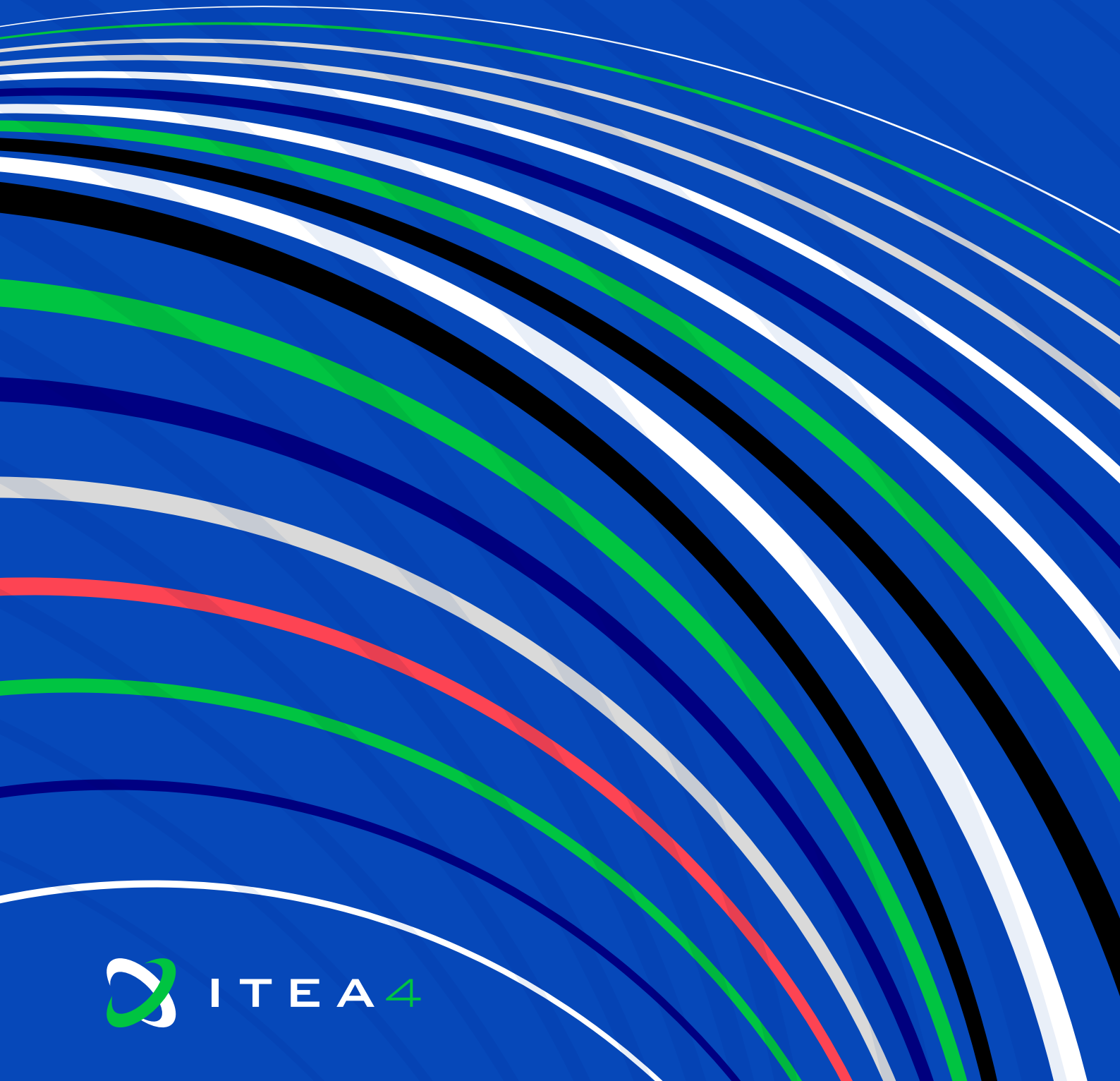
ITEA 4

Strategic vision and technology roadmap



ITEA 4

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Enabling Growth through Innovation by Collaboration

ITEA 4 Strategic vision and technology roadmap

February 2021

Introduction

This document presents the technology vision that will guide ITEA 4 and the Calls that ITEA 4 plans to propose within the Eureka Clusters Programme (ECP). The ITEA 4 domain of software innovation is broad, and it is important to provide some guidance on the technology priorities and on the challenges, on which ITEA 4 aims at having an impact. This strategic vision can be translated into Call topics that will shape the contribution of ITEA 4 to the innovation and impact in business, economy and society.

The IT sector is a very dynamic one and the emergence of new technologies or the modification of past trends can have a deep impact on its activities. To guide ITEA 4, it is important to analyse what are the most important changes we can expect regarding these technology trends. The first section of this document presents some of the relevant trends that must be considered to shape ITEA 4. The objective is not to be exhaustive but to mention the relevant technologies that will influence the field of software innovation during the next four years.

ITEA 4 aims to address customer needs and to solve issues faced by some industry Communities by mastering software innovation. In addition to the technology trends, it is important to present what are the most relevant challenges that ITEA 4 wants to tackle. ITEA 4 has identified eight key domains that can greatly benefit from this research programme. For each of these 'challenges', section 2 of this document presents some issues that can give birth to innovation projects. Again, the objective is not to be exhaustive but to illustrate how a programme such as ITEA 4 can have an impact and make progress in key topics for the future of business, economy and society.

The technology and 'challenges' give a structuring vision and a roadmap for ITEA 4. However, we must acknowledge that the IT sector is sometimes smarter than any analyst and that some key IT innovations have not been predicted. We need to be agile and to be in position to adapt to any important unforeseen change of the IT sector. ITEA 4 plans diverse actions to develop its agility. They are presented in section 3 of this document and are complementary to the strategic vision to ensure the relevance of ITEA 4 for the next four years.

The last section of this document presents the Calls that ITEA 4 plans within the ECP instrument in Eureka. These Calls are a consequence of the previous sections, with the objective of addressing the most important challenges and of keeping an agile positioning that will serve the ITEA 4 customers, the Public Authorities and the industry as a whole.

1. Technology trends

The first technology trend to mention is related to the **hardware evolution**. It may seem strange for our field of software innovation to start to discuss hardware topics but as any software will have to run on a hardware platform, it is important to notice some game changers in the chip industry that enables our innovation. During the last 50 years (1970-2020) we have observed that the CMOS industry has been able to provide chips that double, every two years, their number of transistors (closely related to their computing/processing capacity) while keeping their costs at approximately the same level. The result is that for the same investment as in 1970, we can perform 30 million more operations in 2020. This exponential growth for 50 years is unique in the complete history of industry and technology.

