to upcoming business process needs and opportunities.
- Project Management execution with respect to new IT solution requirements management, development and coding coordination as well as test and deployment tasks.
- Governance, compliance control and capability tracking coordination work.

Obviously, there exist a tendency in global acting enterprises to balance out differences between regional business needs, availability and cost of human expert competences and expenditures for recruitment and knowledge ramp-up. Based on the individual IT business set-ups the organization IT decides on in- and outsourcing strategies. The level of outsourcing has common aspects across the interviewed enterprises and branches, but also significant differences. As a common business approach in information technology divisions a range of tasks is outsourced.

The first group of "highly outsourced IT business tasks" comprise the following activities:

Data center operation and data base administration: on average the outsourcing rate is higher than 80%, the distribution, however varies between 50 and 100%. Two interesting observations are visible:

For companies with a significant global footprint the degree of outsourcing for this task seems to be higher in the European and US locations.

The type of outsourcing differs from *full operation outsourcing* (i.e. outsourcing incl. management of the operation to an outside company) to *mainly labor outsourcing*, i.e. keeping the management control within the enterprise but outsource the actual "doing work" to agency headcount. The later one is more popular in Anglo-American and some far east companies since legislative work regulations in those countries provide the opportunities for mid to long term arrangements of such outsourcing set-ups in contrast of different working laws in many European countries and Japan.

User help desk support, incl. first line support (dispatcher of the central user help desk), second line support (knowledgeable contact persons or "on the job" support personnel to provide the direct user support at the working desk) and third line support (full technical experts and method consultants who back-up the second line support. Common budget practice today is central funding for those operations—service oriented budget contributions from the various business and engineering disciplines have not yet been implemented!

Technical execution of IT application development projects: surprisingly enough, the interview/questionnaire activity revealed that all Automotive OEMs heavily rely on outside companies to operationally execute and technically lead the customization and configuration work of existing market IT solutions and to develop new/additional IT application solutions. In the meanwhile, the majority of automotive, railway and aviation/aerospace OEMs no longer keep the core expertise for such IT development tasks and therefore, in many cases the OEM personnel concentrates on operating on the project-steering level. There seems to exist a difference to other industries (such as Siemens in the technology/energy sector) and even to some automotive suppliers where the level of outsourcing of those tasks is limited to 30–50%.

A second group of outsourcing levels is formed by IT business tasks where the outsourcing rate is usually smaller than 20% at all companies.

This second group of "less intensive" IT business outsourcing consists of the following two activities:

Consulting support of Senior Management for IT enablers in enterprise business strategies. Outsourcing for such as task is limited to special assessments and expert back-ups but not for the entire range of consulting activities.

Project lead of IT application development tasks—please also compare the statements under the third task of highly outsourced task above!

There exist a third group of miscellaneous outsourcing levels with no clear trend across the companies and industry branches.

This third group comprises the following IT business tasks:

IT infrastructure and IT enterprise (architecture) integration: here the level of outsourcing differs between 30 and 100%. It seems that US based companies still keep a higher internal rate within such tasks.

Research studies, new innovations and related pilot projects: there is a significant difference between German based OEMs which favors a significant (at least 30–50% rate!) of outsourced work, based on their excellent and fully trusted network with German universities and research institutes versus Anglo-American and Japanese companies with less than 15% and not necessarily using public/independent but private expertise from outside. Due to a high appreciation of application-oriented research in major parts of Europe (such as Austria, Germany, Italy, Sweden, Switzerland) it is possible that universities and research institutes (e.g. such as Fraunhofer) have established firm and clear intellectual property agreements with industry and still remain well established within the science community. In the Anglo-American world science and research has been treated by industry and universities more as an academic exercise with a clear separation line as compared to industrial praxis. As an additional observation by the author in having exchange with Chinese authorities, China seems to follow the central European way of tight interaction between company and university/research institute innovation work in accelerating innovation schema.

Traditionally, budget spent on Information Technology within an enterprise is subject for discussion, classification and ranking. The expert interviews revealed interesting trends on IT budget spending which can be summarized as follows (in comparison of the period between 1990 and 2010 with reference points in 1990, 2000 and 2010):

The overall IT budget in percentage to the overall enterprise budget has decreased from 2.5 to 4% in 1990 down to 1 to 2% in 2010. Some companies had significant higher IT investments around 2000 and did reduce them again towards 2010. No generic rule exist how to measure IT budget percentage on overall budget (due to the individual definition how to count e.g. BPI, i.e. business practice investment: as IT budget or business budget).

There exists a general trend that operational IT expenditures such as for data center and help desk operation are cut by using outsourcing opportunities and by establishing commodity solution instead of special enterprise customized solutions. IT project budget with a close relation to business initiatives usually remain on a similar level.

Globally acting enterprises have invested intensively within the Asia–pacific region. Hence, those enterprise locations have sharply increased their IT budget by more than 40 to 70% over the period between 1990 and 2010.

There exists a significant difference between the companies on how they use their IT budget with respect to new IT solution development and to the related Business Practice Investment (BPI): companies such as BMW, Daimler and Siemens use double digit percentages of their overall IT budget for such activities, whereas Japanese companies such as Mazda and automotive suppliers such as Continental keep it limited on a low single digit percentage.

The percentages of budget spent on Virtual Product Creation (VPC) respectively Product Lifecycle Management (PLM) solutions versus entire IT budget vary across the enterprises and highly depend on the replacement and innovation cycle of the individual company solution. In all enterprises, however, license cost is the dominant factor and accounts for 70 to 90% of the operational IT budget for this field. Second largest element of the running cost is represented by purchased service for experts, IT consultants and application specialists.

