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Commemorative Lecture at the 41st Honda Prize
Award Ceremony on the 17th November 2020

Industrie 4.0:
Enabler of Economic Growth and Social Benefits

Dr. Henning Kagermann

Chair of the Board of Trustees; Former President acatech
Global Representative & Advisor Plattform Industrie 4.0

HONDA FOUNDATION

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■Date of Birth

July 12th, 1947

■Education Background & Academic Experiences

1972: Diploma in Experimental Physics at the LMU Munich
1973-1982: Doctoral-thesis & additional post-doctoral thesis in Theoretical Physics at the TU Braunschweig
1985: Apl. Professor in physics at TU Braunschweig

■Company Experiences

1982: Development Manager of SAP AG
1991: Executive Board of SAP AG
1998-2003: Co-CEO of SAP AG
2003-2009: CEO of SAP AG

■Political Activities

2009-2015:	The first Chairman supervising the Executive Steering Board at EIT Digital (former EIT KIC ICT)
2009-2018:	President of acatech – National Academy of Science and Engineering
2010-:	Chair of the Steering Committee of the Innovation Dialogue
2010-2018:	Chair of the NPE, National Platform for Electric Mobility
2010-2018:	Member of Hightech Forum
2017:	Global Representative and Advisor of the Platform Industrie 4.0
2018:	Chair of the National Platform Future of Mobility
2018-present:	Chair of the acatech Board of Trustees

■Other Activities

Henning Kagermann held/holds various cooperate board memberships, such as KUKA (since 2017), Munich Re (until 2019), Deutsche Post (2009-2019), Deutsche Bank (2000-2018), BMW (2010–2018), Nokia (2000–2014) and others. He is a member of the Honorary Senate of the Lindau Nobel Laureate Meetings. Additionally, he was a member of the Senate of the Max Planck Society and a member of the board of trustees at the Max Planck Institute for Informatics and the Technical University of Munich.

■Major Publications

- **Reinventing your business model:** M. W. Johnson, C.M. Christensen, H. Kagermann, December 2008, Harvard Business Review (hbr.org)
- **IT-Driven Business Models: Global Case Studies in Transformation:** H. Kagermann, H. Osterle, J. M. Jordan, English version 2010
- **Future Business Clouds:** Appelrath, H.-J./Kagermann, H./Krcmar, H. (Hrsg.), Ein Beitrag zum Zukunftsprojekt Internetbasierte Dienste für die Wirtschaft (acatech STUDIE), München: Herbert Utz Verlag 2014
- **Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group** (Position paper): Kagermann, H./ Wahlster, W./ Helbig, J., Berlin 2013
- **Smart Service Welt – Recommendations for the Strategic Initiative Web-based Services for Businesses Final Report**: Smart Service Welt Working Group/acatech (Eds.), Berlin, March 2015
- **Innovationspotenziale der Mensch-Maschine-Interaktion** (acatech IMPULS): Kagermann, H., München: Herbert Utz Verlag 2016
- **Industrie 4.0 in a Global Context: Strategies for Cooperating with International Partners** (acatech STUDY): Kagermann, H./Anderl, R./Gausemeier, J./Schuh, G./Wahlster, W. (Eds.), Munich: Herbert Utz Verlag 2016. (Print version available)
- **Fachforum autonome Systeme** – Chancen und Risiken für Wirtschaft, Wissenschaft und Gesellschaft. Herausgeber: Fachforum autonome Systeme im Hightech-Forum. Kooperationspublikation, 2017
- **Work in the Digital Transformation – Agility, Lifelong Learning and the Role of Employers and Works Councils in Changing Times:** Jacobs, J. C./Kagermann, H./Spath, D. (Eds.): A paper by the acatech and Jacobs Foundation Human Resources Working Group – Forum for HR Directors on the Future of Work (acatech DISCUSSION), Munich 2017
- **Revitalizing Human-Machine Interaction for the Advancement of Society – Perspectives from Germany and Japan** (acatech DISCUSSION): Henning Kagermann, Youichi Nonaka (Eds.), Munich 2019
- **European Public Sphere:** Henning Kagermann, Ulrich Wilhelm (Eds.), Gestaltung der digitalen Souveränität Europas (acatech IMPULS), 2020

This report is the gist of the commemorative lecture at the 41st Honda Prize Online Award Ceremony on 17th November 2020.

〈Words from the Laureate〉

Receiving the Honda prize is a great honour and acknowledgment for the successful work of all experts who helped establishing the brand Industrie 4.0 and those who continue to implement the original concepts within the organization Plattform Industrie 4.0.

Mass customization, business models of the digital age like everything as a service and the vision of composable and adaptable business processes have been discussed for many years.

In 2009 I retired from SAP, still under the impression of the suddenness and intensity of the economic crisis and convinced that economic shocks will be more frequent and that we had to improve our ability to absorb them easier and smoother.

As recently elected president of acatech, national academy of science and engineering Germany, I was nominated to chair a working group of the Hightech Forum of the German government with the mission to recommend strategic projects for the application area "Communication".

Leveraging the experience with service-oriented –architectures, the internet of things, data and services and the transition from embedded systems to cyber-physical systems, merging real and virtual space, two proposal were made later coined "Industrie 4.0" and "Smart Service Welt".

After the initial publication together with Wolfgang Wahlster and Wolf-Dieter Lukas the concept attracted high attention worldwide. The broad network of acatech within both, the science and business community, was instrumental to assemble a project group of about 40 experts, chaired by Siegfried Dais and myself, with the mission to work out the concept and develop recommendations for a successful implementation.

In April 2013 the final report was published and presented to chancellor Angela Merkel at the Hannover fair. Securing the competitiveness of the German industry and paving the way towards a sustainable, resource-efficient economy was and still is the driving motivation. How can we release employees from exhausting and routine work and how can we establish better and more fulfilling ways of working in the future? Questions which were discussed intensively and promising with the constructive participation of the unions.

