THE FUTURE OF TESTING

imbus Trend Study

3rd updated edition

Imprint

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Foreword

Dear Reader,

Our study “The Future of Testing” we published in 2015 for the first time has raised great interest. It has been downloaded a few thousand times from the imbus download portal. We have been able to hold exciting conversations with many readers and listeners at conferences and lecture events as to which scenarios illustrated in the study are likely to occur.

Even for us and our company imbus, the study is an excellent tool to prepare us for and to adjust to future trends and developments in the field of software quality and software testing.

Therefore, we have asked the futurologist and author Dr Bernd Flessner to update the study with us.

The present, new 2017 issue takes a closer look at the future of software testing for the periods “from 2025”, “from 2035” and “from 2050”. In order to facilitate a comparison, the structure of the study has only been slightly changed compared to the 2015 issue. Anyone who compares both studies, comes to a conclusion that the scenarios have not dramatically changed. However, the pace at which the technology develops and the world changes has further increased.

We hope you enjoy reading our study. Your feedback on the presented scenarios is always welcome!

Best wishes,

Tilo Linz
imbus AG, CEO

Thomas Roßner
imbus AG, CEO

Contents

I. SCENARIO PLANNING

One of the characteristics of the future is its openness which results from the natural laws known to us and not least from the multiple decisions and actions of humans. Deterministic forecasts are therefore only possible for tightly defined time horizons, even with the help of quantitative methods based on mathematical models.[1]

Over its brief history, futurology has developed a series of methods which, to a certain extent, still enable to make statements about distant time horizons that evade a quantitative approach.[2] Scenario planning is probably the best known of these methods; it can be traced back to the American futurologist Herman Kahn and his planning games of the 1950s. Since those days, scenario planning has evolved in many different ways and continues to be expanded with new approaches and variants.

Scenarios are not forecasts. They do not predict the future. Instead, they generate eidetic notions of possibility space defined by the opening of what is known as the scenario funnel. “Scenarios are not predictions – they are hypotheses that describe multiple possible developments”[3], states the futurologist Peter Schwarz. Their primary task is to provide institutions, organizations and enterprises with guidance which can help them to come to decisions. They are therefore also compared to lighthouses which are intended to make it possible “to stay on course, even in difficult waters”[4].

KEY FACTORS

One of the principal elements of scenario planning is the identification of key factors which will, in all probability, define or influence the future development of the scenario subject.

The most important of these are what we call the megatrends, that is the "long-term and overarching transformation processes" that can be observed over a period of decades and which cause "profound, multi-dimensional revolutions"[5].

The closely drawn framework of the study and the scenario subject make it necessary to place four of the 20 megatrends in the foreground, these are "ubiquitous intelligence", "convergence of technologies", "knowledge-based economy" and the "digital culture":[6]

- The ubiquitous intelligence can mainly be characterized by setting up an Internet of Things, by setting up an intelligent infrastructure and by a great progress in the field of developing artificial intelligence. Robotics and smart media are tending to be ubiquitous and have an impact on our everyday life, development and production. Algorithms become creative, write texts and turn into assistants for physicians, lawyers, managers and artists.
- The convergence of technologies lies in the melting and merging of technologies that have been mostly separate so far. Newspapers, telephone, cinema, radio and mail that had once been independent elements of the medial system are today converged to a universal medium in a computer or smartphone. Many other fields of technology are experiencing the same. Especially the fields of nanotechnology, information technology, bio technology, neurotechnology and medical technology are going to merge. Especially the nanotechnology is the main driving force of this development.
- In the field of knowledge-based economy, data and knowledge will dominate our value-added chains. Human education and smart data are decisive factors, whereas energy and resources become less important. This is because both factors are replaced - with the help of knowledge – by new materials such as graphene (modification of carbon with two-dimensional structure) and other carbon products as well as renewable energies. The 4th industrial revolution (4.0 process) is knowledge-based.

- The change to a digital culture is fully under way. New means of communication and participation are evolving, whereas old structures such as private and public archives (libraries, DVD collections, file folders and analog images) are increasingly disappearing. They are replaced by media centers, streaming providers or cloud solutions. Work, leisure time and consumption are digitally based. New consumption patterns emerge (such as using instead of owning), while logistics is further differentiating itself in order to ensure delivery. Human becomes a prosumer who increasingly designs numerous cultural products himself, from music to images.

The other 16 megatrends will not be ignored at all and remain present in the background, as the digital transformation process is not their main driving force.

METHOD

According to the specified scope, the development of the future scenarios is based above all on the evaluation of existing analyses, forecasts and studies by renowned institutes and authors. At the same time, the author has requested numerous correspondents from the fields of research and economy to provide their personal assessments. Six scenarios were then developed on a basis of the extracted data and information and these were discussed with competent partners.
The author is well aware that this procedure cannot take the place of a large team, a multi-stage analysis process and experts‘ workshops.

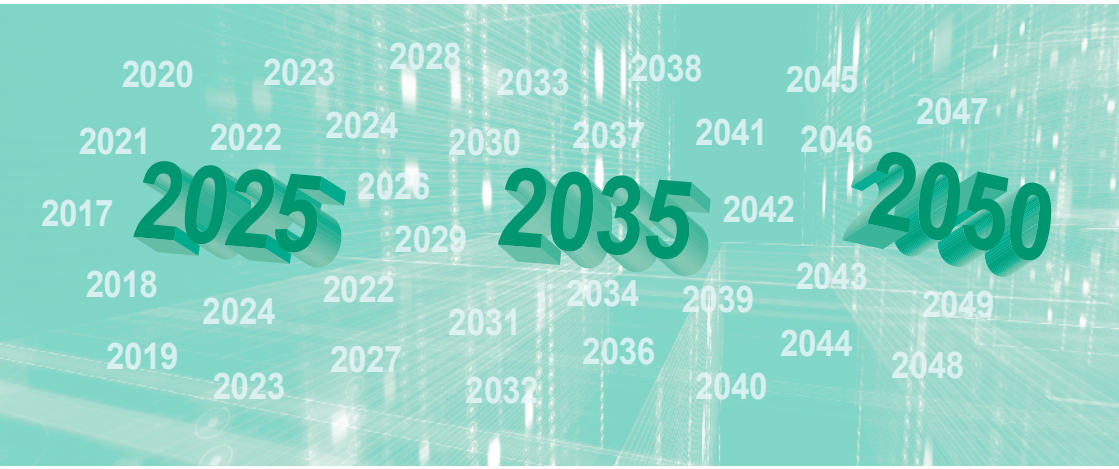
However, he takes the view that the drawn-up scenarios can serve as a basis for subsequent discussions and as an orientation aid within the defined framework. The study is intended as an initial step, comparable with a keynote speech, that can and should be followed by further studies.

Scenario planning

The scenarios have been designed to be additive, i.e. they build on each other. This means that not all the factors are listed again each time. The study is divided into three time phases. These were selected because the intervals are sufficiently large to cover and present significant scientific-technical, economic and social development stages:

- From 2025[7]
- From 2035
- From 2050

The first two phases form focal points, the third phase serves primarily as a visionary perspective. The three-time horizons are intended to allow us to draw or identify lines of development. Two scenarios were developed for each of the periods, one tending to the positive and one tending to the negative. A base-case scenario (trend scenario) was chosen for the last period. Scenarios supply orienting knowledge, neither factual knowledge nor prognoses!



II. THE SCENARIOS

2025

From 2025

Positive scenario: The revolution is coming!

Despite international crises and increasing volatility of markets, economic development is largely stable. Protectionist tendencies of political blocks and states such as the USA had and still have no serious long-term effects and globally active corporate groups and companies have eventually been able to assert their interests, even the American ones.

Globalization 2.0

The process of globalization (Globalization 2.0) that has temporarily come to a standstill is thus being continued. China has risen to be the leading economic nation and has additionally become more and more successful in removing ecological deficits.[5] One of the global trends is an increasing qualitative growth; not more, but better products are produced in many market segments.