Unfortunately, we face an end of this unprecedented trend. Even if in the near future, the CMOS industry will continue to offer an increase of number of transistors, the exponential growth is over. For the last 10-15 years, due to the stagnation of the clock frequency, we already faced the challenge to use parallel operations to translate the growth of transistor count into performance increase. In the coming years, this will not be as effective due to this slow-down of chip capability. Moreover, on the energy side, the energy cost of one operation is not expected to decrease anymore. Since the end of the Dennard scaling around 2006, the energy per operation has continued to decrease but not at the same pace as the increase of transistors. Even this degraded improvement will come to an end and we expect the energy cost of one operation in general purpose architecture to remain at the same level. This is definitely the most important change to consider.

To react to this stagnation of general-purpose hardware performance, some efforts are put into developing more specialised chips that can serve as accelerators for specific operations. This trend will bring in the picture more heterogeneous architectures with the capacity to help on specific tasks, such as the execution of neural networks. Other paths to develop new computing solutions are currently researched but as they are not yet mature, their impact in the next years will be limited. The quantum technologies are not expected to have a strong influence in the medium term. We could see the use of quantum devices for specific tasks (e.g. random number generators, exchange of secret keys) but in the computing domain at best some accelerators could be developed for specialised problems. The most important change related to quantum technologies will perhaps be the replacement of some of our current Internet cryptographic algorithms by new ones that are

'quantum save'. The USA are mainly managing this transition through their standardisation organisation NIST[1].

In the hardware field, we also observe the development of open hardware initiatives. With the availability of open-source instruction set architecture (e.g. RISC V) and other open architectures, a new ecosystem based on these standardised architectures can emerge and provide an easier access to open hardware platforms.

For software innovation, we can see at least three main consequences of the hardware technology evolution. The first one relates to the heterogeneity of the future architectures. In order to efficiently use the upcoming accelerators and current CPUs and GPUs, we need to design highly modular software that can be executed on different pieces of hardware depending on the module profile or that at least can use libraries that will be provided with the specific hardware. This modular approach is the best way to cope with the multiplication of accelerators and has other benefits as reusability or testability. The second consequence is that the software industry will have to produce lean software if we want to see efficient execution. In the past, the hardware performance increase has helped to develop software solutions that were not optimised but good enough due to the more powerful hardware. With the stagnation of hardware performance, the pressure to develop efficient and lean software will be much higher. The third consequence relates to energy efficiency and comes from the stagnation of hardware but also of the growing societal concern of sustainable green development. For each new software solution in addition to the usual 'value for money' we will also have to show the 'value for energy'. As the hardware will not help anymore to reduce the energy consumption, a software innovation will mean additional energy most of the time, and we will face the pressure to show that the energy consumption due to IT is either reducing other sources of energy consumptions or providing a feature that is really important[2].

The second technology trend that needs to be highlighted is the emergence of '**digital loops**'. The combination of different evolutions has enabled this trend. First, affordable digital sensors and actuators are now available and most of our interactions (typing, speaking, perhaps in a near future looking) happen now through digital devices that can transform the information into digital data. Second, different kinds of communication networks have been developed, enabling the data exchange at all ranges (from short range to long range). Third, our storage and processing capacities have been multiplied and organised so to be flexibly accessible thanks to the emergence of cloud data centres. Last but not least, our modelling and simulation capacity has been improved, giving birth to the concept of digital twin, which is the digital counterpart of a real system. All in all, we have now the ability to digitally monitor and control complex systems. To illustrate this trend with a few examples, these systems can be an industrial manufacturing process (Industry 4.0), vehicle traffic (Smart city), retail and e-commerce activities, a surveillance system to protect sites or healthcare

[1] NIST (National Institute of Standards and Technology), see: https://www.nist.gov/news-events/news/2020/07/nists-post-quantum-cryptography-program-enters-selection-round

[2] text

monitoring. Of course, some applications linked to the monitoring of human behaviour open ethical questions that must be carefully looked at. However, this digital loop gives us the ability to retrieve data from the field, to analyse them, to compare them with a digital twin that can make predictions and finally, to end the feedback loop to control and optimise complex systems.

This technology evolution towards digital loops has several consequences and sets new requirements. First there is the need to handle **complex workflows**. The digital loop will be composed of several software modules that will be executed by different resources as IoT devices, edge servers, cloud servers or high-performance computing systems. To manage this chain of processing steps, we must design and control complex workflows. For the beauty of this evolution, the workflow can itself be considered as a complex system to which the concept of digital loop can be applied recursively. The second consequence is that the software chain, which needs to be modular, must also be **configurable**. The software modules need to have the ability to be adapted at deployment time to take into account the specific setting of a complex system. To illustrate this requirement, we can look at the example of video surveillance systems: in order to pilot such systems, we need to design modular software able to adapt itself e.g. to the number of cameras and to the capacity of the different elements of the infrastructure. These modules can be run by the camera, by an edge or a cloud server depending on the resources of a specific configuration. The ability to develop configurable software modules will be a key element for the development of digital loops. Developing an ad-hoc software for each configuration of complex systems will be out of reach. We need to master this configurability feature to successfully and productively control and optimise complex systems. Consequently, we also need an efficient management of the variants for the different configurations. The third consequence of the emergence of digital loop is the increasing need to address the **cybersecurity** problem. With more and more components, with more interactions, the surface of attack of these complex systems will be a growing issue. At the same time, more and more of them become critical systems for our economy and society. We therefore need to master their cybersecurity and provide solutions to design these systems with the right level of resilience. The fourth consequence (we will stop here even if there are other impacts of the digital loop) is the emergence of what can be named **urgent computing**. The objective to control complex systems means that the different processing steps need to be executed in a timely manner if we do not want the results to come at a time where they would not anymore be useful. Due to the high complexity of the systems, we cannot speak of ‘real time’ as for the control of ‘simpler’ systems. However, the implementation of digital loops will imply that the software managing them will be ‘time aware’ and able to control the execution of the processing chain to ensure that the result will come at a time consistent with the need, to control the systems efficiently. We can think about different levels of implementation of this ‘time aware’ control but, definitely, this concept of urgent computing will drive some of the upcoming software innovations.