The next focus of the interviews was centered on the question which internal model is used within the enterprise to determine, define, drive, develop and deploy new Virtual Product Creation (VPC) and/or Product Lifecycle Management (PLM) solutions. Interestingly enough, there is the following difference: today's traditional model within matured European and American enterprises favors a lineup of two separated groups, one central expert and consulting team in IT (sometimes also named Process IT) and another central or networked digital process and method department within Engineering. The Asian model still sees a concentration of such responsibility within the IT organization. Due to the rather fragmented business setup the Energy, Machine and Technology sector (e.g. Siemens, MAN Diesel and Turbo) as well as the railway sector (e.g. Bombardier) run all of their major Virtual Product Creation and PLM projects out of the IT organizations and Senior Management encourages/enforces a link to subject matter experts and/or key users from key engineering departments on a project level only. Today's Senior Engineering Management oftentimes still believe that leadership in driving new Virtual Product Solution might distract Engineering Middle Management from their ordinary operational task and that therefore IT Managers "own this task" and should get supported by Engineering Project Leaders only.

In summary, it is noticeable that the majority of *today's* enterprises still struggle with the fact that Virtual Product Creation and PLM innovation is mainly driven out of IT departments rather than by engineering itself. This explains the dilemma of many companies: new ways of engineering oftentimes are missing the right business motivation and targeted execution path. IT experts and process/method project leaders and consultants are no longer in the position to drive such business conversion if engineering management and experts are not taking up the leadership.

As a forecast into the future, the IT Managers were asked the question how they see the changing landscape in the future, i.e. within next five years. They were given the following three Virtual Product Creation competency set-ups to choose from for a best future set-up:

- Central organization as a combined PMTI (Process, Method, Tools and Information standard) competence team;
- Two central organizations, one information technology competence team within the IT-department, one as best practice Business PMTI team in Engineering;
- Several qualified decentralized information technology and PMTI expert teams under central coordination.

The majority indicated that their set-up of today follows set-up #1 but that they probably will transition to a set-up #2. All managers, however, have shown significant interest in a set-up #3, especially since a set-up mix might be necessary for the future in order to drive the differences of IT enabled business according to the following suggested way:

- Set-up #1 for IT commodities and IT maintenance;
- Set-up #2 to allow best user segmentation whilst keeping a high degree of communization for the backbone solutions;
- Set-up #3 to become capable of following a true business value driven approach to stay competitive in a fast-changing business environment.

From 2015 onwards, the term "bi-modal" IT became popular amongst IT Management. On the one hand companies are handicapped by legacy IT technologies which force them to run on old data base platforms and mainframe computing technology especially in their back-end solutions. On the other hand, new IT development approaches (agile software development, open community design) and new technology elements (e.g. converged databases, html5 visualization etc.) make it possible to quickly establish customer front-end solutions. It is, however, controversially discussed what the best approach will be to merge them or to guarantee smooth co-existence to each other.

The following chapters will provide dedicated insights to the Virtual Product Creation history as well as to the Virtual Product Creation technology and solution landscape.

References

1. Levi P, Rembold U (2002) Einführung in die Informatik für Naturwissenschaftler und Ingenieure. Hanser Verlag
2. Carruccio E (2006) Mathematics and logic in history and in contemporary thought. Aldine Transaction
3. Ihrah G (2001) The universal history of computing: from the Abacus to the quantum computer. Wiley, New York
4. Lister M, Dovey J, Giddings S, Grant I, Kelly K (2003) New media: a critical introduction second edition. First published 2003, second edition published 2009 by Routledge, Abingdon. ISBN13: 978-0-203-88482
5. Eccles WH, Jordan bWF (1919) A trigger relay utilising three-electrode thermionic vacuum tubes. The Radio Review, p 298
6. Zuse K (1970) Der Computer. Mein Lebenswerk. Verlag Moderne Industrie, München
7. Randell B (1976) The colossus, technical report series No. 90. Computing Laboratory, University of Newcastle upon Tyme, UK
8. Dale N, Lewis J (2009) Computer science illuminated, 4th edn. Jones and Bartlett Publishers, Inc.
9. Slater R (1987) Portraits in silicon. MIT Press, Massachusetts Institute of Technology
10. Bernstein J (1984) Three degrees above zero. 1. Bell Telephone Laboratories - History. Press Syndicate of the University of Cambridge, Great Britain
11. Beyer KW (2009) Grace hopper and the invention of the information age. Massachusetts Institute of Technology, USA
12. Godbole AS (2005) Operating systems, 2nd edn. Tata McGraw-Hill Publishing Company Limited, New Delhi, India. ISBN 0-07-059113-X
13. Ceruzzi PE (2003) A history of modern computing, 2nd edn. MIT, USA. ISBN 0-262-53203-4
14. Tannenbaum A (2009) Moderne Betriebssysteme, 3rd edn. Imprint der Person Education Deutschland GmbH, Germany. ISBN 978-3-8273-7342-7
15. Spur G, Krause FL (1997) Das virtuelle Produkt: management der CAD-Technik (The virtual product: management of the CAD Technology). Fachbuchverlag Leipzig. ISBN-13 978-3446191761
16. Carlson B, Burgess A, Miller CH (1996) Timeline of computing history. The IEEE Computer Society. Accessed 17 June 2010. http://www.computer.org/cms/Computer.org/Publications/