Industry 4.0

The technological inventions, innovations and developments discussed at the end of the 20th and beginning of the 21st century and classified more or less as revolutionary, also known as Industrial Revolution 4.0, or simply the fourth industrial revolution, extensively become reality.[9]

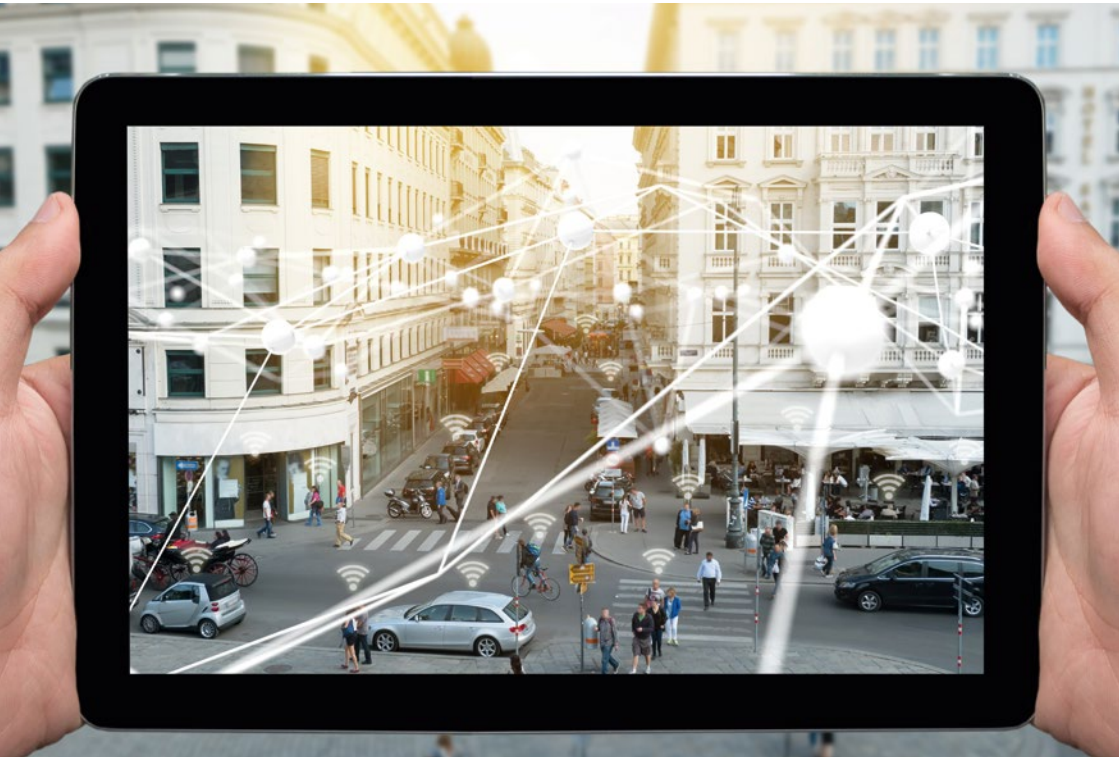
"The fourth industrial revolution becomes reality."

The reindustrialization connected to this revolution leads to the development of new businesses in industrial countries, especially however amongst the pioneers of the process such as Germany. Thanks to an advanced automatization, factories in so-called low-income countries no longer make economic sense.[10] This new Industry 4.0 is comprehensively networked to the Outernet. One of many quantitative indicators is perhaps the increase in globally fluctuating data, the volume of which will have grown from 130 exabytes in 2005 to 180,000 exabytes (180 zettabytes) in 2025.[11]

This increase is thus larger than assumed in the preceding study of 2015, in which an increase to 40,000 exabytes (40 zettabytes) was predicted.[12] China and India will have recorded the greatest growth.[13]

Intelligent algorithms

At the same time, human-machine communication is covering more and more areas of work and everyday life and convergence also takes place in many other fields. This starts already in the education sector, where algorithms are increasingly taking over the controlling and handling of learning processes.[14] Automatic, autonomous learning, deep learning and intelligent algorithms are quite natural in many decision and production processes and replace human or assign other tasks to him. A hardly predictable number of knowledge workers, among others also lawyers, physicians or architects, will no longer be needed.[15] By 2025, this digital transformation process will also have affected the creative branches. Algorithms that can paint, write poetry, create texts and compose are taken for granted and we can no longer imagine the media without robotic journalism.[16]



In many branches, smart algorithms are superior to human performances.[17] In fact, the whole world of work is simultaneously based on knowledge and software.[18] This also applies to creative and artistic processes that have exclusively been part of human labor so far. Algorithms that compose or generate works of art will have been accepted in many areas of pop culture by 2025.[19]

Mass customization

Especially medium-sized, specialist companies, among them many start-ups and spin-offs from universities, exploit the advantages of the accelerated 4.0 process and supply their customers quickly and reliably with personalized or individualized products that meet their wishes (mass customization) in 2025. At the same time, the traditional mass production of identical products becomes less important.[20] With the aid of a digitally transparent production, the product range becomes richer in variants and even enables inexpensive one-off production in more and more fields.[21]

Smart sensors

One of the core sectors in Industry 4.0 is that of smart sensors which allow different users to query information about the current status of a product in real time, including and above all, from mobile devices. The other way round, production can be controlled from mobile devices that are already partially equipped with augmented reality. The consequence is an enormous increase in transparency, the possibility of decentralized control and the deployment of software wizards and software agents which, for example, autonomously purchase the necessary process parameters from the Internet, control logistic processes or automatically order spare parts and materials.[22]

AI on demand

The use of intelligent software (weak AI) is taken for granted in 2025 and even available on the net as “AI on demand”. AI is vital mainly in the area of collaborative robots and virtual assistants, such as recommendation systems.[23] It is an essential part of decision-making and design processes in all fields of economy. Nevertheless, humans remain the decisive key factor.[24]

The scenarios from 2025

The threshold for automatization has declined dramatically; this does not, however, necessarily replace humans immediately, although their tasks are increasingly shifted to the control area. Furthermore, it is obvious in 2025 that automatization has reached all branches and has become a global driving force of economic development.[25]

Smart product

Flexibility is more organized, while the difference between production workers and knowledge workers diminishes. Production workers are working more and more creatively and in a problem-solving way now, while knowledge workers need to better control productive processes.[26] In the Industry 4.0, the smart product booms which automatically controls and monitors its own production and distribution. However, it is far from being a standard. The number of manufacturers who monitor their smart products, even including their disposal and recycling, is still low, but is increasing rapidly. Services of this kind become an important segment of the Outernet.[27]

However, significant fields of industry continue to work with conventional (in relation to Industry 4.0), although modified and modernized production technology in 2025. However, these fields are also affected by this change. Especially agriculture shows deficits, because it only reluctantly deals with digitalization and automatization. Nevertheless, weather apps, drones and other data management systems are increasingly used to optimize soil and harvesting procedures. Cloud solutions, feeding and harvesting robots, measuring systems and sensor technology are offered by many suppliers.[28]