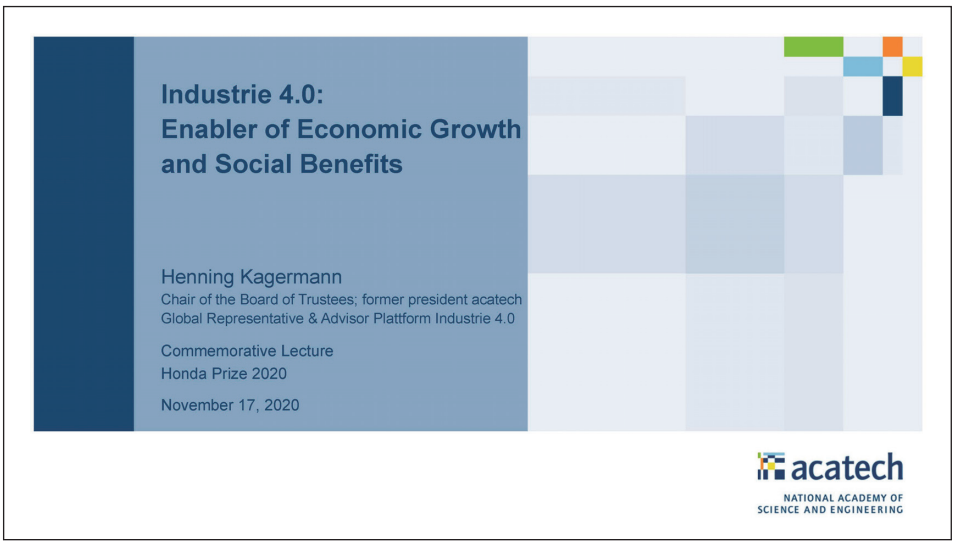
During the subsequent years I initiated with the support of our government and my colleagues from acatech the projects "Smart Service Welt"-together with Frank Riemensperger- and later "Autonomous Systems", which emphasized new societal and ethical challenges, particularly for a harmonized human machine collaboration.

International cooperation was one of the key objectives from the very beginning and since 2017 I have the opportunity to promote Industrie 4.0 as Global Representative and Advisor. Sharing knowledge, experience and best practise is key for success just as mutual respect that solutions may differ as a result of diverging societal trends and culturally related approaches to solve issues.

Many have contributed, but only a few could be mentioned. I owe all of them thanks for stimulating ideas and enormous support.

Industrie 4.0:
Enabler of Economic Growth and Social Benefits

Henning Kagermann



Distinguished Guests and Dear Friends,

Right now, we are experiencing a second wave of the COVID-19 pandemic in Europe, unfortunately. Whatever conclusions we draw, one is for sure: we have to accelerate the digital transformation. That was exactly the same conclusion we came to 10 years ago when we saw the last economic crisis.

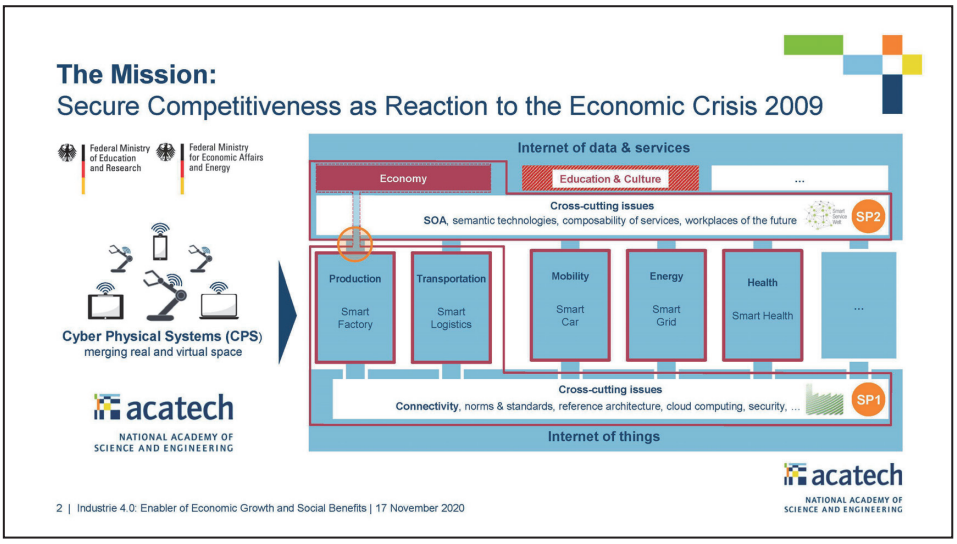


Fig. 1

〈Fig. 1〉 When I retired in 2009 from SAP, I was still under the deep impression of the suddenness and the intensity of that crisis and felt the need to improve our strategic ability to absorb unexpected shocks more easily. I also believed that we could leverage the advances

in key technologies which had reached a level of maturity to implement them on a broad scale. So the main idea was to use these technologies and merge the real and the virtual space into so-called cyber-physical systems taking advantage of the progress we had made at the internet of things and services. Connecting not only people but also smart objects, leveraging service-oriented architectures, composing services and data from different sources into new business processes, opens up opportunities for innovative business models, but also for new societal solutions in areas like education and media.