The third technology evolution that must be mentioned is of course the development of **Artificial Intelligence** (AI). Again, the rebirth of AI is the result of the conjunction of several events. First, as already seen with the concept of digital loop, the availability of data in digital form offers new opportunities and asks for the development of data-based methods. Second, some new technical improvements of the concept of neural networks (developed back in the 90’s) have revitalised the

field of deep learning. Third, the availability of cheap storage for the data and inexpensive and large computing resources have made the normally compute-intensive AI methods tractable and affordable. The development of AI is not new and started several years ago, but we have not yet experienced all its impacts and it will remain a major driver for the software innovations in the mid-term.

AI will increasingly find applications in more and more diverse sectors. The introduction of AI is not always straightforward and most of the time there is the need to have access to high quality data. Therefore, in many sectors additional efforts are mandatory to develop the use of AI to fully benefit from it. The use of AI will also impact our Community with the application of AI for software development and operation. This trend of **AI for software** will be key to tackle some of the challenges that we have already identified in this technology evolution analysis. To develop lean, modular, energy efficient, configurable software and to run complex workflow, AI methods will be an important enabler. To apply AI to progress in all these dimensions will require some important research investments. Another research trend, that we will name **software for AI**, is to progress further in AI methods. The current level of AI methods is already effective, but we can expect more, by developing more powerful software for AI. One axis is innovative software engineering for the development and operation of AI methods. Another direction is to work on the introduction of new features for AI-based systems. We can think of 'explainable AI' or 'validated AI'. We can also more strongly develop the hybridisation of AI with other methods. Data-based methods can be complementary to model-based approaches. These are only some of the opportunities to develop software innovations that will bring AI to the next level of effectiveness and reinforce its potential impact.

At the end of the analysis of the AI field, we want to notice the emergence of very big neural networks with hundreds of billions of parameters. These enormous networks addressing the field of Natural Language Processing (NLP) have been developed by Google (GShard) and Open AI (GPT-3). Although it is still unclear, what will be the full impact of this trend, we can already speculate about two possible consequences. First, some of the AI applications will be more and more resource-intensive and thus out of reach for small players. Second, the most efficient implementations might have to rely on the access to these huge networks giving their owners a central position in the future development of AI.

There are additional technology trends that could be mentioned but the objective is not to try to be exhaustive. With the trends analysed above, we have a good vision of the technology evolution, which enables us to shape the content of the ITEA 4 programme.

2. Trends within ITEA 4's smart challenges

This panorama of technology trends must be complemented by an analysis of the needs of our society and economy. This will help us to define the ITEA 4 priorities and to develop the relevant research approach to increase the efficiency of the ITEA 4 programme. To this purpose, ITEA has experimented with a customer-oriented approach to learn from the user point of view about their concerns and the challenges faced. We are focused on eight specific challenges for which ITEA 4 aims to contribute to significant achievements:

- Smart cities: to support the management of cities whether in terms of housing, energy, mobility or emergency services
- Smart health: to propose solutions for a more efficient healthcare chain from drug and therapy design, to hospitals and home care
- Smart industry: to provide new design, manufacturing, maintenance capabilities and to support an efficient supply chain
- Smart communities: to offer new means with greater efficiency, more personalised and human touch, with more trust, enabling the development of communities (at work, leisure, politics…)
- Smart mobility: to innovate towards new sustainable transport systems and services with improved efficiency, autonomy and energy consumption
- Smart energy: to develop green energy sources and energy distribution networks and to improve the energy efficiency for a more sustainable society
- Smart engineering: to expand our capability to engineer complex systems and software
- Safety and Security: to increase the resilience of critical systems and to protect against cyber attacks

ITEA has developed different activities to dialogue with and to collect the challenges faced by the potential users of software innovation. One of these actions is to organise 'customer workshops' which are a place for the users to express their concerns and the problems they would like have to solved. These events have been very useful to elaborate the vision of the challenges that is presented in the following paragraphs.

2.1. Smart cities

Urbanity is a key trend of our society, already more than 50% of the worldwide population is living in cities. This concentration facilitates the interaction from a societal and economical point of view. One objective would be that it also enriches everyone by the easy contact with the others. However, today cities are becoming less and less comfortable and make the social contact more complex. The result is that we are deploying a large amount of innovation and technologies in the cities to retrieve the advantages of the city and reduce the drawbacks of the concentration. Cities face today several challenges that are highlighted below.

The first challenge to mention is the **participation of the citizens** to the city's choices. The E-democracy must be developed to put the citizen at the centre of the city development and to enable

her/his participation to the life of the city. Being able to understand the needs and to provision the right services for the inhabitants are some major concerns for the city decision makers. E-democracy will be a path to a more active participation of everyone to shape new services and to take part in some of them. It will also improve the transparency and the accountability of the city processes. This challenge asks for innovative communication and collaboration systems. It pushes also for developing our ability to share, browse and search data relevant for the future of the city.

The second challenge for cities is to rethink their development in the context of a **sustainable society**. This means to work on an efficient use of energy and to reduce the greenhouse gas emission. Cities have a central place in this global trend of our society because they can act in a context where the complexity is tractable, and it is easier to get the stakeholders' involvement. To be effective, cities need to develop solutions for e.g. smart lighting, new energy distribution systems and new rules for building construction. In this journey towards green cities, we will have to develop new IT systems to monitor and control the use of energy and their impact on the quality of life of citizens.

Another challenge for cities is the development of **crisis management** capabilities. Here again, the city, by its size and connection with its inhabitants, is in the driving seat for most of the crises. The sources of crisis are unfortunately growing: weather disasters, terrorism, uncontrolled crowd situations, pandemics, or critical infrastructure failures. Most of them ask for local answers and the cities must be prepared to face such crises. To address these needs, we must develop new systems. First, we must deploy more innovative sensors to get a more agile alarm and monitoring capability. Second, we must implement data analysis and aggregation to improve the situation assessment. Finally, we need to put in place new planning and optimisation capabilities to react and to avoid uncoordinated actions. Various technologies are relevant here, such as geographic information systems, crowd sensing systems and command-and-control centres but must be tailored to the crisis management by the cities.

A more positive challenge for cities is to develop the **ability to plan their own development** and to increase social networking. The development of a pleasant living environment within the city enables a higher number of social activities. We need a good integration of houses, buildings, infrastructures, services and green spaces. To work on this harmonised growth, new solutions can be developed with technologies such as 3D visualisation, modelling of the city and simulation. The digital twin approach of the city can be effective to better prepare the investments, to analyse citizen proposals and to interact with them.