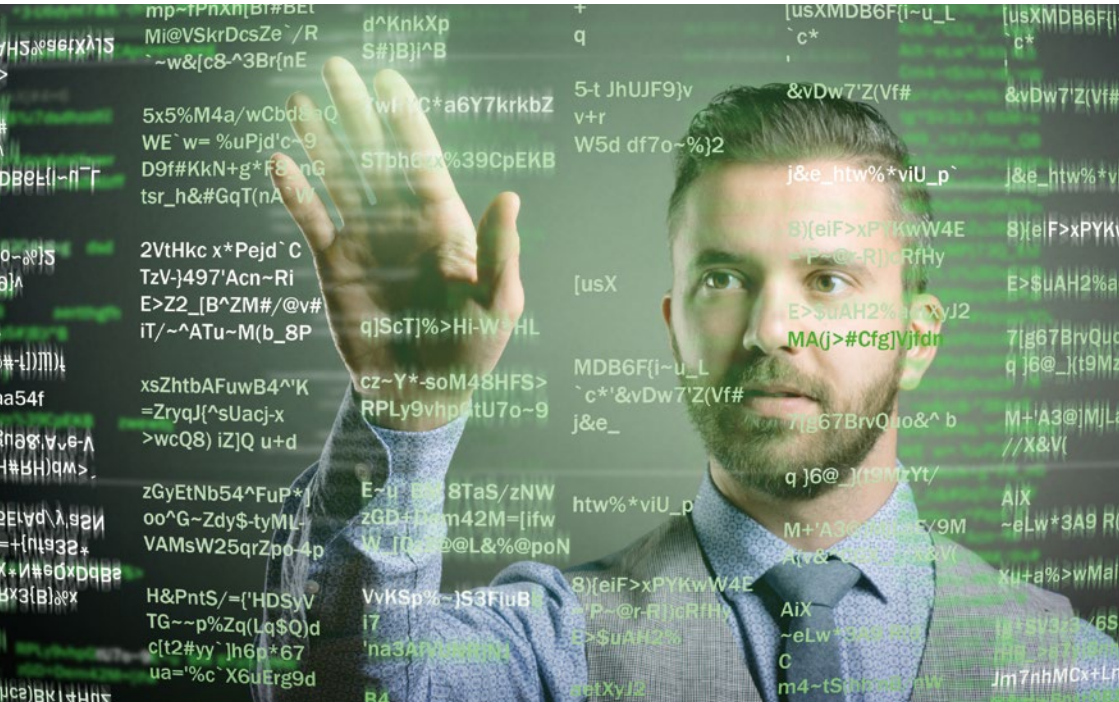
Outernet

In parallel to this development, the Outernet is also taking shape. In 2025, approximately 8 billion humans co-exist with 200 billion products, commodities, machines and objects connected via Internet. Even if every human uses several phones, tablets and computers, it would be clearly outnumbered by the connected world of things in 2025.[29] A greater and greater proportion of global data transfer takes place between smart objects without any human intervention. Wireless sensors (Wireless Sensor Networking) that collect and exchange data from different segments of industry, trade and living are experiencing a special boom.[30] About 50 % of all data circulating on the Internet and Outernet originate from more than one trillion of RFID chips and smart sensors of the Outernet.[31] Connectivity is thus reaching a new quantitative peak, while dynamics of this development is not decreasing. Qualitatively, the increasing connectivity leads to a simultaneous increase of transparency in all fields of society, politics and economy.[32] The global market for Outernet-based products is rapidly growing and will have increased from a volume of 20.35 billion USD in 2017 to 75.44 billion USD in 2025.[33] Following the mobile Internet and AI applications in the field of knowledge work, the Outernet takes the third place in the ranking of the digital economy segments with the highest turnovers.[34]

The scenarios from 2025

Polytronics

One of the consequences is a radically changing relationship between producers, service providers, logistics companies and their customers. Thanks to smart sensors, machines can e.g. indicate their impending failure and thus be repaired before the event occurs.[35] The location and status of each individual product can be determined and tracked in real time, also from mobile devices. Thanks to polymeric electronics (polytronics) and other new print techniques, more and more chips are printed on paper, cardboard, plastics, metals and even clothing.[36] A further feature of the Outernet is "autonomous or semi-autonomous action by objects within their networks"[37]. Should e.g. a product finds out that it is damaged, it can initiate its return to the manufacturer or inform the responsible provider. The Outernet will begin to establish itself in its whole range of applications and be used by all branches only as of 2025. Dynamics of even this development may, however, already be noted in the whole economic system, especially in logistics.[38] In this field, logistic drones and delivery robots will be used increasingly.[39]



Augmented reality

Development, production, logistics and service providers will be already using augmented reality (AR) in many areas in 2025. The technology of cyberglasses of all types has matured so far that it has become practical. The speed of development can be observed from the fact that the first AR apps for smartphones became available in 2009 and a global turnover of 181 million USD was recorded very soon in 2011. According to a study from Goldman Sachs, the global turnover related to AR products will be up to 80 billion USD in 2025.[40] AR does not stand alone as a separate application in the context of the convergence of technology, but is a fixed integral element of the global media system, including Internet and Outernet. Numerous tasks and services are no longer con-

ceivable without AR from 2025, as smartphones, cyberglasses, smart lenses and smart glasses allow access to images and data from Internet and Outernet in real time. Production processes, safety checks of e.g. aircraft and repairs of e.g. cars are more and more frequently carried out with cyberglasses that provide the wearer with all the important information, so that the use of manuals, written instructions and similar analog aids becomes obsolete.[41] However, AR is also increasingly used in cars, aircraft and other means of transport and as well as in the consumer sector where the customer can try on or try out clothing and other products in AR within seconds.[42]

"The technology of cyberglasses of all types has matured so far that it has become practical."

Augmented reality is far from being just a medium in the world of work. It is also a segment of the (globalized) media system that is comprehensively modernized and converged thanks to the digital transformation process. Editorial and production departments work with various AI variants, use deep learning and big data mining, while smart algorithms contribute to creative processes. The so-called robotic journalism is also used by public service providers. Algorithms also take over a part of content creation and write e.g. scripts.[43] Professional work techniques quickly penetrate into amateur sector, so that image processing software that was only available to professionals in 2015, will be available at a reasonable price and on demand in 2025.

The scenarios from 2025

Fabbing

The process of reindustrialization comprises not only the Industry 4.0, but also the fabbing technology (3D printing etc.). In 2025, the fabbing technology is on the rise in commercial sectors and private households and is about to become a serious economic factor.[44]

Bioprinting

Fabbing has already firmly established itself by 2025 in professional sectors, which also include medicine (bioprinting).[45] While the global turnover related to fabbing products was 2.5 billion USD in 2013, it rises to 550 billion USD by 2025, with around two thirds coming from the services sector.[46] The customer recognizably becomes an element of the value-added chain and a co-developer and co-producer. A trend that has been known for a long time by the keywords prosuming, open innovation, user innovation, customer-go-creation etc.[47] Transfer of production phases to households is in full swing.

Structureware

Blanks, fab-materials of all kinds as well as the necessary software (also known as structureware) are important commodities.[48] More than 3,000 components of a new car will be produced with fabbing machines in 2025.[49] Fab-shops offering production or duplication of personalized products will become crowd pullers in pedestrian zones. As of 2025, fabbing of furniture will also be increasingly offered, so that this sector also changes permanently.[50] The material technology experiences rapid progress, as it can provide the fabbing trend with new materials. On the other hand, there are not many software-based smart materials. The dream of nanotechnologically "programmable materials" cannot be implemented yet. At the same time, products made with nanotechnology boom in 2025.[51]

Cobots

Robotics is now also finding its way into craft sector and small and medium-sized enterprises, just as in the case of the current 2017 Baxter model, a humanoid robot for various operations, for the use of which no specific IT knowledge is required.[52] Many medium-sized companies from trade to services use the so-called collaborating robots (cobots).[53] Robots of various construction increasingly become direct partners of humans. Although they were a marveled exception few years ago, they are already on their way to normality in 2025. "The human-robot teams pave a new revolutionary way for middle-sized companies allowing them to automatize their production to the highest technical level"[54], explains Dr Martin Lechner, manager of technology trade fairs at Messe München.

Cobots can be found in many hospitals in 2025, especially in the field of surgery and here mainly within the minimally invasive procedures.[55] Among others, the "Medical robotics" at the Karlsruhe Institute of Technology is leading in Germany. The manager is Dr Jörg Raczkowsky, whose prognosis has proved to be true in 2025: "Robotic technology will be integrated into future operating rooms similarly as intraoperative imaging in a modern hybrid operation room today."[56] Caregiving robots are already taken for granted. Prognoses that there are eight million caregivers missing only in Japan in 2025 have also proved well-founded. Government incentive programs have helped to develop

Cobots

the necessary robots up to their series production readiness and to at least partially compensate the predicted deficits in the western countries.[57] At the same time, a change of robot image takes place. While triple "D" (dirty, dangerous and dull) was used to characterize a robot in 2010, triple "M" (mobility, manipulation and messiness) is used today. Robot becomes a firmly integrated element of our culture – initially in companies and institutions and later in private households. This development even implies human sexuality, because sexually active androids will also belong to our everyday life as of 2025.[58] More and more robots are voice-controlled. Control by brain-computer interface is still an exception, although a development progress cannot be overlooked.[59] Smart speakers, i.e. voice-controlled virtual assistants, can be found in more than 60% of all households in 2025. The current devices are notably smaller and more unremarkable than the first versions. They also allow mobile use and/or are available as an app.[60]

"Robots become an integrated element of our culture."

A further, very relevant field for use of robots is the defense industry. Robots of the most diverse constructions – from a drone to a battle robot for urban warfare – are a firmly integrated armed services branch for a long time, the capabilities of which are far from being exhausted yet. AI and deep learning are developed by military research institutions in an accelerated way.[61]

The scenarios from 2025

Robotics

In 2025, robotics is still on the way to become a key industry, which actually provides all sectors of economy, military, research and everyday life with specific products. At the same time, car industry loses its attribute to be still a key industry in the future. As a consequence, the most car industry suppliers are strongly oriented towards robotics and become important players in this expanding market.

Robot cars

Thanks to legislative procedure completed by that time, robot cars are already approved for many roads from 2020 and are very popular in 2025. Electromobility does not play a secondary role anymore, but establishes itself rapidly. At the same time, traffic researchers see a "digital mobility revolution" in the development.[62] Cars become a segment of the Outernet and an IT periphery of the smart home. Approximately 45% of all vehicles are networked (car-to-car communication) and exchange their data; about 40 % of them are equipped with a sensor-based automatic brake system.[63] By tendency, less cars are sold, but they are more frequently rented and/or ordered in a mobile way as robot cars instead.