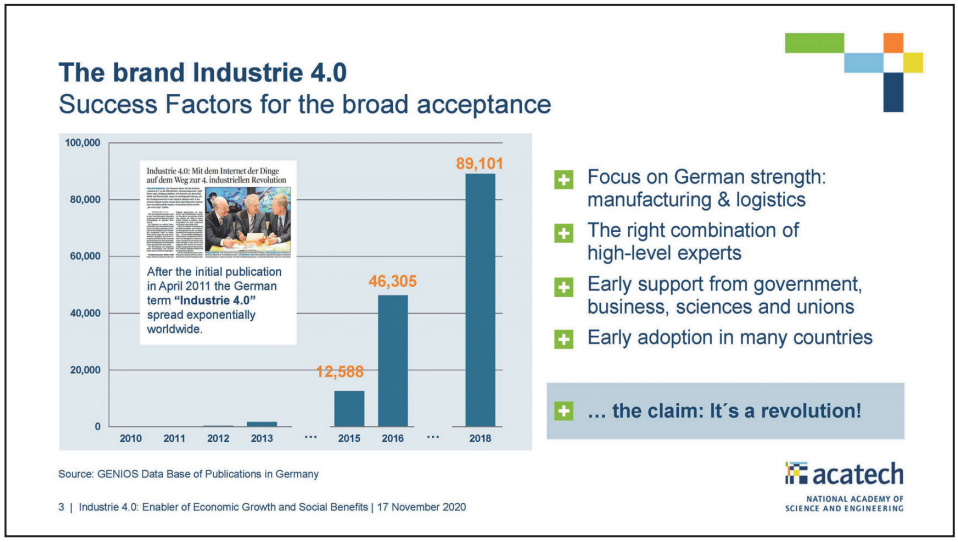


Fig. 2

〈Fig. 2〉 At the same time, the government commissioned the so-called Research Council to recommend strategic projects to secure the competitiveness of our country after the economic crisis. In my function as president of acatech, I was asked to chair the working group communication. Obviously, the ideas I just explained apply to all application domains shown in Fig. 1, but we were convinced that focusing on production and transportation is of highest priority because countries with a strong manufacturing backbone got better through the crisis.

In 2011, Wolfgang Wahlster, Wolf-Dieter Lukas, and I published an article and introduced the brand Industrie 4.0 for the first time. It got immediately high attention worldwide as you can conclude from the number of publications.

What were the success factors for this broad acceptance? Let me mention only a few: We focused on Germany's strength: manufacturing. We could fall back on the broad network of acatech and convince experts from different domains to support the concept and join a powerful working group. We got strong support from government, from business and the unions, and –very important- from representatives of other countries.

Last but not least, I have to admit, that we made the claim, "this is a revolution" attracted a lot of attention.

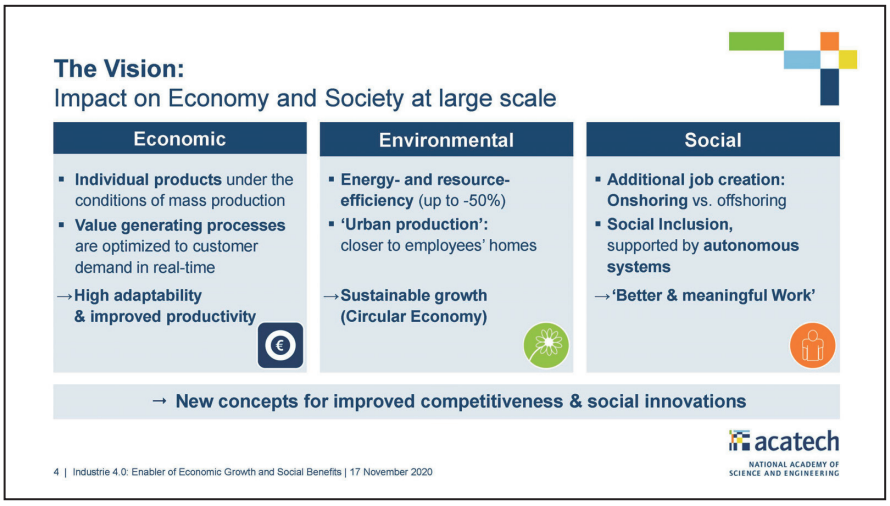


Fig. 3

〈Fig. 3〉 Finally, the vision we outlined was convincing because it promised significant progress not only for the economy but also for the society at large scale.

If you look to the economic aspect, we promised a shift from mass production to mass customization producing individual tailor-made products under the condition of mass production. We requested a move from traditional automation with pre-determined outcome to learning and self-adapting machines and environments to react in real time to changes in customer demand as well as to unexpected disruptions.

As a result, we expected a significantly higher productivity and adaptability.

From the very beginning, resource and energy efficiency was a goal in order to decouple economic growth from resource consumption. And finally, the promise of better and more meaningful work, job creation through near shoring and the inclusion of older and disabled people supported by autonomous systems.

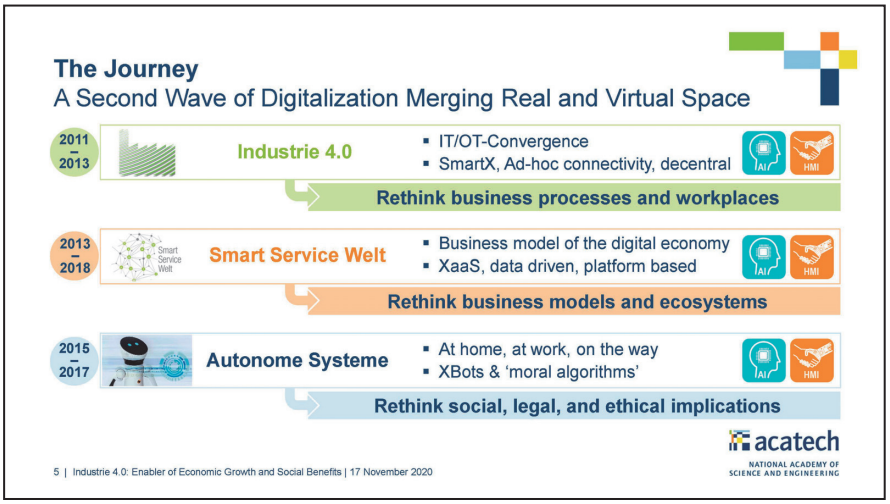


Fig. 4

〈Fig. 4〉 One can describe our journey in three phases.

The first was Industrie 4.0, combining the operational processes with the IT processes,

enhancing everything digitally: machines, products, components, tools, aiming for ad-hoc connectivity and fast decentral decision-making and leveraging recent progress in artificial intelligence and human-machine interaction. That required a fundamental rethinking of all business processes and future workplaces.

In the second phase, we asked ourselves what are the business models of the fourth industrial revolution. The answer was: smart services created in dynamic ecosystems -data driven and based on digital technology platforms.

Meanwhile it became obvious, the flexibility and adaptability we needed required the implementation of learning and self-determining autonomous systems. This is the third phase. However, in the future autonomous systems will play an important role not only at work but also at our daily commute with driverless cars and at our smart homes with service robots and intelligent chatbots. A holistic view of the social, legal and ethical implications, of moral algorithms and autonomous systems was needed.

