The Sensing Enterprise
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EXECUTIVE SUMMARY

Our digital society is giving rise to diverse expressions of entrepreneurship, up to the point that it is redefining the meaning of the word 'enterprise' in a context where 'the network is the business'. The almost organic combination of two Internet research domains, the 'Internet of Things' and the 'Future Internet Enterprise Systems', engendered a new Quality of Being necessary to overcome future competitiveness challenges, the 'Sensing' capability. The 'Sensing Enterprise' would then be an enterprise making use of the sensing possibilities provided by interconnected 'environments', anticipating future decisions by using multi-dimensional information captured through physical and virtual objects, and providing added value information to enhance its global context awareness.

This article goes beyond an implementation of the Internet of (Nano-)Things to the enterprise context, and explores different scenarios for the re-instantiation and re-definition of the Enterprise concept in a given techno-culture. Furthermore, it reaches out to more traditional sectors of the economy, like the manufacturing sector, and argues that the integration of sensing capabilities will unavoidably and fundamentally change the way these sectors would develop, collaborate and link with their stakeholders. This will give birth to a new, more resilient, enterprise.

The authors strongly believe that one of the valid models of successful enterprises of the future will be the one of organisations quickly integrating the paradigm of intelligent sensing virtuality in their business and organisational strategy. This is why Europe needs to research and develop a new generation of sensing networked systems going beyond current enterprise systems to fully exploit the promised potential.

We ought not to forget that any description of the world by means of mechanics will be of the completely general kind. For example, it will never mention particular point-masses: it will only talk about any whatsoever.
Ludwig Wittgenstein, Tractatus Logico-Philosophicus, 6.3432

Take it in what sense thou wilt.
Shakespeare, Romeo and Juliet

Introduction

Our societies are changing continuously, and so are our organisations. Today’s networks create a myriad of new possibilities. They transform collective intelligence, making it ubiquitous and coordinated, and helping it to enhance our interactions in real time. As access to knowledge progresses and net technologies pervade almost all aspects of life, interactions between social actors and machines are also evolving. In the business context, the compound provision of digital services and the effortless access to (open) data is also spectacularly modifying the way in which we are doing business.

1 European Commission, DG CONNECT 02. The views expressed in this paper are those of the authors and do not necessarily represent the views of, and should not be attributed to, the European Commission. Any mistakes are obviously the sole responsibility of the authors.
The evolving notion of ‘enterprise’ was already identified in the 2011 FInES Position Paper\(^2\) as a result of the evolution of business in the forthcoming Knowledge Society. The authors of this Position Paper, presenting the views of the FInES community members, previously claimed that the digital society is giving rise to, and even already sustaining, diverse expressions of entrepreneurship, up to the level of individuals being (at the centre of) the enterprise. They labelled this rising phenomenon in the digital world with a simple aphorism: ‘everyone can be an enterprise’.

The authors explored key concepts of business and economic theories, and integrated new ones, observed the fusion between governmental organisations, enterprises, employees, consumers and citizens gradually dominating the business landscape, proposed new paths to encourage business ideation, and more. This led to practically redefining the meaning of the word ‘enterprise’ and concluding that ‘the network is the business’. In support of this claim, publicly-funded European research in ‘ICT for the digital enterprise’ opened up to alternative research landscapes to move its focus from continuous improvement to continuous innovation. A new era for the European enterprise could be envisaged.

*Business as usual* cannot be the answer to the complex changes that we are facing today. Enterprises need to find new means to leverage their performances. In this context, the FInES Cluster has identified several *Qualities of Being*\(^3\) that the enterprises should acquire in order to overcome these challenges and build successfully a new economy supporting societal needs. These *Qualities of Being* are not mutually exclusive, nor are they necessarily all together. Future enterprises should be *humanistic, community-oriented* and *cognizant*, fully integrating the human capital by putting people at the centre of the activities, and creating common, shared knowledge, wealth and well-being. They should also be *inventive* and *agile*, while having both a *glocal* – local and global – perspective. At the same time, they are urged to consider impact on the environment and fully integrate *sustainable* processes. In integrating such a high degree of adaptability, the boundaries of the future enterprise are likely to become increasingly fuzzy, thus creating a *liquid* enterprise that barely distinguishes between what is ‘inside’ and what is ‘outside’.

A beneficial instantiation of these ‘Qualities’ can be found in the combination of the Internet of Things and Enterprise Systems research domains leading to a new paradigm that we will call the *Sensing Enterprise*. This innovative concept has been first coined by the Future Internet Enterprise Systems (FInES) Research Cluster with the support of the European Commission in various publications and events\(^4\). The FInES community acknowledged the fact that businesses are facing unprecedented challenges, given the current economic crisis, but also more systemic changes related in particular to the shortness of resources, environmental changes, and ever changing societal needs. Therefore our enterprises are desperately in need of innovative ideas to adapt to these changes and remain competitive, or sometimes, even simply survive in the digital era. The *Sensing Enterprise* concept is an attempt to reconcile traditional (non ‘pure’ Internet) organisations with the tremendous possibilities offered by the cyber worlds (from the clouds to the dust). This is the concept that the authors of this paper would like to introduce and define.