Cyborgization

A further trend is the cyborgization of a human being, i.e. the use of implantable electronic elements such as cardiac pacemakers, brain pacemakers, cochlea or retina implants, but also smart exoskeletons. While already about 10 % of people in the USA had electronic implants in 1995, this percentage had tripled by 2025.[64] In addition, the proportion of healthy people using cyborg technologies is growing rapidly.[65] The optimization and upgrade culture already noticeable in 2017 has further established itself and ensures a rising demand for cyborg technology.[66] Sales volume exceeds already the level of 2 billion dollars in 2025.[67]

Smart homes

The market for smart homes has considerably gathered pace in 2025. 10 to 20% of all new buildings in Germany are smart homes equipped with corresponding technology, including smart metering and robotics.[68] The trend is complemented by an increasingly intelligent energy supply including virtual power stations, decentralized energy production and smart grids.[69]

Fintech

The widespread use of digital currencies and payment systems that has established within a few years is economically consequential. Blockchain, Bitcoin and Fintechs boom, while use of cash even in Germany is regressive. Money thus also becomes a segment of the converged media system.[70]

TESTING OF SOFTWARE AND SYSTEMS FROM 2025 – CONSEQUENCES FROM THE POSITIVE SCENARIO

The world of the year 2025 and beyond is more digitalized and software-based than expected only a few years ago. According to this, the demand for software tests needs to be rated higher. The reason is that all aspects of the digital transformation process as well as the 4.0 revolution are dependent on the fact that an increasingly complex software is working correctly and reliably.

Therefore, the importance of testing is again notably higher from 2025 than that in 2017. The reasons for this include the increasing operational risks caused by system-related rising connectivity and data fluctuation. The software increasingly becomes a strong link in the value-added chain, on the reliability and security of which large parts of the economic system are dependent.[71] Smart products, fabbing, Industry 4.0 or the Outernet cannot be implemented without a reliable software. In other sectors, assistance systems and systems which tend towards autonomy or are completely autonomous as in robotics or robot cars give rise to new risks. Systematic and permanent testing shares responsibility and is indispensable for the necessary functional and operational reliability.

Test-driven-development

Among others, the test-driven development (TDD) is providing successful and low-risk innovations in more and more sectors. Not only in medical technology, but also for all products and applications in which the health of users or consumers is affected or safe behavior even in a case of faulty operation, system failures or accidents needs to be given, TDD is mandatory in fact.

Security

Data protection and general security against cyberattacks are just as important. The success of the entire fourth industrial revolution depends on the solution to digital security problems.[72] Thus, the testing branch is more involved in security tasks from 2025 than it was in 2017. The enormous quantitative growth in data fluctuation and the demand for and use of software in practically all sectors of work and everyday life is significant for the years after 2025. In many branches, led by the car industry, the number of needed staff with software skills will have been doubled by 2025.[73] This means that the quantitative demand in the software QA sector will also grow at a correspondingly rapid rate from 2025. The number of testers required will more than double, as new software-relevant sectors such as the Outernet have arisen compared to 2015.

Test of AI

The fact that more and more learning and autonomously deciding software is entering the IT industry has great impacts on test strategies and test methods. The testing branch is facing new questions: how to test that a system is learning the right thing? How do test cases, which check that certain facts have been learned correctly, look like? How to test that a system correctly processes the learned knowledge by forgetting for example wrong or obsolete information or abstracting other information? How to test that (for example with robot cars) self-learning software follows specific ethic rules? How to formulate test strategies and test cases in such a way that they can handle the "fuzziness" of the behavior of AI systems?

Test tools with AI

The already wide range of variants of test types, methods and tools extends more and more. As a consequence, testers become more and more specialized. Mechanisms already known and used today such as crowd testing, cloud-based testing tools and services and classic testing automatization are only partially capable of coping with the growing demand. Therefore, AI is also entering the test tools. It is applied in the knowledge-based selection of optimal partial amounts of test cases for regression tests and for automatic conception of test case designs for systems whose complexity cannot be understood with human intelligence anymore. It is also applied in the results evaluation of software with "fuzzy" (as it is AI-determined) nominal behavior. Using AI during testing relieves human test experts. However, it also raises new questions regarding the significance of and trust in tests.

The scenarios from 2025

As the permanently increasing connectivity represents not only a quantitative, but also a qualitative challenge, the testing branch needs to adapt to this development accordingly. It is becoming less and less possible to test components of IoT systems and AR solutions in isolation, as removing them from the overall system distorts the results or conceals (automatic) interactions with other system components. The tools and methods have to be adapted and developed anew. The paradigm shift in software development is reflected in the testing sector:
"Away from monolithic stand-alone systems towards open, networked, scalable and service-oriented cloud-based test solutions."[74]

Safety and security

IoT as well as AR systems interact strongly with humans. Therefore, the functional safety of these systems becomes a significant quality feature. To ensure that safety cannot be compromised by attackers, these systems have to achieve a high level of security. Higher safety and security requirements lead to an accordingly higher and more specific demand for testing. However, the aging process of such systems, whose functionality increasingly depends on hardware such as sensors, camera lenses etc., also requires a new thinking and procedures from testers. Hardware that gets more and more unreliable and inaccurate with age influences the functionality of the software.

"Testing is happening with more participation and in networks and it continues to be shifted to global teams; working in the crowd and cloud increases significantly."

Testing is happening with more participation and in networks and it continues to be shifted to global teams; working in the crowd and cloud increases significantly, with the customers also sitting at the virtual table. Testing is increasingly being offered as a "managed service". The so-called "citizen developer" appears as a new player. As an example, he brings a rising demand for the integration of the widest variety of components into the "smart home" and for testing of this highly specific integration. This offers a chance for a new profession: "smart home integrator". These experts also need to have a basic software testing knowledge. On the part of the established software testing services providers, new services are emerging that are offered to citizen developers, smart home owners and integrators. The business model extends from B2B to B2C (heading: "smart home plumber").[75] Due to the number of smart homes and the frequency of changes, end user-friendly automated diagnosis and acceptance routines will be required to secure the correct and secure operation of the smart homes whenever their logic is changed or enlarged.

Product liability

The fabbing boom also creates a demand for new test tools and ervices. The reason for this is that objects that are individually produced by the "citizen developer" (via 3D print, among others) must also be suitable for the software that controls them and function as intended. For products that are produced individually by fabbing, it will be difficult if not practically impossible to enforce standards and to ensure that these standards are met. Therefore, many disputes regarding product liability will have to be solved.

As the users of fabbing tools come from all possible classes of population, flexibility, usability and operability of fabbing tools will become important quality features that need to be secured by appropriate tests.

NEGATIVE SCENARIO: THE REVOLUTION IS A LONG TIME COMING

The international financial and modernization crises at the beginning of the 21st century were a significant impediment to economic development. Even the capitalistic system is facing difficulties, as the strongly increased global wealth inequality has turned out to be an impediment to investments.[76] Regional military conflicts are getting more serious, old threat scenarios return and new ones are added. An increased number of states tries to counteract using autocratic structures and to avoid losses of control. However, these attempts fail and global instability further increases. Interventions in economy and society are mainly ideologically motivated and therefore do not solve the actual problems. The migration movements caused by this increasingly uncontrolled development are practically impossible to regulate or control, the international security situation becomes more unstable.[77] Another politically as well as socially motivated trend became more and more important in 2025.

Hostility towards science

In the course of a development that has been described by the British political scientist Colin Crouch as an emergence of post-democratic structures, the resentments of a growing part of the population of western democracies are directed towards the institution of science.[78] Although this development became apparent already in 2017, its meaning has continually grown. The intensive efforts on the part of science to ignore these developments have failed.[79] Scientific findings in the range from the man-made climate change over vaccinations up to evolution are increasingly denied, while post-factual, emotional, esoteric and ideological perspectives are characteristic for many discourses. The anti-scientific movement mainly fights the digital transformation process, the Industry 4.0 project, but also nanotechnology and other research fields and disciplines. They are held responsible for rising unemployment and other grievances. The hostility towards science changes in a hostility towards technology.