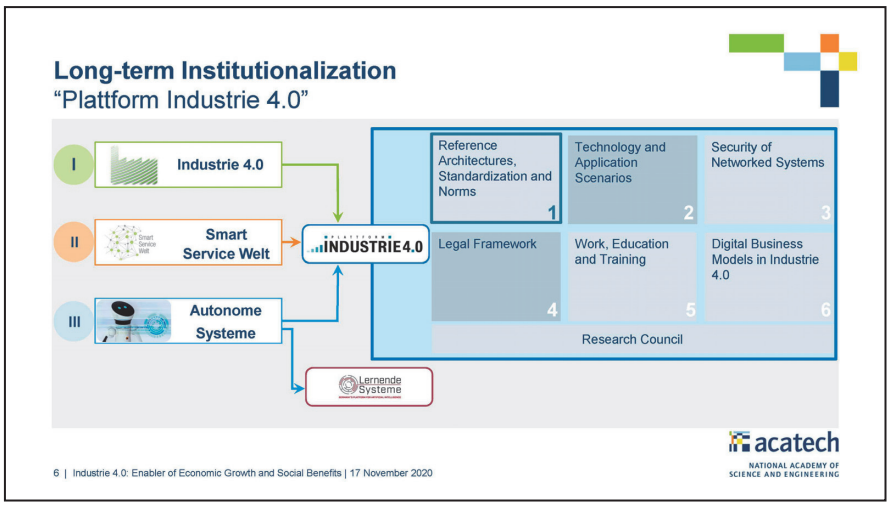


Fig. 5

〈Fig. 5〉 If you want to make a long-lasting impact you must secure new concepts through long-term institutionalization. Already in 2013, the leading business associations agreed to set up an organizational platform and two years later the German government joined and established the so-called Plattform Industrie 4.0, a body in which hundreds of experts continue to work on use cases, standardization, reference architectures, security issues, the legal framework and the future of work. Somewhat later, a working group was added with the focus on future digital business models, building on the ideas resulting from the strategic project Smart Service Welt.

After all, the project on autonomous systems led to a second organizational entity: Germany's platform for artificial intelligence – "Lernende Systeme".

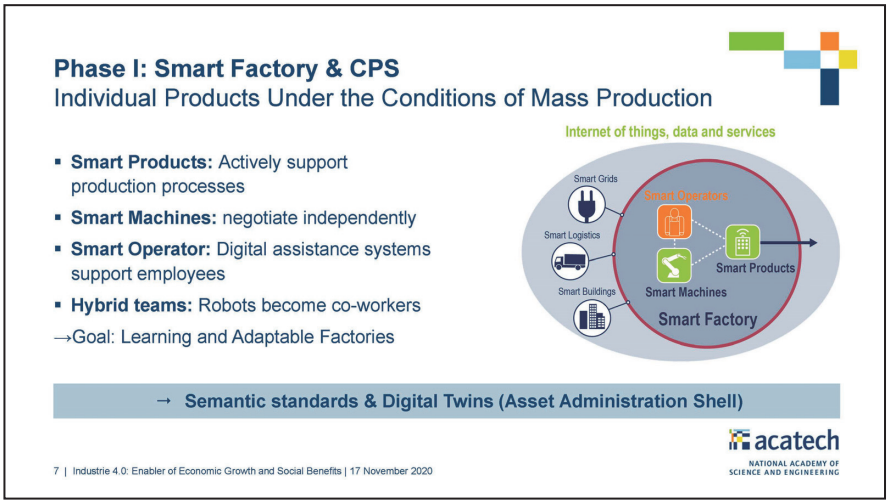


Fig. 6

〈Fig. 6〉 During Phase 1, the smart factory and the implementation of cyber-physical systems have been in the center of our discussions. In future, smart products would know how to be manufactured and they would actively support production processes.

Machines are intelligent and can negotiate independently which one can best take over the next order. Digital assistance systems support the employees, converting them into smart operators; robots leave their cages and become co-workers in hybrid teams. With that, we believe we would end up with learning and adaptable factories. To achieve that ambition semantic standards are important as well as digital twins, which are digital representations of physical objects with all the capabilities and functions that these objects might have: mechanical, electronic, hydraulic etc. The bridge between the analog and the digital world is the so-called asset administration shell. A lot of conceptual and standardization work has been done since then to position the asset administration shell as a common tool in the community.

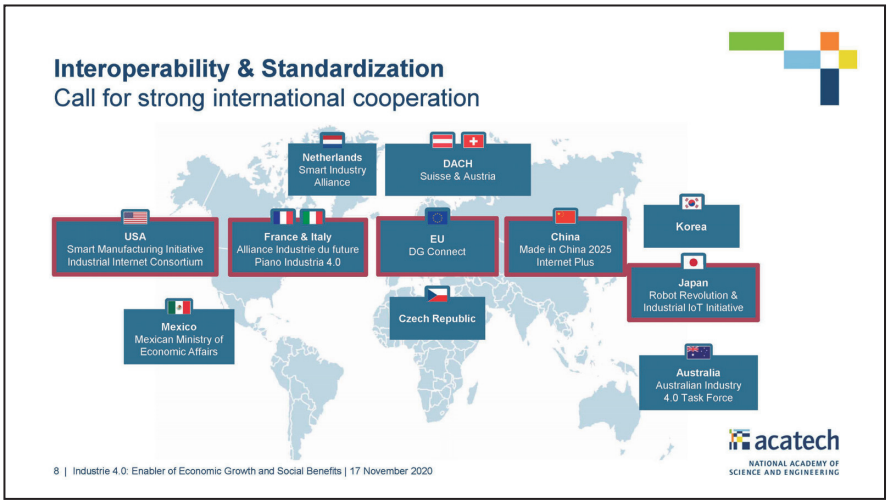


Fig. 7

〈Fig. 7〉 Standardization and semantic interoperability calls for strong international cooperation. As this slide shows, the main countries Germany is working with, in order to

move this concept forward, are the EU, mainly through a trilateral corporation with France and Italy, the US and in Asia, Japan and China.