\(^{4}\) See Annex 1 of this article.
1. Towards a definition of the Sensing Enterprise

In the 2011 FInES Position Paper\textsuperscript{5}, the Sensing Enterprise is described as an enterprise anticipating future decisions by using multi-dimensional information captured through physical and virtual objects and providing added value information to enhance its global context awareness. That is to say, the enterprise will not only capture selective information from the environment (physical, virtual and social), but it will also integrate decentralised intelligence into its decision-making process.

After one year of considerable discussion and debate, there is growing consensus in Europe on the objective of collaborative research and innovation on Sensing Enterprise. The authors therefore propose the following vision for the Sensing Enterprise concept as a result of these conversations:

By 2025, building upon advances in Internet technology, Sensing technology and Virtuality, business actors will create and implement strategies and new uses among a multiplicity of connected objects, both physical and virtual, by developing ad hoc sensor networks that allow intelligent fusing of data from disparate devices and bringing of real world and real-time information into fully immersive virtual worlds and vice versa.

Because of the ‘organic’ link between the Sensing Enterprise and the Internet of Things, it is necessary to specify what the latter means for the enterprise world. The Internet of Things is about ‘Internet’ (i.e. the ‘ad hoc sensor networks’ and associated enabling technologies) and ‘things’ (i.e. the ‘disparate devices’ from where data will be fused). We shall detail the two components of the concept separately.

1.1. The Internet dimension

First, on the Internet side, the Internet of Things will develop and thrive in the new competitive environment at the confluence of nanoelectronics, communications, sensors, smart phones, embedded systems, cloud computing and software. It will provide ‘things’ with the capability to be connected all the time everywhere and to support unprecedented product and process innovation affecting a wide array of industrial sectors. The Internet of Things will create smart environments/spaces such as Smart Energy (voltage and power sensors, meters and breakers, and fault detection for the Electric Grid), Smart Transport (ITS, HEVs, electric vehicles), Smart Cities (lighting, water management, monitoring & security, and traffic control for Connected Communities), Smart Living (independence through technology, information-when-you-need-it, and connected-when-you-need-it for Entertaining and Leisure), Smart Health (people monitoring, bio-sensors and probes, and remote health for the Healthcare System), Smart Buildings and Homes (thermostats, HVAC, lighting, presence sensors, lockers, actuators, meters, smart-plugs), Smart Planet (environmental sensors, water and power leak detection, and pollution and weather monitoring for a Green Environment)\textsuperscript{6}.

Today, ubiquitous networks consist of all types of automated wireless technologies working independently or together to identify, locate, and detect the security or condition of objects as they move through the enterprise value chain. These networks then transmit their data to a


centralised information system or, with progress in Autonomic Computing which allows the systems to self-manage complexity and in the Internet of Things which exponentially increases the scale and the complexity of ICT systems, tend to become self-adaptable, self-organised, self-optimising, self-configuring, self-protecting, self-healing, self-description and self-discovery networks in which objects can make autonomous decisions on behalf or for human beings and social organisations7.

For the Future Enterprise, this means that its IoT environment (which could be as vast as the Universe itself) will sense and alert in real time the deviations caused by internal and external events and will collaborate and respond to these deviations across the extended, ‘liquid enterprise’8. Continuous awareness leverages all types of sensors to integrate object information, thus providing the enterprise with ‘sense and respond’ capability regarding a wide-ranging set of business stimuli. The Sensing Enterprise is characterised by decentralised intelligence and fusion between the virtual world and the real world, but it also implies context awareness, dynamic configurability and multi-identity oriented virtual entities.

**Context awareness**

The Sensing Enterprise receives real time information about its environment – an environment which is ‘global’ by nature, with tweets, sensing information, RFID or GPS data being a few examples of underlining technologies and applications that leverage the sensing capabilities of the enterprise. Real-time information from both the physical and the virtual surroundings of the enterprise is fed constantly into its decision making process, whether the latter is still controlled by the ‘subjects’ (i.e. the human beings) or by the ‘objects’ (i.e. the various sorts of IoT-enabled artefacts).

**Dynamic configurability**

Dynamic configurability is needed to support a system with a great deal of flexibility in how it operates. Since IoT systems are potentially made of thousands of nodes and devices, such as sensors and actuators, their configuration is therefore complex and even ‘strategic’ for enterprises where the security of the information infrastructure is critical. Dynamic remote configuration facilities need to be provided for enabling self-management applications to automatically configure the parameters required for the applications and the users.