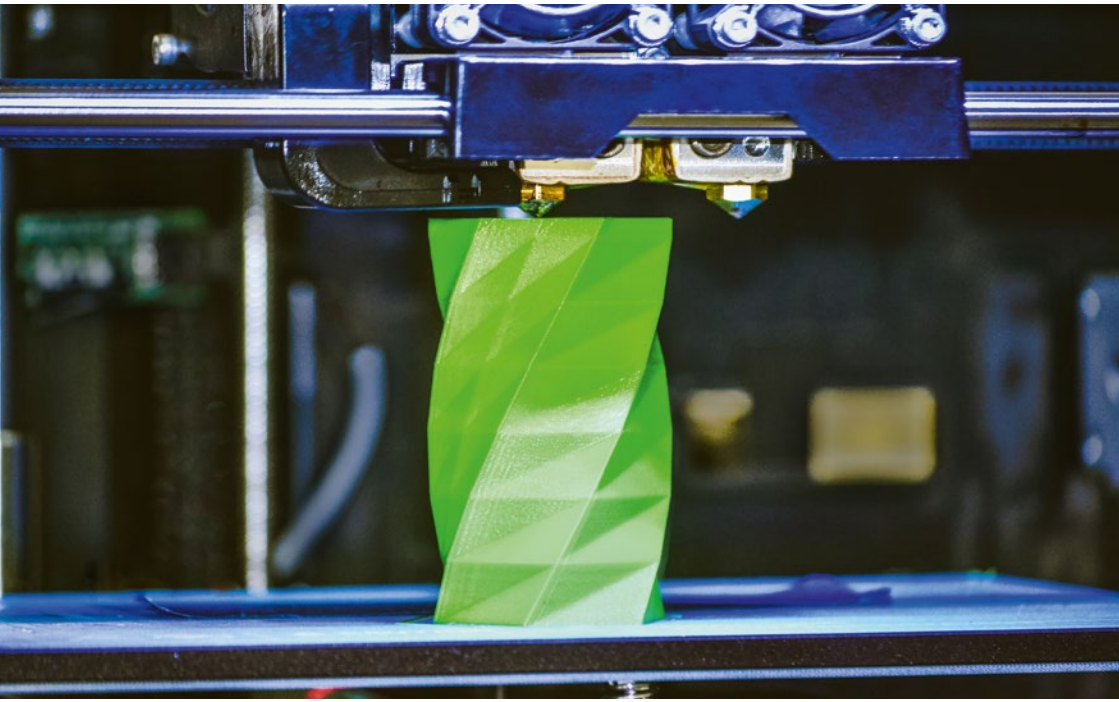
„Scientific findings are denied. Ideological perspectives are characteristic for many discourses."

The modernization crisis at the beginning of the 21st century is vastly more serious than previously assumed. Many people are not only looking ahead, but also to the past. The consequences for economy are disastrous and not difficult to analyze: “Hostility towards science as impediment to investments”[80], stated Ferdinand Knauß roughly already in 2017 in “Die Wirtschaftswoche” magazine.

The presidency of Donald Trump, Brexit and a fragile situation in the EU have left notable marks. A consolidation of the EU cannot be expected soon, whereas the remaining of Greece or Italy in the EU continues to be questionable. Other countries, amongst others Poland and Hungary, aim to leave the EU based on the model of England. There is a fear of a domino effect.[81] More and more states tend to take protectionist measures, while roughly 50% of all globally-operating corporate groups have shifted their headquarters to China.[82]

Many branches are hit by a lack of investments and world trade suffers from the aggravating military conflicts. The process of globalization not only stagnates, but is even revised to a certain extent. China has finally achieved its position as economic leader and dominates the production of goods, while Europe, the USA and Russia cannot get their economic crises under control. Ecological crises, such as more and more noticeable climate change and the shortage of resources eventually lead to a downturn in production.[83] The insufficient measures against the climate change turn out to be particularly serious. Global warming is now widely felt in general and leads to changed climatic zones, heat records, severe draughts and to a rapid melting of polar ice masses.[84] At the same time, fresh water resources are globally decreasing. Military conflicts and migration movements are the consequence.[85]

I 4.0 The technological inventions, innovations and developments discussed at the end of the 20th and beginning of the 21st century and classified more or less as revolutionary, also known as Industrial Revolution 4.0, are delayed. Initially, the production methods that have been well practicable so far are kept or only slightly modernized. Political initiatives were not able to bring any change to this, too.[86] Therefore, the fourth industrial revolution until 2025 and beyond is only partially successful. The car industry experiences difficulties to shift towards e-mobility and German manufacturers are still struggling to cope with the diesel scandal and other homemade crises. The consequence is an asymmetric economic and technologic development. While some sectors are still being modernized and promote the digital transformation process, others are falling behind.[87]



Fabbing

Even the Outernet is growing only sluggishly and is far behind expectations.[88] The same applies to the fabbing technology that does not make any significant progress, too. Although the global turnover of fabbing products rises compared to 2013 (2.5 billion USD), it is not able to achieve 20 billion by 2025 and beyond and also develops only sluggishly after this date. The cause for this cannot only be seen in the slowed down economic development, but also in an increase in commodity prices.[89]

AR applications

Following an initial boom of cyberglasses with a wide offer of AR applications, the providers experience a downturn, as the new technology features too many first-time production difficulties. Furthermore, it has remained too expensive or incomprehensible for the average consumer. Although connectivity grows in terms of quantity, it does not open up any new qualitative dimensions, but remains within a more or less tried-and-trusted framework.[90]

Robotics

There is a quite similar situation with robotics where, although technical progress is made, only a few models make it to the production stage because of the lack of investments, particularly by small and medium-sized enterprises. Robots are increasingly used in certain sectors only, such as caregiving or services. Bureaucratic and safety-related hurdles also cause delays.

Robot cars

This also includes the delayed homologation of robot cars that takes place only after 2030. After various accidents during test drives, the relevant legislative procedure has been suspended and general introduction has been long delayed. As a consequence, the corresponding companies have cancelled or slowed down the development process.

Smart home

Decreased investments and the enduring economic crisis also affect the construction sector. Although building is still going on, it is predominantly using conventional methods. The boom in the smart home sector has not occurred, as intelligent homes are very cost-intensive. Furthermore, the construction industry turns out to be an impediment to the digital transformation and adheres to conventional methods. Whereas only 6 % of the branch used digital planning instruments in 2016, this proportion is about 20 % around 2025. As a consequence, the construction industry participates notably less in slowly rising Outernet and barely uses the AR technology, robot systems and other fields of application.[91]

Moore´s Law

The software and hardware industries naturally experience stagnation in the areas of application, which leads to turnover drops related to development of new software. Sales of hardware also stagnate in the end user sector as well as in the business sector. Mood of crisis spreads, while IT trade fairs have no real innovations to offer. Warnings of renowned IT experts regarding a possible end to Moore‘s Law before new computer technologies become available bring further insecurity.[92] Should this actually occur, it will, in conjunction with the declining readiness to invest, lead to a notable reduction in further developments in information technology as a whole.

IT security

However, the greatest problem is the digital security that gets out of control, despite all measures taken by the state and private sector. The situation threatens to escalate as new mathematical methods become known which allow practically anyone to break complex cryptographic encryption.[93] Additionally, terrorist organizations increasingly exploit weak points, e.g. in energy, transport and building networks, in Outernet and in smart homes to carry out their attacks.[94]

On the other hand, the secret services increasingly exploit the same and other weak spots to keep up detailed surveillance on potential terrorists, but also respectable citizens. Deficient IT security technology and open security gaps destabilize society.[95] It is not only the large companies, banks, hospitals, universities, transport companies and state institutions that suffer from increasing economic damage caused by intensified cyberattacks, but also large sections of population.[96] The consequences are global, serious and even lead to a partial reversion to analog technologies in some areas of the economy and everyday life. Typewriters enjoy growing popularity and letter post as well as regional economy experience an unforeseen renaissance. However, the digital revolution will not take place without digital security.[97] Sceptics are even talking about a possible end of the digital age.[98]

TESTING OF SOFTWARE AND SYSTEMS FROM 2025 – CONSEQUENCES FROM THE NEGATIVE SCENARIO

As of 2025, demand for software stagnates and experiences only partial growth. In line with this, demand for software tests also rises only slightly. The global modernization crisis characterizes the activities and offers of the testing branch.

IT security

Under these conditions, functional testing, load and performance testing and also usability and safety testing are being developed slowly, because the relevant fields of application are not booming as expected. However, security testing is booming and becomes a critical factor socially and economically. Producers try to gain the lost trust of population again with obtainment of security certificates. Within the permanent race between hackers and security measures, not only producers of security software, but, under certain circumstances, also the testing companies specializing in security testing themselves increasingly become the targets of attacks by those groups that use cyberattacks as a tool. These testing companies themselves are technically attacked in order to pick up know-how or to steal unauthorized security certificates. In addition to this, there could also be attacks aimed at infiltrating these companies.