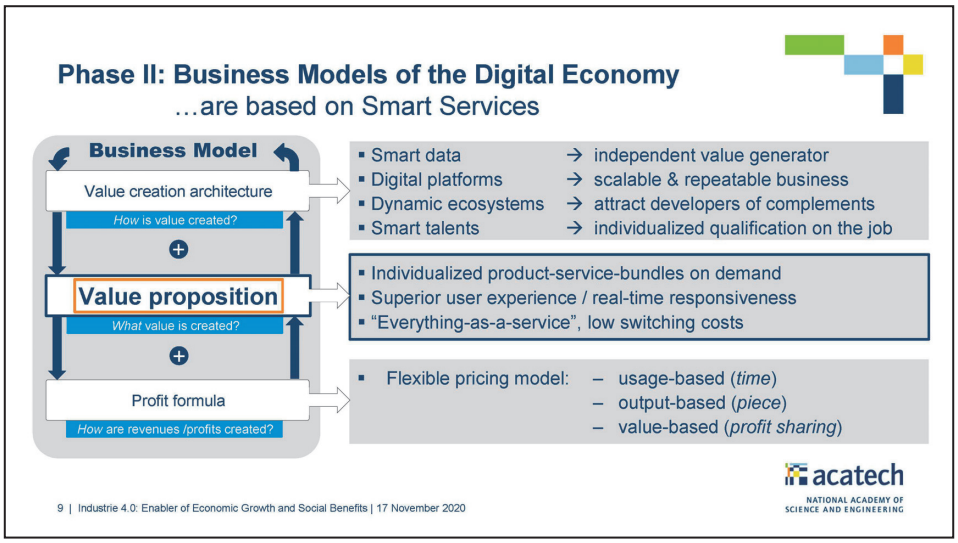


Fig. 8

〈Fig. 8〉 Now in the second phase, we asked ourselves again what is the business model of the digital economy, given the concepts just outlined are broadly implemented.

Usually, you start asking what will be the value proposition, and our answer was: individualized product-service bundles on demand, with superior user experience and a tendency towards "everything-as-a-services"- business models with low switching costs and therefore no lock-in.

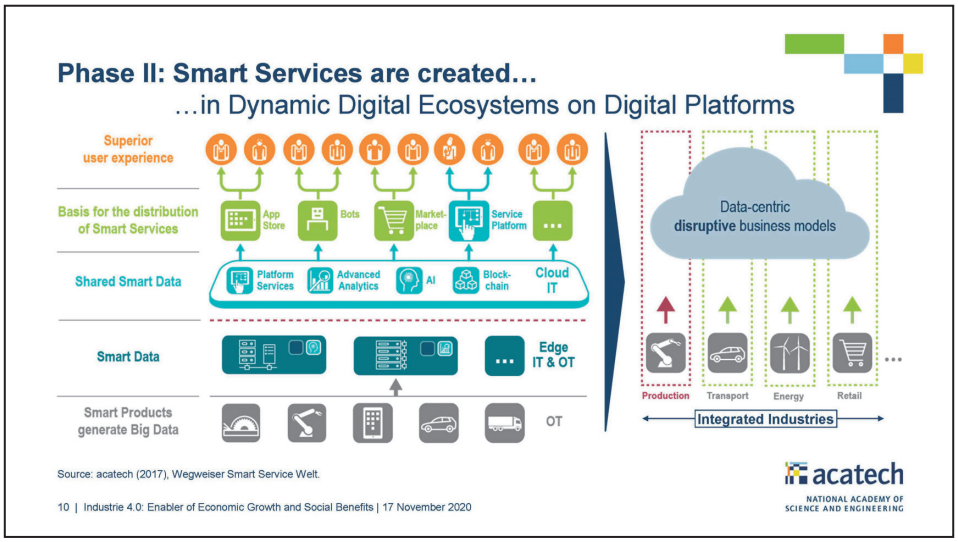


Fig. 9

〈Fig. 9〉 Next question is what is the supporting value-creating architecture? Obviously, it's based on smart data, an independent resource and generator of business value. Data are refined from raw big data into smart data on digital technology platforms, which are the

digital factories of the future, and the basis for dynamic business eco-systems where many business partners work together in order to response seamlessly to shifting consumer demand. The employees are equipped with digital assistance systems and get more and more individualized training in needs-based units on the job, making them smart talents. That allows, then, to finally answer what the appropriate profit formula could be. In this setup you are flexible to implement different pricing models, either based on output or on usage, on time, or on value.

How are smart services created? As I already said: in dynamic ecosystems on digital technology platforms. On the lowest level, you find all kind of digitally enhanced objects: products, tools, components or appliances, and they generate nearly for free huge amounts of real-world data. These data are locally pre-processed and converted into smart data on the level of edge computing where OT meets IT.

Next, data are shared either within an enterprise or amongst members of an ecosystem, supported by digital technology platforms which also serve as tool boxes of innovative new IT solutions, f.e. in the area of advanced analytics or Artificial Intelligence.

This is the basis for the development and distribution of smart services with superior user experience. The architecture allows to compose services from different industries into new offerings and innovative solutions and facilitates a convergence across industries, sometimes called integrated industries, starting point for disruptive data-centric business models.