Besides these four important challenges, the Smart city faces many other ones, which cannot be all analysed here. Some of them, such as Smart communities, Smart mobility or Safety and Security, are shared with other stakeholders and will be explored in the next paragraphs.

2.2. Smart health

Health is the first concern of our populations and a large sector of our economy accounting for around 10% of the European GDP (Gross Domestic Product)[3]. Aging populations, the increase in chronic diseases and economic realities are completely reshaping the healthcare landscape. Healthcare is now embracing the digital revolution, as consumers and health systems turn to innovative technology to help them address the very significant challenges they face. One recent example is the COVID-19 Pandemic, which is driving unprecedented demand for virtual care and digital health solutions, for both hospital inpatients and patients receiving care at home..

One important challenge is to optimise the '**patient workflow**' and especially to decrease the time for decision making for patients in hospitals. Here, the support of IT can help to solve some basic questions, like the choice of the best treatment and hospital depending on the patient's situation (local versus more specialised centres). There is also a need for a better exchange of information throughout the healthcare chain to take the right decision, especially between hospitals and independent physicians. Inside the hospitals, the planning of activities is also an important matter with the need to optimise the patient journey.

One trend in healthcare is to encourage as much as possible to care for the **patient at home**. This means to switch from a hospital-centric view to a patient-centric approach. To progress in this direction, efforts must be undertaken to train the patient to become more active in the management of her/his health. We also see a need to develop the involvement of the patient's relatives, as the availability of healthcare personnel is limited. All these actions can be supported by new IT systems that will help to share the responsibility between the different levels of the healthcare chain: patient, relatives, local health personnel and hospitals.

The development of new health sensors, medical instruments and innovative treatments is promising for the improvement of our healthcare system. However, we face the challenge of the **integration of these new means** with a new definition of the processes. At the hospital level, new imaging and robotics capabilities offer the opportunity for better treatment and more efficient protocols. Most of the time however, complex software systems must be developed to benefit from these innovations. We also see a huge change with the multiplication of personal health sensors. Connected watches or wearables are developed to record health data that can be interesting for the health-related decision-making process. The integration of these new sources of information is to be developed keeping in mind the relevant issue of connecting two fundamentally different approaches; one led by a commercial business model and one governed by a collective insurance model.

[3] Most of the figures provided in this document are for the European market. However, ITEA 4 ambitions are global, address the worldwide economy and the role of non-European Eureka countries is central for our success. European statistics are just easier to access and we believe that they are meaningful to seize the importance of the economic sectors even for non-European Eureka countries.

This development of new sensors and the digitalisation of the treatment processes, health data and protocols results generate a great opportunity to use all these **data to optimise and personalise healthcare**. Linked to this opportunity, we face the important challenge to develop a new health data science with the goal at global level of extracting from these data new information regarding efficiency and specificity of treatments. The availability of more patient data with precise genetic information, treatment protocols and results offers the opportunity to compare between different treatment options, to assess in which cases they are efficient and to build new health knowledge. This challenge of data analytics is also present at the patient level. All the data related to a patient can be integrated, searched and analysed to have a better understanding of her/his health situation and can be coupled with the new global knowledge to propose personalised treatments. This big health data challenge asks for new IT solutions and we have just started to tackle this important challenge.

Another crucial challenge in the health sector is related to the **privacy and security of health data**. Health data are very sensitive personal data and must not be comprised in inappropriate uses or disclosures. At the same time, as seen in the previous challenges, there is both a need to share these data along the healthcare chain as well as the opportunity to use the data to discover new knowledge. New solutions must be proposed to keep a good balance between these conflicting objectives. The generation of anonymised data for statistics is a potential approach but must be developed with a specific care to cover indirect analysis. The cybersecurity of medical data and hospital IT systems is also a growing concern because they are becoming more and more attractive targets for cyber attackers.

2.3. Smart industry

Industry remains a major pillar of the economy and represents in the European Union almost one quarter of the GDP. Industry, and especially manufacturing, has always been striving to increase the productivity and more recently to improve their sustainability. The digital transition offers new opportunities to go in these directions. Some of the most important trends are presented below.

The industry is one of the first sectors to seize the opportunity offered by the **digital loop** approach previously described. The **end-to-end digitalisation** of the production line and of the product life cycle is a key challenge for industry. The objectives are to optimise the production, to increase worker safety, to improve quality, to increase flexibility, etc. The main actions to achieve this digitalisation are the deployment of IoT devices, the installation of more advanced robotics, the development of digital twins, the use of simulation and of course the implementation of Artificial Intelligence methods. The industry must progress towards a global vision of the production plant and of the product life cycle.

In its evolution, industry also faces the challenge of a more and more **integrated supply chain**. The growing complexity of the products and markets increases the pressure to work towards this integration. Today, it refers not only to digitally exchange all the data related to the commercial transactions but to exchange data on the features of the components and their models and to be

able to build the global view of a system of systems from the digital information provided by the different actors of the supply chain.

Another important challenge is the **personalisation of the products** or variant management. With the ambition to export worldwide and to be as close as possible to the customer's needs, industry must be able to efficiently create product families or even customised products. This adds a new complexity, which can only be handled in an efficient way with the help of new IT solutions to support the design, the production and the maintenance of the personalised products.

Moreover today, industry has the challenge to better collect, organise and learn from the **industrial data**. The digitalisation generates more data that are relevant for the industry sector to improve its processes. This is true to optimise the productivity, but also during the complete product life cycle, such as for example to improve the maintenance through new predictive maintenance methods based on AI. The collection, storage and exploitation of data ask for the development of new middleware that can automate these tasks.

The industry also needs to **integrate new production technologies**. Technology developments in robotics, 3D printing or virtual/extended reality can help industry in its search of more efficient processes. This integration can be disruptive in some cases and it is quite a challenge to take the full advantage of this progress in production methods.

To end this short survey of the challenges faced by industry, we must mention the objective of industry to **save energy and to reduce its greenhouse gas emission**. We will further develop the associated challenges in the section on Smart energy, but within the scope of Smart industry, these concerns are now at the top of the priorities. To go towards these objectives, new IT systems need to be put in place to better track, predict and monitor energy usage and greenhouse gas emission. All the processes of the enterprise currently have to consider these criteria and to propose multi-dimensional optimisation. This challenge relates as well to the supply chain in order to promote a circular economy.