The scenarios from 2025

Test tools with AI

Since cloud systems become the most important target of attacks because of the data volume they hold, they lose significance for the users and therefore become economically less interesting as test objects and as a test tool. Complex smart ecosystems are established at a much slower rate and demand only few innovations of the testing branch. The hopes for breakthroughs in core competencies of the testing branch, such as AI-supported testing methods or testing tools, are not fulfilled. The existing market for testing providers stagnates and causes competition growth and increase of cost pressure on providers. Risk assessment determines test strategy and test planning more than ever. Known procedures and processes such as test-driven development, consistent requirements engineering and agile working are applied more and more consistently due to economic constraints and become the critical success factor for testing services providers.

FROM 2035

2035

POSITIVE SCENARIO: AFTER THE REVOLUTION

The various crises at the start of the 21st century have been weathered, political upheavals have settled, the Near East has calmed down and searches for a new and modern identity now. Return to nationalism, protectionism and steering towards post-democratic systems have proved to be wrong and have been revised.[99] Europe has even come out of the crises strengthened and has been able to reform itself successfully. Neither the Brexit, which was gradually revoked again, could change this.

Globalization 2.0

It was possible to promote Europeanization in all sectors of economy and society so that the EU has become one of the four economic giants, still behind China, but in front of the USA and South America.[100] Germany was able not only to keep, but also to expand its economic position. Declining significance of the German car industry was compensated with an intense growth of robotics. Germany still belongs to the winners of modernization.[101] Globalization 2.0 has brought the economic areas even closer together, largely overcome protectionist barriers and even removed bureaucratic hurdles here and there. Several free trade agreements ensure a permanent growth. At the same time, the leading economic nations and/or unions have agreed on a large number of standards and thereby removed or at least reduced numerous risks. There is a new global climate protection agreement that has also been ratified by the new president of the USA and that will be followed by the signed nations. Chances for global warming limitation have thereby gone up.

On the contrary, energy and resource transitions become driving forces for economic development.[102] Although the consumption of fossil fuels continues to rise in 2035, the renewable energy sources turn out to be the most rapidly growing form of energy with a rate of growth of approx. 10 %. The global energy demand is in total 30% higher than in 2017. Coal and fossil oil play a steadily decreasing role in this energy mix.[103] China has taken over the lead in this development and produces more green energy than the USA and EU together.[104]

The economic and ecological framework conditions are good, poverty is declining worldwide. Thanks to a globalized labor market and successful integration of approx. 3 million fugitives, Germany was able to largely overcome the feared lack of qualified and highly qualified workers. Instead of the predicted four million, only one million qualified workers are missing.[105] Population of Germany decreases to 78.2 million by 2035, while the number of households increases by approx. 3 million.[106] A longer working life, permanent qualification measures (life-long learning) and a significant increase of automatization in practically all sectors have all made their contribution to easing of tension.[107]

I 4.0 The fourth industrial revolution is already widely successful for a long time in 2035, restructuring and rebuilding of the economy are completed in many sectors and secure the status of an industrial nation for Germany, as industry persists, although it has transformed into a completely different one.[108] Production has achieved flexibility and transparency which were difficult to imagine in 2017. Every step of production from the earliest stage of development until use of the product by the consumer can be traced at any time and naturally also by mobile devices.

AR technology

Processes can be monitored and corrected in real time, not least with the help of a highly developed AR technology. In 2035, this includes not only cyberglasses of all kinds, but also innovative wearables, smart lenses and flexible display films which make a product's content transparent in many ways and display processes and production details or parameters.[109] Market volume in the virtual reality and augmented reality segment has increased from 80 billion in 2020 to 2.16 trillion dollars in 2035; in particular the AR technology has proved to be the driving force of development.[110]

Brain Computer Interface

4.0 production processes are primarily controlled by voice or via the Brain Computer Interface (BCI). Naturally, customers and consumers are directly involved in development and production so that many products are personalized from the outset. Transitions to fabbing technology (3D printing etc.) are fluent.

Fabbing

Fabbing machines are found not only in factories and SMEs, but now also extensively in fabbing shops and private households.[111] Practically any product can be fabbed, from a toy, through a car to a house. 3D printers with the performance scope from 2017 became toys a long time ago. But this is not always sensible and cost effective and so industrial production and craft sector are far from being completely replaced.[112]

Structureware

The fabbing technology becomes a key industry. Software, also called structureware in the context of fabbing, becomes a critical link in the value-added chain. Anyway, the entire economy is largely based on software and knowledge. More and more resources, particularly the so-called „spice" metals such as tantalum or germanium, have been meanwhile replaced with alternative materials, such as carbon products produced by nanotechnological means. Nanotechnology is the main driving force in many fields of the Industry 4.0.[113]

AI

The Outernet is fully established, ubiquitous and present in all sectors of economy and society. Weak AI, which e.g. enables robots to act autonomously to a large extent, is also doing major leaps in development. Parts of the network act and react independently by means of weak AI. Based on this, e.g. smart products determine the logistically fastest and least expensive transport route and select the corresponding container. Human-machine communication is part of everyday life, voice communication with production plants, cars or smart homes is a technical standard and is socially accepted. Compared to the old smart speakers such as Alexa or Siri, the new devices feature a semantic understanding. This also applies to the AI-based simultaneous translation of languages that is mastered by every communication module from an old smartphone to cyberglasses in 2035. However, the hopes of strong AI continue not to be really fulfilled, only people are able to make relevant decisions in almost all areas. Autonomous robots which would pass the famous Turing test exist only in development laboratories, if at all.

Cyborgization

There will be different forms and modifications of the BCI (Brain Computer Interface), from the headset to the implant, and cyborgization will also be generally accepted of society.[114] Implanted chips and sensors (Wireless Body Area Network) that collect medically relevant vital signs and submit them to control centers, are an integral component of the repeatedly reformed and highly automated health care system.[115] Thus, the convergence of technologies also involves human who tends to become a segment of the Outernet and Internet.[116] In 2035, the AR technology is an integral part of our everyday life and a firmly integrated component of the human construction of reality and of the global media system.[117] Transitions between film, television and gaming are fluent to such an extent that they cannot be differentiated anymore. The world has become post-medial.[118]

Avatars

Digital avatars and robot avatars are part of the occupational as well as private everyday life and take over many tasks of their owners.[119] Eventually, it is no longer parts of the world that are networked, but the whole word itself. Transmission rates of more than 100 GB per second are standard, while they were 100 MB per second in 2017.[120] Most terminal devices used by people are mobile, while cloud solutions have largely taken the place of previous archives (files, books, photo albums, CDs, DVDs, hard drives etc.).[121] The PC has also disappeared. In general, computers and IT systems are diffused and integrated in products and goods to such an extent that they have become not only ubiquitous, but also "invisible".

"Growing hazards of the digital technosphere can only be partially reduced and thus the digital technosphere has to struggle again and again with problems of image and trust."

Robotics

Robotics conquers more and more areas of production, services, caregiving, medicine, household and defense and overtakes the car industry as the key industry. The personal robot (PR), who can be found in nearly every fifth household, is indispensable for the elderly care, but also part of the common smart home infrastructure.[122]

Robot cars

Robot culture also includes robot cars which already represent 30 % of all trucks and cars in 2035 and are growing in popularity.[123] The (insurance) legal framework conditions have been resolved, the experience – economic and ecological – is positive. The mobility of senior citizens is maintained, road safety is increasing constantly. In Germany, about 30 % of all vehicles are e-vehicles. Worldwide, the number has surpassed the 100-million mark.[124] In some states of the USA, in many cities in China and in the EU, e-mobility is in the process of replacing the internal combustion engine. Driving bans in cities for cars with internal combustion engines as well as new energy supply systems using induction are driving the change.[125]

Nuclear fusion

A breakthrough in the development of the nuclear fusion until 2035 can be considered a wild card[126], so that its practical use starts in 2035. In this case, we expect declining energy prices as well as a greater and faster boom in electromobility.[127] In combination with renewable energy sources, the nuclear fusion is driving the global exit from the utilization of fossil fuels and nuclear energy.

Cobots

Anthropo-oriented assistance systems such as smart exoskeletons and robot suits for the disabled require no explanation. Car-to-car communication is an integral part of urban traffic control systems.[128] Robots and cobots of different types have become self-evident partners of humans in many economic segments, however, they are still being controlled by humans. The use of AI is also a matter of course, in the creative field as well. Numerous jobs - from media designer to engineer - can no longer be performed without AI. In any case, AI has become an important economic factor providing continuous economic growth, particularly in Germany.[129]

The scenarios from 2035

From mobility to energy supply and smart home – in 2035, all the once separate areas of work and everyday life are part of the periphery of the Outernet, although there are still some exceptions. Connectivity and the flood of data (big data) have grown such that it has not been possible to monitor them for a long time. Although software is still being developed and designed by people, it is in part also being configured and generated by an autonomous software.