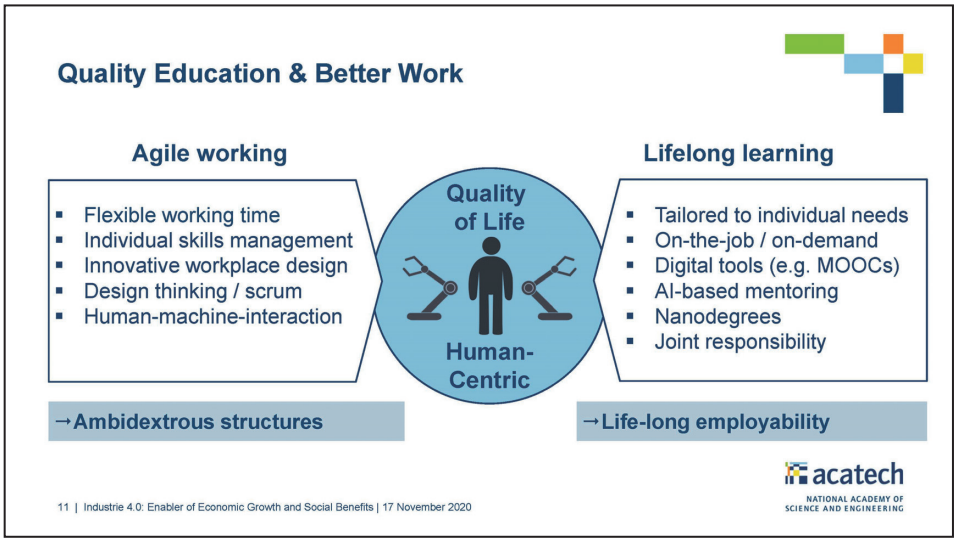


Fig. 10

〈Fig. 10〉 Will all of this result in higher quality of work and therefore higher quality of life? Of course, if the corresponding adjustments are made in the organizational structure and leadership style. It starts with implementing an agile working environment with flexible working time, individual skills management and so on. Also advanced human-machine collaboration must be implemented supporting a symbiosis of human and machine which

benefits both. A key role plays life-long learning, tailored to the needs of the individual worker and provided on-demand and on-the-job, supported by digital tools and AI-based mentoring. However, this requires a joint preparedness and responsibility from both employees and enterprises to secure life-long employability in the market - even beyond the requirements of the employer. Therefore, employees must be more self-reliant and managers must delegate decision making to decentralized teams more often and be able to provide leadership in ambidextrous structures, a combination of appropriate organizational set-ups for existing proven business areas and new disruptive ones in parallel.

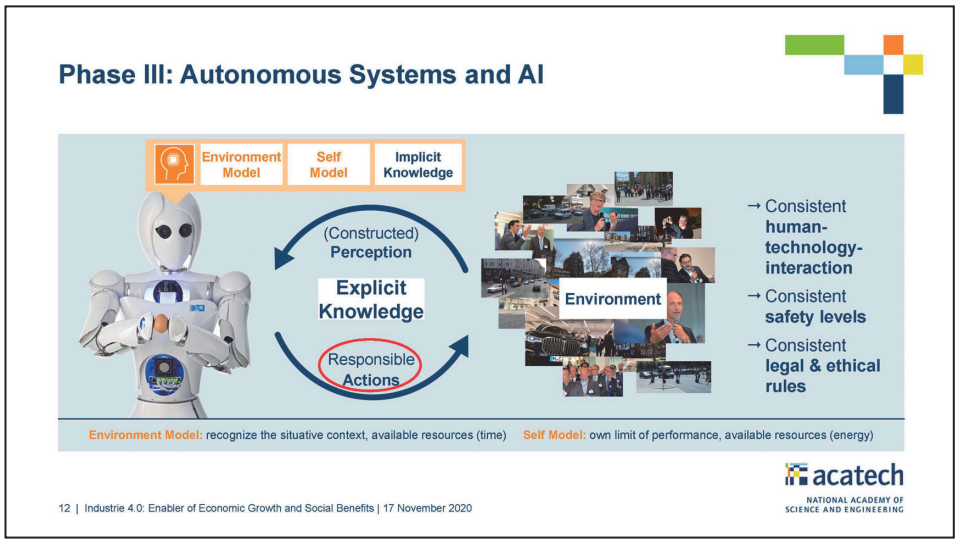


Fig. 11

〈Fig. 11〉 Within the third phase of our journey we developed recommendations for the introduction of autonomous systems. The challenge is that they perform actions with consequences which cannot be anticipated because they continue to learn and act according to their acquired knowledge base.

But we want them to perform responsible actions, which requires explicit knowledge, acquired through advanced sensor technology and AI, but also implicit knowledge, for example certain laws of nature, like Maxwell's equations, but more important: legal and ethical rules. So, a combined knowledge base for their environmental model which they need in order to act responsible without unintended damages to the environment, but also for their self-model to make them self-aware of their own limitations, the limits of their performance, potential shortage of energy or shortage of time to perform the calculations necessary to decide on the next action.

All of that requires consistent safety levels but also consistent legal and ethical rules as well as consistent human-technology interaction.

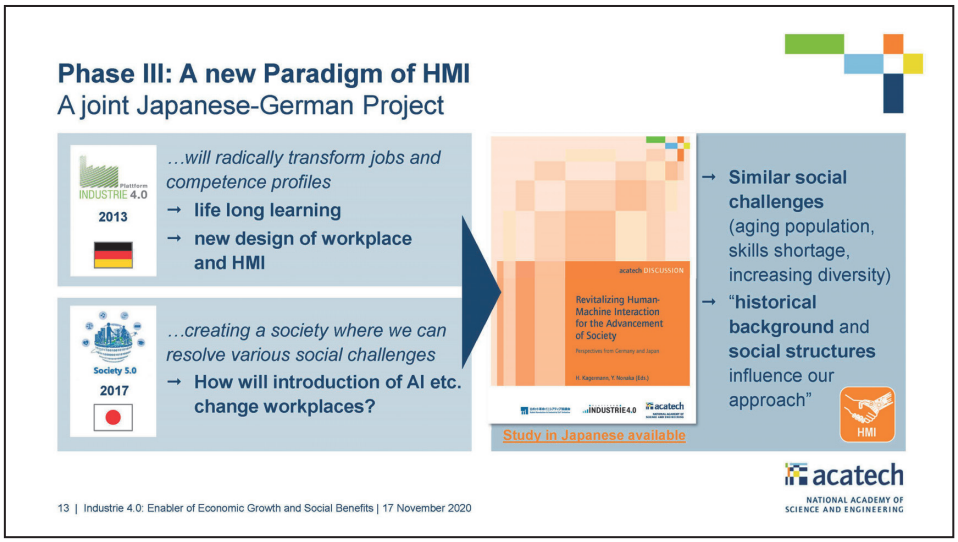


Fig. 12

〈Fig. 12〉 That's why we engaged two years ago with colleagues from Japan, from both science and businesses, to work on a new paradigm of human-machine interaction.