2.4. Smart communities

The digital era has strengthened the community focus in all the dimensions of our lives (at home, with relatives, at work, worldwide connections, etc.). People today are more connected to communities across borders and it is important to design software innovation to support this trend. The COVID-19 pandemic has also highlighted the importance of appropriate solutions to maintain communication of high quality within our communities while even in circumstances where physical meetings must be avoided.

Solutions offering a better communication experience face the challenge of efficiency within and between **heterogeneous communities**. We need to develop tools that can help to break the silos and to build a common ground that enable effective communication. One dimension of the solution is the emergence of a common data model to facilitate these exchanges. Another dimension relates to trust: how can trust be managed and especially how it can be built across the supply chain in the

frame of commercial exchanges. The support of heterogeneous communities also leads to the issue of keeping a fine-grain control of the access to the data when these are sensitive.

A second challenge is the development of **collaborative learning**. There is an increasing need of continuous learning inside a company or a community. It is important for a group to keep its knowledge even in the case of members leaving and to extract new collective knowledge from complementary skills. The representation of knowledge and its management are therefore key concerns for the support of communities and their ability to learn. At the crossroad of collaborative learning and heterogeneous communities, we see also a need for new training platforms that may be organised as marketplaces with innovative business models.

There is also a challenge in extracting new knowledge from activities, which in turn can then be used to improve these activities. As an example, by monitoring the design activity within a company, we can extract information on what works and what does not work and thus progress towards what can be named '**embedded learning**'. The same approach can be applied to other processes such as the sale process. There is a need for new solutions to enable this embedded learning and to present the extracted information to different types of users. This ability to translate one corpus of knowledge into different trainings for heterogeneous groups of people is also an important competence.

The last challenge we would like to mention is related to **collaborative working tools**. There are several directions, into which we could innovate. First, there is a demand for more advanced communication tools that allow bottom-to-bottom, bottom-up and top-down communication in a smooth way. Second, there are opportunities offered by the virtual reality technologies to improve the way people can communicate and work together. Third, there are some requests for solutions enabling consensus building. Mission preparation is another topic of interest. The field of collaborative working tools is very diverse and at the same time relevant for many of our activities.

2.5. Smart mobility

Mobility is a very active field with many innovations shaping a new landscape: multi-modality, digital service platform, electrical vehicles, and autonomous transport means. It is a very important sector as on average 13.2% of every European household's budget is spent on transport goods and services.

The first challenge that we want to highlight is the transformation of the current transportation systems into **mobility as a service**. There is a strong demand coming from the users of the transportation system to get a unified view of all the potential transportation means and to have a unique contact point to buy multi-modal travels. This puts some pressure on the existing players to develop common payment solutions and global travel planners and it opens opportunities for newcomers to offer the aggregation of the services of the incumbent transport providers. Anyway, new digital platforms are being developed, and it could be a way to propose disruptive business models with strong impact on traditional businesses as car selling or railway transportation.

A second challenge is the **optimisation of traffic**. The growth of traffic and the existence of peaks in demand put high pressure on the transportation infrastructures. At the same time, a higher sensor density and variety coupled with the ability to collect data on the transportation systems can open

opportunities to optimise these systems. Several developments could lead to this improved management of transportation means. First, new sensors like cameras, drones, crowd-monitoring systems need to be put in place and integrated to get a good and accurate monitoring of the actual traffic. Second, these data and other relevant information (historical data, weather forecast) must be analysed to elaborate predictions and optimisation plans. Third, this knowledge needs to be forwarded to the different travel planning systems or directly to the users. These developments are challenging and simultaneously touching difficult technical topics, such as multi-criteria optimisation, scalability of data analytics or urgent computing.

A third important challenge is the **safety and multimodal sharing of the transportation infrastructures**. In city streets today, we have public transportation vehicles, individual cars, bikes, scooters, Segways and pedestrians that must share the same space. We also foresee the emergence of autonomous vehicles either for passenger transport or for goods delivery. To provide a safe environment for all these street users, new solutions need to be developed where IT will be central. We can think of new sensors to alert people, new collision avoidance systems or new sign systems for the infrastructures. Anyway, this safety and sharing challenges require new solutions.

The emergence of **autonomous vehicles** is a challenge by itself. The first dimension of this challenge is to develop the capability of IT systems to control a vehicle and to plan its movements in a complex environment. We must progress on difficult technical domains as sensor fusion, real-time control, machine learning and planning of complex tasks. The second dimension is to develop the capability of the autonomous vehicles to interact, first, with the driver (if any and if we can still name the 'person in charge' by this word) and second, with other potential users of the same infrastructures. We need some new solutions addressing behaviour models, joint planning or human interfaces.

The last challenge linked to mobility that we would like to mention, is related to **energy and greenhouse gas emission reduction** for transportation systems. In 2016, transportation systems accounted for 27% of the greenhouse gas emission in the EU-28 (of which 72% for the road transport). The reduction of gas emission in this sector is therefore indeed very relevant. One option to progress towards this objective is the development of electrical vehicles that could be charged from green energy sources. This is an ongoing trend facing some interesting issues, such as the development of new charging solutions and bi-directional charging linked to micro-grids. A second option is to develop hydrogen vehicles, with the hydrogen also produced by green energy sources. Again, this option means new solutions in terms of infrastructure to support these new vehicles and the production of hydrogen. IT can help to optimise several steps involved in these transitions. We also continue to see room for improvements thanks to IT solutions in the reduction of the energy used by gas-based engines and in the reduction of the noise generated by vehicles. Progresses in the domains of engine control or advanced maintenance can contribute to the reduction of energy and pollution.

2.6. Smart energy

ITEA 4 has identified Smart energy as a new challenge for several reasons. The energy sector (extraction, production and distribution) is an important one for the European economy, as it directly

employs about 1.6 million people in the EU and generates an added €250 billion to the economy. This sector has a strong demand for software innovations to solve challenges linked to its evolution towards renewable energy sources. In parallel, our society targets to reduce its greenhouse gas emissions as quickly as possible and to develop a sustainable development model. Consequently, there is also a demand for software innovations from all the economic sectors to help them to undertake this transition.

The energy production subsector faces the challenge of **optimising the production of renewable sources**. These renewable sources are diverse (biomass, wind, solar, geothermal, ocean) but in each case, software solutions can help to increase the efficiency of the new infrastructures. On one hand, simulations and digital twins can support the optimisation of wind farms, or the material used in photovoltaic plants. On the other hand, some control and prediction systems can help to optimise the operations of the energy production infrastructures.