Moore's Law is upheld as the development of new computer technologies (DNA computing, photon computers, quantum computers, etc.) is advancing at a surprisingly rapid pace. Eventually, there is success in gaining control of security problems and rapidly detecting and stopping attacks of all kinds. The danger may not be completely averted, but it has become manageable. The expenses of the state and private industry are indeed high, but indispensable.[130]

TESTING OF SOFTWARE AND SYSTEMS FROM 2035 – CONSEQUENCES FROM THE POSITIVE SCENARIO

The testing sector is recording an unparalleled boom, since the entire economic and social development – at the forefront of which is the knowledge-based economy – depends completely on the reliability and security of the software used. This is the only way to mitigate the significantly increased technological risks. The gigantic flood of data (big data) ultimately undermines all evaluation processes and can therefore be used less and less sensibly. At the same time, the complexity of systems and system components is growing such that the test types, processes, tools and methods are barely able to keep up. By 2035, testing has become a supporting pillar of the overall economic and social system to a far greater extent than today. Also, due to the increasing personalization and individuali-zation of the systems, more testing is required to cover the increased diversity of variants and functions.

"AI is the most important way to still allow the provision of the necessary testing effort."

AI The trend towards an increased use of AI in the management, design and evaluation of tests, started in 2025, becomes the most important way to still allow the provision of the necessary testing effort.

The testers' advisory function has also gained importance; this function is broad in scope and is available both as a real function (personal) and virtually (crowd, avatar). The differences between developers, testers and customers continue to fade, here, too, convergence is not without consequences. People are also (still) indispensable in the development of testing strategies, so that the demand for staff is high, and can only be covered with difficulty. Testing is characterized by innovative integration and system tests, while component tests, to the extent that they remain sensible, are run automatically.

Ministry for System Security

The demand for validity and significance of software tests increases significantly. The individual test types are subject to strict standards and state controls, embedded in international treaties intended to guarantee reliability and security. In Germany, this responsibility rests with the Ministry for System Security, whose establishment in the 2020s was a political response to serious accidents with robot cars and disasters caused by errors in highly automated, AI-controlled industrial plants. The Ministry defines new approval procedures, but also provides funding for the development of new test strategies, methods and tools.

Testing of quantum computer software

A large part of these funds is used for research in the field of testing of quantum computer software and BCI communication protocols.

For both of these issues, there are currently no verified insights or best practices for appropriate test strategies or test design procedures, although the appropriate software is becoming more and more important and is increasingly used in critical scenarios.

Crowd and cloud working

Global crowd and cloud working are standard practice, as is high flexibility, and not just in a geographical sense. The accelerated development of the technosphere demands a similarly consistent, continuous qualification. This primarily concerns new procedures with which testers run some test types cognitively using BCI, think themselves into the components to be tested in a way that is still difficult to conceive today and there, perhaps, run prefabricated, embedded testing modules. AR methods and imaging methods that visualize software components are also new. Testers (and their synthetic partners) are able to detect and identify defects visually once they have gained suitable experience, and also testing procedures will be monitored visually.

The scenarios from 2035

IT security Major challenges remain, as ever, in the areas of connectivity and security which make the continuous development of better methods and tools necessary. Thanks to the combination of automated and specially designed test methods, even the testing of complex, embedded and heavily networked system components is possible.

AI The development of weak AI here comes to the assistance of the test methods which are assigned tasks by the tester or come up with suggestions themselves. It is these dialogic human-machine methods which permit successful work, even in complex networked systems. On the other hand, these dialogic methods also permit less qualified people to run a limited range of tests.

The trend is to abandon naive software developments without risk assessment and systematic testing because of the enormous increase in risk and, not least, the economic risks. Following numerous negative experiences, also consumer behavior has changed significantly so that both safety and security now determine purchasing behavior. Products that have weak points in this regard are listed online in respective portals and customer quickly avoid them.

"The testing sector becomes the system security sector."

System security sector

The testing sector becomes the system security sector that tests and analyzes development processes, system architectures, system components and entire systems in collaboration with customers and consumers. The testing experts themselves are embedded in the complex invention and innovation process and represent the interface between the digital world and the real world with respective responsibility.

NEGATIVE SCENARIO: THE DELAYED REVOLUTION

The global situation is fragile and economically as well as ecologically tense, the world is in a state of permanent crisis. The EU critics have succeeded in blocking urgently needed reforms, the EU is therefore more or less history. The investment climate is hence very volatile, and also the Asian economic area and the USA struggle with economic problems. For instance, the USA and China have underestimated the

"The EU is more or less history. The oil price has tripled as compared to 2017."

negative consequences of their various ecological deficits for decades and are now paying a high price for this.[131] One third of their budget must now be spent for the elimination of the environmental destruction. Global agricultural production is declining, hunger is increasing again, food prices are rising.[132] Energy prices are also out of control due to investments being too low in the last few decades. The oil price has tripled as compared to 2017.

Protectionism

Many countries, among them the USA and Russia, try to defend their (economic) areas of influence using protectionist measures. The globalization process has not stopped, but is progressing sluggishly. In addition, in many countries and regions water shortages, desertification and extreme weather conditions resulting from climate change are becoming serious, even existence-threatening problems for the economy. The EU is affected as well.[133] Environmentally motivated conflicts and the lack of resources more frequently lead to wars, while the migration pressure on Europe is increasing permanently.

I 4.0

The fourth industrial revolution declared at the beginning of the 21st century is happening, but it is significantly delayed. Thanks to Industry 4.0 and relentless recycling measures, the costs of production can be maintained or even reduced. Hopes for synthetic raw materials generated by nanotechnology have come true only partially. Due to the high oil price, plastics have become more expensive as well, and plant-based bioplastics are only a limited substitute.

Fabbing

Fabbing, while being practicable, hence remains an expensive and thus exclusive technology. Although there is a number of affordable devices on the market and there are fab shops, there can be no talk of a boom. The scarcity of resources also limits the possibilities of hardware developments such as robotics whose products also remain costly and thus do not lead to the establishment of a mass market.

Robot cars

Since power storage technologies have also not been able to develop cost-effective alternative batteries and induction systems are far too expensive for the transport ministries, the boom in e-mobility also remains elusive. Small cars with very low consumption characterize traffic. Robot cars have made it onto the road, but are an exception. Assistance systems for cars integrated into the Outernet have only achieved limited penetration, particularly since the expectations in respect of reliability have not been met. The systems and sensors are too error-prone. Even if the hardware is working, the software of the assistance and control systems misinterprets the respective traffic situations too often.

Moore's Gap

One key factor has a particularly negative effect: Moore's Law is no longer applicable, the increase in performance of conventional chips is lower and lower year after year, while the anticipated breakthroughs in the development of new computer technologies have not materialized.[134] Moore's Law has become Moore's Gap, a hardware gap yawning over many years. Although there are signs that this gap will close, production-ready solutions for mass implementation are not yet available.[135] Moore's Gap is also holding back the development of weak AI, which had put its faith in the continuous growth of performance. Although the application of smart ecosystems, in which information systems, emergent software, embedded systems, mobile systems and cyber physical systems are brought together, is available, these remain under serious threat from cyberattacks.

IT security

Despite numerous measures from the state and the private sector, it has not proved possible, even in 2035, to get to grips with the many digital security threats. The cyberattacks, which bring large parts of the overall system to a standstill again and again, increase as do the costs of eliminating these damages. The initiators almost always remain in the dark. The only thing that is clear is that many cyber- attacks are motivated by political, military or economic reasons and are executed very professionally.[136] Especially small and medium-sized enterprises suffer strongly from these attacks.[137] A differentiation of civilian and military attacks is no longer possible, the world is in a global cyber war, the result is unknown.[138] The media and IT ecosystem, including the Internet and the Outernet, which is both global and ubiquitous, can no longer fully develop its capabilities as websites and chips regularly come under attack. Online trade is virtually dead. Consumers react accordingly and increasingly demand more secure or analog products. Especially

the car industry struggles as cars have become the preferred targets of attacks. But also, robots and smart homes are affected.

Progress in security systems can, however, be seen. The fourth industrial revolution is more of an evolution which has come to the fore with a significant delay over expectations. The increase in data volume stagnates significantly, connectivity has lost its dynamics, but is still growing. Politicians are very slow to define generally binding security and testing standards.