Back in 2013, the recommendation from the working group Industrie 4.0 already indicated a radical transformation of jobs, and asked for life-long learning and a new design of work places. Similar observations were made in Japan's Society 5.0, with the goal to create a society where one can resolve social challenges, raising the question how artificial intelligence will change working environments. The project team identified similar social challenges like aging population or increasing diversity, but had to accept that according to different historical backgrounds and social structures, in some cases local experts would recommend different solutions.

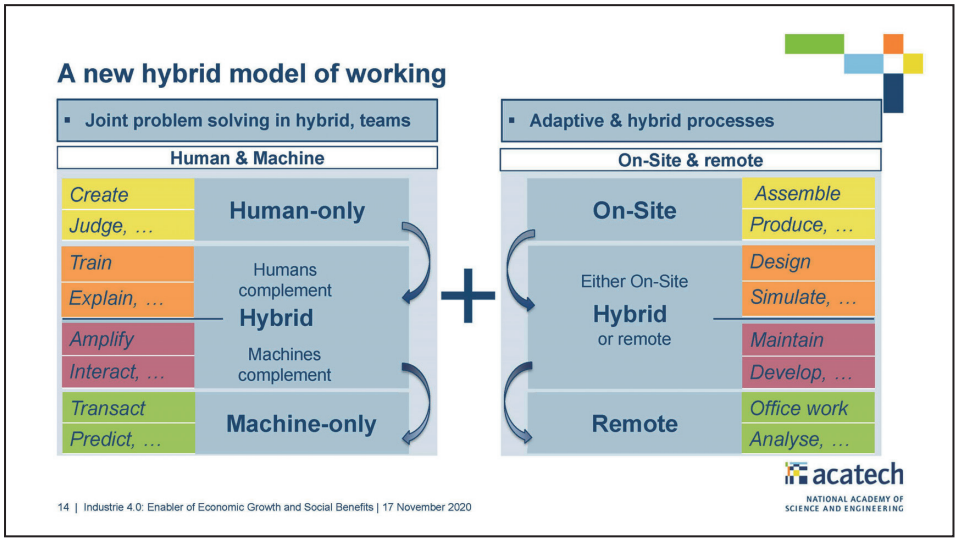


Fig. 13

〈Fig. 13〉 This discussion results in a new hybrid model of working combining the demand for close cooperation between human and machine to jointly solve problems in hybrid teams

with the need to be able to perform as many tasks as possible remotely, reacting to the new challenge of social distancing from the current pandemic.

The result is a new kind of business processes engineering. For each task must be decided whether the task can be better performed by machines, like transactions or predictions, or by humans, like making judgements, creating something new, or if machines can complement humans f.e. by amplifying their physical strengths, or if humans can complement machines by training them or interpreting their results.

The same procedure has to be applied to the discussion which tasks can be done remotely or onsite. The ultimate goal is to get a level of flexibility where most tasks are hybrid and can be performed either remotely or onsite. Cyber-physical systems and digital twins are exactly the instruments that help us converting more and more of the tasks into hybrid ones.

Fig. 14

〈Fig. 14〉 What's next? Last year, experts from the German organization "Plattform Industrie 4.0" evolved the Vision for Industrie 4.0 up to 2030 with the headline: shaping digital ecosystems globally. That means we must continue to make progress with interoperability and international cooperation in open ecosystems which permit plurality, diversity, and flexibility. We continue to aim for a sustainable economy where economic growth is decoupled from resource consumption and for autonomy or rather sovereignty as self-determination on all levels: team, company, ecosystem and country.

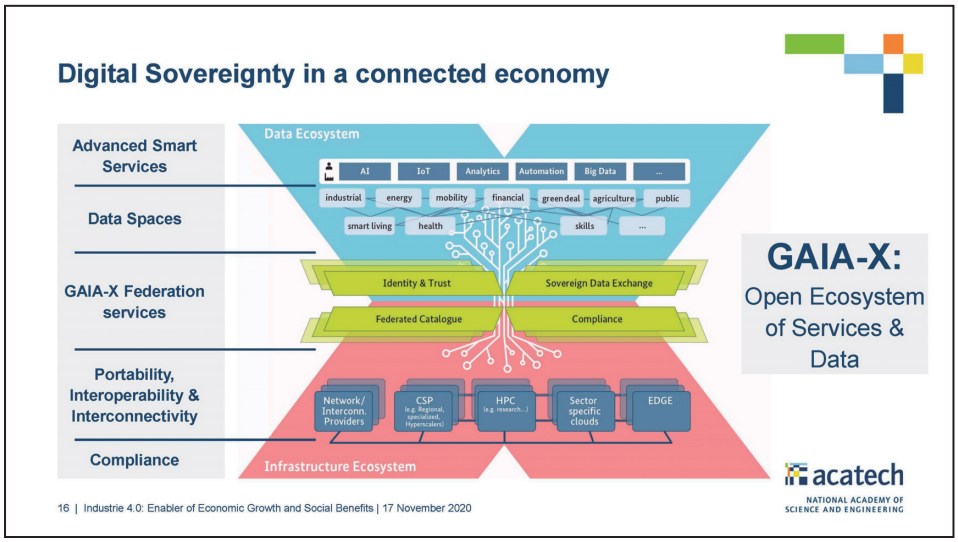


Fig. 15

〈Fig. 15〉 What does self-determination mean in the context of a connected economy? Mainly the freedom to select the technology of choice, the business partner of choice or the location of choice, in particular the location where data are stored and processed. A potential answer is GAIA-X, a framework for open collaboration. Open to all business partners, as long as they support European values.

GAIA-X addresses both layers, the infrastructure layer with edge- and cloud computing, where it's about frictionless portability, interoperability, and free choice of location. And the federation of data and services in open data spaces for all business domains, providing generic development tools and applications for advanced analytics or artificial intelligence.

Last but not least, the required federation services are provided in the area of compliance, data privacy, data security, e-identity.