The software contribution will even be more important to tackle the challenge of developing new **energy distribution** systems supporting the transition to renewable energy generation. In addition to the current few large continuous energy sources, the distribution systems need to connect many new (and occasional) energy sources. This leads to several open questions: the scalability of the solution to deal with many sources, the difficulty to ensure the safety and security of the global infrastructure when so many producers are involved, the development of new business models with the newcomers, and last but not least, the need for new regulations targeting more open competition. The complexity (of the market) will strongly increase as most of the consumers may occasionally become producers. In this picture, we also see new opportunities with new smart meters or other instruments giving more information about the energy usage and can thus be helpful to adjust the energy consumption by e.g. dynamic pricing. As we can see, the development of smart grids being able to ensure a good balance between demand and supply is a big challenge with many opportunities for new software solutions. The prediction of both the energy production and consumption is a topic where software can play a key role. To introduce flexibility in the distribution system, new solutions can be developed to better control the production and the consumption over time: some sources can adjust their level of production while at the same time some of the consumption activities can be delayed or planned according to the production peaks. We face in this domain a highly complex optimisation and control problem for which important IT developments are mandatory.

In parallel to these disruptions in the energy production and distribution sector, we also observe an important trend for all energy consumers to improve their **energy efficiency**. Even with this strong movement towards green energy, it is worth to work on an accountable use of energy that will contribute to a more sustainable development model. This challenge of energy efficiency is important for all economic sectors and households, with the greater impacts in transport, building and industry as the larger energy consumers. For the IT sector, there is also a big challenge arising as explained in the analysis of the technology trends, that is to show convincing evidence that its new developments will bring ‘value for energy’. To tackle this challenge, we must first develop our capacities to monitor the energy consumption. These accurate data will feed the second step aiming

at the optimisation. Having a good view on the energy consumption of complex activities is not obvious and even in the narrow field of IT we are not aware of the energy cost of simple actions such as sending an email or storing a file in the cloud. The energy awareness is something that we must still develop for most of our activities. The optimisation problem is also quite complex as energy is only one parameter of the equation and other criteria, such as productivity or safety, must also be taken into account. The energy efficiency challenge can definitely benefit from software innovations that will provide more insights on energy usage and help to optimise how this resource is used.

2.7. Smart engineering

As seen in the previous sections, systems and software become more complex, increasingly needed and ubiquitous. This requires new methods and tools to be able to develop complex systems and software at an acceptable cost in a short time and with a higher quality.

The main challenge for software development is to handle the **complexity** of the new software we would like to deploy including the features arising from the technology trends mentioned previously: modularity, configurability, time awareness and energy awareness. The complexity is mainly due to our needs to implement digital loops managed by software that will be deployed on a heterogeneous and distributed system. An approach based on a system-of-systems architecture can help to handle this challenge. It will allow to develop a hierarchy of software components that will then be orchestrated to work together in order to implement complex workflows. To deal with the time constraint of the digital loop, new approaches are mandatory. Real-time programming methods are too restrictive to deal with most of the digital loop applications. As time constraints in the digital loop are looser than in the control of real-time systems, we need to develop new methods to deal with the introduced concept of ‘urgent computing’.

A second important direction for software engineering is to develop **AI for software**. AI methods can be applied to the production of software. There are several areas where AI can be useful to the software industry. We can mention the generation of tests where AI can increase the test coverage. Debugging is another domain where AI methods can help to find the root cause of the failure. We can also think of AI being used to optimise the efficiency of the software by selecting relevant parameters at compile or run time. These applications of AI to software production and operation are only starting and must be developed further.

Another challenge is the adaptation of software to **heterogeneous platforms**. As explained in the technology trends section, we will have more and more different types of accelerators to compensate for the performance plateau of general-purpose CPU. These accelerators will be useful only if the software is designed with the ability to target this specific hardware. New software development methods must be proposed to handle this issue while at the same time, new software stacks with specific compilation and runtime tools are needed.

We have also noticed that there will be a strong pressure to propose **energy efficient software**. At the same time, we see a trend to use high-level interpreted languages, as Python, Julia or domain specific languages, to increase the productivity of the programmers. These languages are not

renowned for their efficiency. In this context, to tackle the challenge of energy efficiency at software level, we must develop an environment that will be able to transform codes programmed with high-level languages into software components that are less resource hungry. Proposing software development methods that can predict and optimise the energy consumption of the software is a complementary option to advance towards lean software.

The software industry faces moreover the challenge of increasing its **productivity**. Software engineers are a scare resource at a time where/when we need to develop even more software. The productivity issue can lead to new methods based on reuse of on-the-shelf software components. We see more and more Community effort to provide software commons that can be reused, thus improving the productivity. In many cases, new tools can support the production of variants of existing software. These can monitor their dependencies generate the relevant new tests, thus speeding-up the processes their production and validation.

In summary, software engineering is a very active field with several challenges requesting new approaches. Its progress will have a strong impact on our ability to timely and efficiently develop all the software innovations needed by the other sectors analysed/presented in this document.

2.8. Safety and security

The digital revolution has a huge potential in all stages of our lives, but it also increases both the dependencies of critical infrastructures from IT and the potential surface for cyber-attacks on these new systems, putting us under the pressure of hackers (for fun, for money, activist, state…). Any digital transformation must therefore be associated with a strong effort to ensure safety and security.

The first challenge is the **resilience** of the critical infrastructures that now depend more and more on IT systems. Our society is supported by critical infrastructures as hospitals, transportation systems, energy production and distribution systems, telecommunication systems that need to be resilient against either failures or attacks. To design resilient systems there is no silver bullet but a collection of methodologies and technical tools that can help towards this goal. The main methodology is linked to an analysis of the risks, either of failures or of attacks, and the elaboration of contingency plans to react to negative events. In addition, some root-cause analysis approaches can be used in conjunction with isolation methods. One effective approach is to build a system of systems where the failure of one system can be compensated by the activation of others. The introduction of digital twins is appealing, as it will help to test more situations and thus to improve prediction. All the methodologies and approaches targeting the design and the operation of resilient systems must be supported by new software solutions.

The increasing complexity of the economical networks creates the need to develop **collaborative security**. In many industrial sectors, we now have a complex supply chain, more stakeholders that need to exchange information, services or goods and, at the same time, the ambition for greater efficiency, to closely integrate all the IT systems of these actors. This leads to the challenge of collaborative security where we must manage the trust that can be given to the different players of

the game and the risks associated with the collaboration. New approaches and solutions must be proposed to tackle this issue.