TESTING OF SOFTWARE AND SYSTEMS FROM 2035 – CONSEQUENCES FROM THE NEGATIVE SCENARIO

The testing sector is enjoying a quantitative and qualitative boom, even in this scenario; however, it is considerably less energetic than in the positive scenario as the digital technosphere is developing more slowly. Conventional methods and tools, dating from the beginning of the 21st century are still in use in many places, modified and adapted accordingly, yet smart ecosystems and AI-based system components can only be tested with new methods and tools, with BCI, cognitive methods, prefabricated, embedded test modules, AR and imaging methods being used which still sound utopian in 2017. However, since greater funding programs fail to materialize, many of these technologies are still in the fledgling stage, the testing sector cannot develop in the same speed as the general software development. The global risk due to a lack of software quality increases again for the first time in decades.

Moore´s Gap

As Moore's law no longer applies, software development must take new paths – or rather old ones again – in order to be able to process the increasingly complex data evaluation, encryption and communication algorithms: instead of complex high-level languages, resource-hogging frameworks and user interfaces, tools and technologies from the 20th century are being used again, for example, direct programming in machine language, in a kind of "retro movement of software development". On the one hand, this calls for a deep technical understanding of the tester and, on the other hand, leads to the development of new test strategies and test methods for the quality characteristic of "efficiency". Added to this is the fact that some producers bank on reusable, proven components. They expect that these also work in the context of the new application – and therefore forgo the supposedly unnecessary tests.

Cyber crime

The problems characterized by increasing connectivity are also present here and have to be detected using new strategies, methods and processes. However, the testing sector, too, is suffering from the permanent arms race between cyber criminals wherever they come from and the activities of the security industry. Crowd and cloud working are only employed for certain projects, geographical flexibility, on-site presence has proved to be more secure and more sensible. Unfortunately, it is the cyber criminals who gain the advantage again and again, with the boundaries between white hats and black hats blurring here, too. Ultimately, the digital, knowledge-based industry is impeding itself.[139] One of the reasons is the absence of state or private sector standards or control mechanisms.

Robot cars risks and responsibility

"Testers are more and more often due to the growing assigned the role of witnesses or even defendants in court."

Also in this scenario, due to the growing risk alone, the testing sector is a main a mainstay of the system, but the system, can only decrease the increasing risks of risks of the digital technosphere to a limited extent and must thus always deal with image and trust issues. As soon as a robot car is involved in an accident, for instance, criticism is aimed at the sector, even though it is not responsible for the complexity of the systems becoming more and more difficult to control. More and more often, testers are assigned the role as witnesses or even defendants in court, ultimately, the entire discipline has a bad reputation. Testers do not manage to abandon their reactive role to become proactive, participative and collaborative. The development of hardware and software often continues to follow anarchistic and experimental, rather than rational, target-oriented and sustainable principles.

FROM 2050

TREND SCENARIO (BASE CASE): MEGACITIES CALL THE SHOTS

The world of the year 2050 is dominated by megacities inhabited by around 80 % of the world's population of 9.7 billion people. According to a forecast by the Federal Statistical Office, Germany has a population of approximately 76 million people in 2050. Hence, the German population does not grow but declines slightly.[140]

Ecopolis

As is true even today, there are modern cities with an appropriate infrastructure and cities with development deficits. The modern cities in Europe, North America, Asia and South America are characterized by the concept of an "ecopolis".[141] They only work so well because strict ecological and economic standards are observed. In many areas there is no alternative anyway. Thus, the production of waste is reduced to a minimum, while certain resources are barely available, if at all. They are replaced, above all, by nanotechnology products (artificial material, artificial resource) and secondary raw materials obtained through recycling processes.

Urban industry

The entire infrastructure of the megacities is comprehensively localized and decentralized. This is even the case for the production of foodstuffs, far more than 50 % of which comes from urban farming. Consumer goods are likewise, where possible, produced in the cities, with the transitions between the almost completely automated factory and fabbing production in the smart home having become fluent and being summarized as "urban industry". The "Industry 4.0" concept is antiquated and is now hardly ever used. It is not rare for factories to supply unfinished products which are completed at home. Consumption is highly dematerialized, people trade knowledge instead of products. On the one hand, megacities represent the concentration of human activity in a few centers, on the other hand, this concentration is characterized by a long-term trend towards decentralization.

"The transitions between an automated factory and fabbing production in the smart home have become fluent."

Structureware

To which are added the new assembler-based molecular machines which produce products to order using nanotechnology processes. Finally, Eric Drexler's vision of being able to program material structures at the molecular level takes hold.[142,143] As was the case with fabbing technology, the software (structureware) is the critical economic factor and the central link in the value-added chain. This software is designed jointly by people and robots, with the people, as ever, taking care of the creative and monitoring aspect, which does not in the slightest mean that the robots do not have leading functions in the hierarchies of various economic projects. Their production is already a key industry in 2050. Robots are embedded and integrated parts of the world of work and everyday life, with it no longer being possible to distinguish easily between the two areas. Corporate groups, as we understand them in 2017, no longer exist; the economy is knowledge-based, project-oriented, highly transparent; work is accordingly defined in different terms.

Energy harvesting

The energy supply in the majority of megacities is based on an energy mix from renewable sources, including energy harvesting, such as the use of piezo technology on roads and paths. Additionally, there are innovative nanotechnology products such as paintable nanoparticles which work like the now obsolete PV installations on roofs and walls.[144] Just like other sectors of the technosphere, the supply of energy has become largely "invisible". The mix is controlled with the aid of AI. Anyway, the consumption of energy has declined considerably as compared to 2020, as all devices run extremely efficiently.

Supergrids

Of course, mobility is concentrated in the megacities. The difference between private transport and public transport has vanished; electric, smart on-demand systems characterize urban transport. There is almost no one driving himself. Ownership of a car or scooter is the exception and also no longer necessary or of any social importance. Goods transports partially run via supergrids (underground railway-like systems) and are therefore also "invisible".[145]

New reality

"Invisibility" is also a characteristic of communication, as visible devices such as smartphones or tablets have vanished, either having been internalized (e.g., as implants) or only becoming visible when needed (such as films, holograms or room walls consisting of nanodisplays).[146] A differentiation between the once separate areas of virtuality and reality is no longer possible and also no longer needed. The concept of "augmented reality" is also antiquated. Only a few self-declared Luddites live outside the "new reality", as the mix has come to be called.

In addition to chip technology, which is still in use but now exclusively printed, new computer technologies determine the development. Photon and quantum computers as well as neuromorphic computers characterize the state of development. Quantum teleportation and photon technology are standard.[147] Moore's Law still holds. The technosphere in which people live is smart, ubiquitous, organically structured, self-organizing and holistic, while human is an integral element of this technosphere and, according to the criteria prevailing in 2017, every human is a cyborg.

The technosphere of the year 2050 is software-based in a way that is practically inconceivable today. Terms such as “connectivity” or “network” are no longer adequate to describe the state of development; they are obsolete. The transformed IT system and its innumerable self-optimizing segments in the hardware and software field may be at best compared with organic structures. The technical world has become an ever present, practically seamlessly closed technosphere which encloses people as the biosphere. For the majority of people, a life outside this technosphere is barely conceivable, not to mention barely possible, if at all.

Technological Singularity

The high penetration of AI reached by this time must also be considered, although it is difficult to estimate. It is highly likely that by 2050 it will already have surpassed the Technological Singularity predicted by Vernor Vinge. This means the point in time from which hardware and software can continue to develop themselves, increase their intelligence and also become aware of this. AI and human intelligence are thus equivalent, although structured and characterized differently. The Technological Singularity naturally includes the possibility that AI ultimately exceeds human intelligence.

TESTING OF SOFTWARE AND SYSTEMS FROM 2050 – CONSEQUENCES FROM THE TREND SCENARIO

Methodically, software testing in 2050 is only remotely comparable with that of the year 2017. However, nothing has changed about the task itself. As before, testing experts must ensure that the software, which has a far more comprehensive significance in 2050 than in 2017, works as defect-free and reliably as possible, especially as it now affects people (as cyborgs) themselves. As the consequences of the Technological Singularity, should it occur, cannot be estimated, its consequences for the testing sector can also not be described. It is, however, certain that the hazards to which the technosphere is exposed when failing can safely be described as astronomical.

Testing continues to exist, but looks quite different than in 2017. People order AI-based agents, robots and avatars to test other sub-systems, simulate their future behavior and monitor this continuously. Human testers use brain computer interfaces (BCI) to "watch" and monitor this. There is a permanent and ubiquitous test process that is recording the technosphere continuously and in toto. Hence, the method is called: in toto testing.

The question as to when exactly some system behavior should be assessed as "faulty", however, often remains open. Because the distinction between a "wrong" and a "surprisingly creative", because really intelligent response of a system, is and remains indeterminable.

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