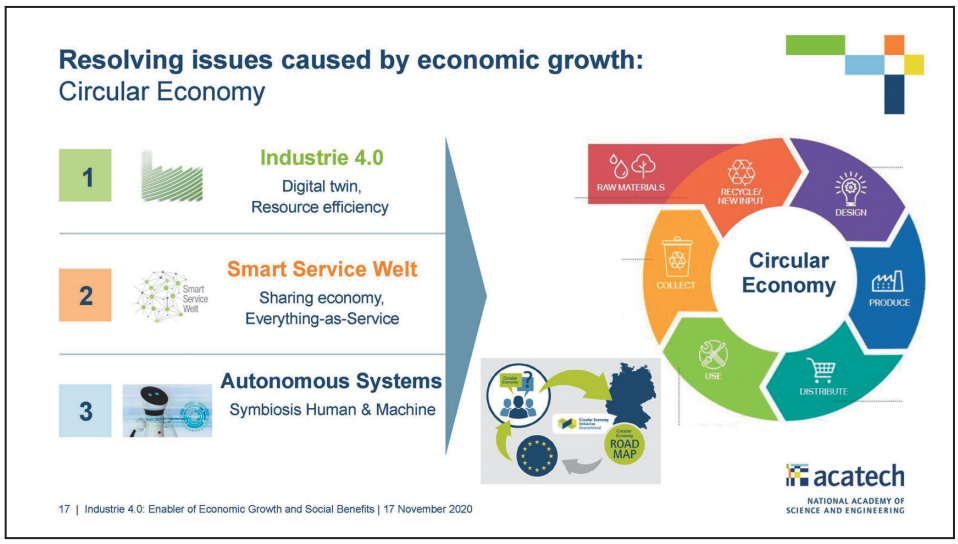


Fig. 16

〈Fig. 16〉 What are the missions the Honda Foundation is committed to? One is how to

resolve issues caused by economic growth. One answer is the concept of circular economy, a fundamental transformation of the entire life cycle of a product, starting with the selection of raw material, ending with the collection of used components and products in its entirety and high-quality recycling. But in between there are three phases where we can take advantage of Industrie 4.0, smart services and autonomous systems. First, the design phase, where it's about designing products for reusability of components, and re-manufacturability, tackled by smart engineering, one of the characteristics of Industrie 4.0. In production and distribution significant resource efficiency will be gained from introducing digital twins and other concepts of Industrie 4.0. And during the phase of usage, smart services make a huge contribution with new as-a-service business models.

For two years, acatech is moderating a circular economy initiative to push these topics along.

Fig. 17

〈Fig. 17〉 Another mission the Foundation is committed to is resolving issues caused by technology; a key topic raised by many stakeholders during our work on autonomous systems. The final recommendations were presented to Chancellor Angela Merkel and to Prime Minister Abe in 2017.

More than hundred experts from all societal groups had agreed on these recommendations and the conclusion that autonomous systems provide not only situational adaptability, they also have the potential to solve major social issues. But there are challenges, in particular legal and ethical issues. That's why we recommended to implement autonomous systems via use-cases, gradually and experience-based, and decide case by case if they are beneficial for the society. If not, we should not pursue those cases any longer.

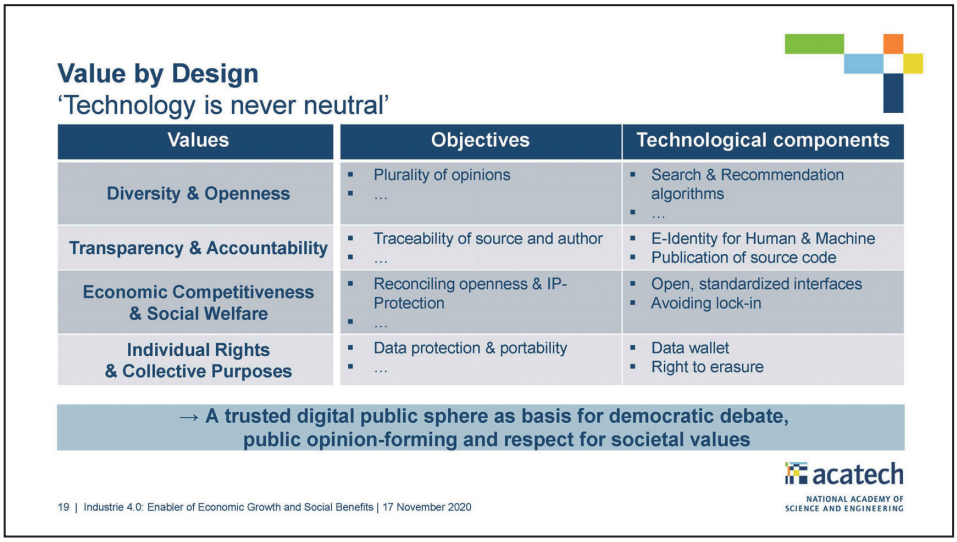


Fig. 18

〈Fig. 18〉 Whenever legal or ethical issues are concerned, the slogan "Value by Design" comes up. In reality, technology is never neutral. It depends on the intention with which a technology was developed. Is this maximizing advertising revenues or keeping the attention of a consumer as long as possible on a certain web page?

Of course not if we engage in a democratic debate where we expect a balanced and trusted reporting on different opinions in order to make up our own one and to achieve public compromises during this debate, respecting societal values.

In Fig. 18, I have listed a few examples and the associated technological components. One value is diversity and openness, tolerating a plurality of opinions. This objective has an impact on the underlying search algorithm or recommendation systems. If one promotes transparency and accountability, the traceability of source and the publication of source code is important. A fair balance of economic competitiveness and social welfare requires reconciling openness and IP protection, which calls for open standardized interfaces and avoiding lock-in. The right balance between individual rights and collective purposes calls for data protection and portability.

Fig. 19

〈Fig. 19〉 Managing these challenges which emerge from the current disruptive transformations, and balancing out very carefully the three dimensions of sustainability, requires effective partnerships among all stakeholders to build trust and credibility and decision-making based on best available evidence.

Most challenges are global and call for international cooperation. So, we must strengthen international cooperation, share our knowledge, our experience and our best practice. It may be that in some cases, a solution of a country differs from the solution another country adopts due to diverging societal trends, or to culturally related problem-solving approaches. But our response can only be self-determination and open collaboration, and not self-sufficiency and protectionism.

Thank you.

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