The digital revolution also introduces a new concept of **digital territories**. This concept can be applied at a multi-states level, national level, but also at enterprise level. It relates to the idea that in the digital space, there is a perimeter where each of us want his/her regulations or internal rules to be applied. The management of this digital territory is not easy, and we often find fuzzy borders in the digital space. Again, new approaches and software solutions must be offered to the organisations that have the legitimate ambition to control their digital territory.

Improving cyber security led to the deployment of different IT tools and methods but most of the time we still lack **global vision** of security and face a question of **assurance**. The use of heterogeneous security tools (network surveillance, identity management, access control…) and also sometimes the existence of multiple IT systems with different security tools make it difficult to have an integrated view of the protection level and the risk coverage. At the same time, we also need to check the compliance with regard to regulations, which in turn can be complex in the case of global companies that have to cope with different legislations. Therefore, there is a need for new approaches to give a global vision of the level of security reached and to assess the current compliance. These new solutions will enable a better management of the cyber security and provide assurance related to regulations.

As we have seen, digitalisation introduces more threats and more complexity in the systems to monitor, while the cyber security specialists are a scarce resource. Therefore, we face an **automation and real-time monitoring** challenge. We need new software solutions that can be more efficient than the current tools and rely less on cyber security specialists. AI methods have an interesting potential to meet this goal. It is also important to address the challenge of **usability** of the security solutions. Often security tools introduce barriers that are too cumbersome for the users who consequently try to use a workaround them, thus introducing severe risks. More user-friendly AI methods can be a good research direction to solve these different challenges.

3. Agility

The analysis of the technology trends and the ITEA 4 challenges gives us an interesting vision of the domains that should be addressed by the programme. However, we must remain humble and keep in mind that the prediction of the future in the IT field is a difficult task. History clearly shows that, in this very dynamic sector, many innovations have been a posteriori meaningfully explained but were not predicted beforehand. To protect ITEA 4 from developing a too rigid predefined research agenda, we plan during its timeframe to continuously adapt the programme and to develop an agile approach to guide us towards the best software innovations.

ITEA 4 will put in place several processes to further expand the well-known and long-established ITEA flexible and bottom-up approach in order to quickly adapt itself to the fast-changing environment and to address the urgent needs of its stakeholders, i.e. the industry and the Public Authorities.

The intense **dialogue established with the projects** will greatly help ITEA 4 to remain agile and focused on the right priorities. The set of ongoing projects is a very strong asset and can be viewed as a network of sensors that directly report to ITEA 4 the information from the technology and market fields. The running projects involve at any given time about 500 organisations that are part of the ITEA Community. The project partners from universities, research institutes, small and medium-sized enterprises as well as large companies are able to exchange with us information either coming from the latest technology progress or the new market trends thanks to the high-quality and trustful dialogue that has been established and will of course be kept throughout ITEA 4. The yearly reviews conducted with each project belong to this powerful toolset. These meetings serve to report the activity of the projects and in addition to discuss the evolutions, the lessons learned, and the new ideas generated by the ongoing research. The open mindedness and the sharing spirit of this assessment guarantees the fruitfulness of this intense dialogue. Additional exchanges of information with the projects, through the regular Project Progress Reports and joint communication activities, are other opportunities for ITEA 4 to learn from the projects. With our already bootstrapped set of projects, ITEA 4 will benefit from a strong instrument frame to set the right priorities and push for new relevant projects.

The **Project Outline Preparation Days** (PO Days) is another instrument contributing to the agility of ITEA. This event is organised every year for our Community to work on the preparation of proposals to the bottom-up Calls (which have a two-stage process with a Project Outline, explaining the name of the event, followed by a Full Project Proposal). The event is open and welcomes newcomers in addition to the existing ITEA Community. It works as a collaborative brainstorming on interesting ideas that could be transformed into ITEA research projects. Due to the mix of past participants that have already experienced the advantages of this approach and the newcomers, the event is very productive and the origin of most of the POs that are submitted to the bottom-up Calls. A dedicated IT tool supports the brainstorming process and helps the idea owners in both structuring a research proposal and forming a strong consortium to tackle the identified challenges. The IT tool is then used throughout the project lifecycle and helps to minimise the administrative burden of project management. The PO Days are a very active event (even the last one that was held online) and a way

for ITEA to collectively produce relevant projects. We will continue to organise this yearly event throughout the ITEA 4 programme.

ITEA 4 will also continue to organise thematic **international customer workshops**. These events gather on one hand some key customers in a specific domain and on the other hand technology providers. It is a win-win dialogue where the technology providers learn about the customer challenges and needs, and the domain stakeholders get a vision of new developments that can be relevant for them. In addition to this mutual information exchange, the participants are able to brainstorm together and we have seen several very relevant research project ideas emerging from these workshops. For ITEA 4, the international customer workshops will continue to be a powerful tool both to keep its focus on priorities that can really have an impact on the customer needs and at the same time to generate new projects.

In addition to these international customer workshops, ITEA 4 will put in place **customer advisory boards** in some of its key domains of interest. These boards will be an instrument to further stimulate a continuous dialogue with key stakeholders. For some of the eight identified ITEA 4 challenges, we plan to gather a reduced but strong team of important players with a customer profile and to organise events with them on a regular basis. The objective of the customer advisory boards is to steer continuously our innovation projects towards customer needs and so to increase the potential of impact of the ITEA 4 programme.

ITEA 4 plans to continue and even increase its participation to **customer-oriented events** as international sectorial fairs. These events provide an opportunity to reach a greater audience and to showcase the results of the projects increasing the impact of the programme. At the same time, this is a way to meet new organisations that can enrich the ITEA 4 Community and become partners of projects. These events also belong to our continuous analysis of the market trends and help us to detect new challenges or customer needs that then can be translated into project ideas to be developed by the ITEA 4 Community.

All these activities will serve our ITEA 4 objective to be agile and to quickly identify new technology and innovation trends. This keeps us being able to set up relevant projects and to develop results that can be introduced to the market in a timely manner.

4. ITEA 4 vision on topics for future Calls

The technology and 'challenges' vision and our agility objective presented in this document leads ITEA 4 to propose a programme of Calls within the ECP framework.

ITEA 4 plans to organise a **bottom-up Call each year**. The main reasons for these bottom-up Calls are:

- We want to offer our Community the opportunity to come with new ideas that have not been foreseen and anticipated.
- The ITEA 4 domains of interest are broad and the openness of bottom-up Calls offers opportunities to propose research projects for all the identified challenges and technology trends at least once a year.
- The bottom-up Calls help to get a smooth flow of projects on each ITEA 4 challenge and to have a continuous coverage of these topics while keeping our ability to correctly follow the evolution of each topic and to have an impact on them.

The bottom-up Calls have already shown their effectiveness and efficiency throughout the ITEA, ITEA 2 and ITEA 3 programmes and benefit from a strong support of the industry. ITEA 4 plans to continue this successful path and to further improve this instrument with more activities to generate strong project ideas for these Calls.

In addition to the bottom-up Calls, ITEA 4 plans to propose some thematic Calls within the ECP instrument of Eureka. These thematic Calls will be either technology driven or oriented towards a specific challenge. On the technology side, the most relevant topics are:

- **Digital loop**: this topic could be named 'digitalisation', but we prefer the concept of 'digital loop' which highlights that the complete value creation arises when we are able to close the loop and to control and optimise complex systems. This topic includes the development of the **digital twin** concept, which is a way to provide a digital representation of the system of interest (used) in conjunction with the control and optimisation of the real system. The digital loop topic is central for all the IT current developments and a concern for every sector aiming to benefit from the digitalisation. With this theme, we expect to foster research on topics such as IoT-based systems, complex workflow architecture and deployment, simulation and modelling methods, and predictive maintenance.
- **Artificial Intelligence**: although we already have significantly invested in AI research, we need to further expand this effort to exploit this set of technologies to its full potential. We must continue to foster research on the application of AI methods in various sectors (industry, health, transportation…), including the field of software design and operation. It is also important to address some of the current AI limitations by developing more advanced AI methods. We can expect to progress in domains such as hybrid AI (coupling of AI and other methods), smooth integration of AI at the edge and AI in the data centre or explainable AI.
- **Cyber security**: our increasing dependency on IT systems calls for a larger effort on cyber security. We must protect the critical infrastructures and more globally IT systems against cyber-attacks. The current security level of most IT systems is not satisfactory, and some progress is needed. A Call on this topic can contribute to significant advancements in

domains such as collaborative security, compliance and assurance management, automation of cyber security and improved usability of security tools.

ITEA 4 also plans to promote Calls related to challenges. These Calls differ from the previous ones, as they are not prescriptive on the technology approach but want to address the needs of a specific sector or Community. For these challenge-oriented thematic Calls, ITEA 4 priorities are:

- **Smart green city**: cities have a central role in organising economic and social activities. For many issues, the city is the most effective level to propose and implement solutions. It is also easier to experiment new solutions at city level before planning a broader deployment. We can progress in many domains with more investments in research targeting the objective of a smart and green city. Among them we can mention more active citizen participation, local energy grids, multi-modal transportation system, crisis management system or planning development systems.
- **Smart health**: the conjunction of new medical instruments (imaging, robotics, genomic sequencing), availability of data and digitalisation of the health value chain opens new opportunities that research projects can seize. We expect, from some additional research investments in this field, strong impacts in drug discovery, personalised treatments, patient pain reduction in clinical treatments, optimisation of the healthcare chain and improved recovery levels.
- **Smart industry**: the industry faces great opportunities but also fierce competition. A thematic Call on Smart industry will help to seize the opportunities of digitalisation to optimise the production and the related services as well as to adapt industry to the new environmental context. Its expected impact will be a more integrated supply chain, an increased ability to personalise the products and more efficient production means.
- **Smart engineering**: with this topic we target the community that develops and operates the software systems now supporting most of our activities. As our dependency on software increases, we need to improve its quality, to master more complex software and increase the productivity of software developers. The data driven development trend has to be integrated within the DevOps tools. Such a Call can also have an impact on the energy efficiency of the IT infrastructure.

For these thematic Calls, both technology driven and market oriented, ITEA 4 plans to join the Joint Calls of the new ECP instrument. We hope to find with the other ECP Clusters some common interests for the topics described above. If this would not be the case for some topics, we might still launch them as ITEA 4 Calls with the support of the Public Authorities, in order to progress on these important subjects.

Nevertheless, we are very confident to find common grounds and to issue Joint Calls. We hope that this analysis can be shared by the other ECP Clusters, and are at the same time convinced that important synergies can be developed with them. ITEA 4 sees common interests with all the existing Clusters. Some of them are mentioned below:

- **Penta-Euripides²:** as already mentioned, no software innovation comes without a hardware platform to support it. Therefore, we need the innovations developed by the Penta-Euripides² Communities. A collaboration between hardware and software designers can deliver important benefits especially as one trend refers to the development of accelerators targeting some application domains. Software also needs to interface with API and libraries coming from hardware platform providers and again cooperation is valuable here. Simulation and modelling are methods used by both Clusters and we can again find synergies on these topics.
- **Celtic-Next:** telecommunication networks of all ranges are central to any complex IT system and the development of new telecommunication services can have a great impact on the software architectures of the applications targeted by the ITEA 4 Community. Telecommunication is also one of the most software-intensive sector and we have common interests on software engineering and the emergence of more energy efficient IT infrastructures.
- **Eurogia^{2020}:** the development of new technologies for energy can be supported by software where it can e.g. help to optimise the energy production or better handle the balance between supply and demand. Eurogia^{2020} and ITEA 4 also share the objective of reducing the carbon footprint and can work together on innovative solutions aiming at this goal.
- **Smart:** advanced manufacturing and software innovations are closely related. Most of the manufacturing innovations will include a software layer that can benefit from interaction with the ITEA 4 Community. On the reverse side, new robots, for example, will be important means to solve some of the ITE4 challenges in Smart industry, health or mobility. The two Clusters also share the issue of human-system interaction and can find some synergies in this field.

In addition to these synergies with other Clusters, ITEA 4 also expects ECP to further develop its links with the Public Authorities. The precise objectives of the thematic Calls will be defined in close relationship with the PAs in order to take into account their priorities and research strategy. This interaction will represent a central step before taking the decision to launch thematic Calls.

ITEA 4 is also ready to work with the PAs on new ideas to foster innovation. The Eureka Cluster concept has proven to be an effective partnership between Public Authorities and industry to manage research programmes. Its agility, its impact and its efficiency (time from idea to project as well as management costs) have demonstrated its ability to compete with other models. We can imagine expanding the success of this partnership for research programmes to other services aiming to boost the innovation in the participating countries. ITEA 4 has the ambition to serve this objective and to be a toolbox for the PAs and the industry willing to develop new initiatives with a strong target of innovation.

ITEA 4

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ITEA is the Eureka Cluster
on software innovation