**Multi-identity oriented virtual entities**

Access to and usage of IoT systems will restructure the DNA of the enterprise. Is the modern car manufacturer in the information delivery business (bits)9 or in the manufacturing business (atoms)? The same question could be asked for a large and growing number of businesses. The point here is that the Sensing Enterprise is one where the division between atoms and bits is blurry. This suggests not only the changing nature of the enterprise that integrates more and more technology into its ‘fabric’, but also a continuous flow of digital information. Smart

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7 Man-Sze Li once used the term of ‘self-reinvention’, which may indeed well be used to summarise all the ‘self’ elements mentioned here.
9 We consider here ‘sensors’ as Smart Sensing Entities (SSE) including RFID classes 4 and 5, sensors, actuators, smart cards, medical devices, navigation devices, embedded systems, PLC, and all other devices that allow access to databases and processing units for updating and upgrading processes, can be identified, and are able to interact.
10 For example, electronics in today’s car already exceed 35% of the total vehicle value.
objects are becoming actors in the enterprise, a sort of ‘second rate’ employees. They will increasingly act on their own and react to exogenous and endogenous stimuli. They will be themselves multiple instantiations of the enterprise.

Within the theoretical framework described above, a Sensing Enterprise would be an enterprise making use of the sensing capabilities provided by interconnected environments, as described in the Internet of Things vision, opening the enterprise to a new spectrum of opportunities while exploiting new development areas.

The Enterprise world will of course not remain unaffected by the Internet of Things – and later the Internet of Nano-Things (i.e. nanomachines endowed with communication capabilities and interconnected with micro- and macro-devices)\textsuperscript{11}. Object-to-person communications, and vice versa, and object-to-object communications will dramatically influence logistics (quality of shipment conditions, item location, storage incompatibility detection, fleet tracking) and industrial control (M2M applications, indoor air quality, temperature monitoring, ozone presence, asset indoor location, vehicle auto-diagnosis), thus changing the factory to make it more productive and reducing waste – i.e. a Sensing Factory (smart, adaptive, autonomous, and ambient machines) – but more broadly metamorphosing the enterprise to make it adopt some or all of the features of a Sensing Enterprise. In other words, the rise of the Sensing Enterprise is more than an implementation of the Internet of (Nano-)Things to the enterprise context, or just a new market opportunity for developing innovative business applications. It is, above all, a re-instantiation and a re-definition of the Enterprise concept in the digital era. We suggest thus a step further in the theory of organisations, which could lead to a disruptive way of doing business in the future.

1.2. The Things dimension

Second, on the Things side the objects will continue their evolution. Adopting the terminology used by Bruce Sterling\textsuperscript{12}, we can identify six overlapping stages in the history of objects which are intimately related to certain types of businesses and economic landscapes (technocultures) that exist at a given time:

- the Artifact (early civilisations), a simple object made by hand, used by hand, powered by muscle – the typical users are Hunters and Farmers;
- the Machine (industrial revolution), a complex and precisely proportioned artifact with integral moving parts using a non-human/non-animal energy source – the typical users are Customers;
- the Product (mass production era), a widely distributed commercially available object anonymously and uniformly manufactured in massive quantities – the typical users are Consumers;
- the Gizmo (our current technoculture), a highly unstable, user-alterable, baroquely multi-featured object, commonly programmable and generally of a brief lifespan – the typical users are End Users;
- the Spime (our next technoculture), a ‘space and time’ manufactured object, designed on screens, fabricated by digital means, and precisely tracked though space and time;


throughout its earthly sojourn, whose informational support is so overwhelming extensive and rich that it is regarded as one of the promises of big data, the material instantiation of an immaterial system – the typical users are Digital Trailblazers;

- the Biot, a biologically engineered object, the blurring and logical intermeshing of the boundary between humans and spime, which means that it is both object and person – the typical users are Cyborgs\textsuperscript{13}.

Whatever terminology is used and prophecy is chosen, the important point is that ‘objects’ have never been and will never be fixed entities but rather temporary and evolving representations of a given technoculture. This is true also for the enterprise where today the value of a ‘machine’ lies more in the information it contains than in the labour time spent in manufacturing it. The Sensing Enterprise will be a sort of radar in perfect osmosis with an ecosystem of ‘objects’ supported by several private area networks (PANs) and delivering in real time a wealth of unstructured data, not only more data but also new data. Artificial intelligence techniques will transform the collected data into knowledge and will enable almost instantaneous decisions. We can contemplate many different scenarios and possibilities. For instance, ‘sensors’ may not be strictly object-related and bring data directly from the virtual world, as it would be the case of ‘social media sensors’ feeding into the business process information. In other scenarios data/information/knowledge could become commodity, i.e. one enterprise owns the objects, sensors and networks, but other companies can use them to provide value added services. In this new horizon of possibilities, the sky is the limit.

2. The Sensing Enterprise: A response to the decline of Europe’s manufacturing industry?

In 2011, the top 200 global manufacturing companies invested more than 160 billion euros in research and development of new products\textsuperscript{14}. As the manufacturing industry is clearly an innovation leader in terms of patents, spending on research and development, and introduction of new products. Europe just cannot let its manufacturing industry tumble.

Yet the situation in Europe is challenging due to a changing world: the enlargement of the Union with its effects on the domestic EU market, on specialisation and its associated economies of scale and scope; globalisation with decreasing resources becoming more mobile, economies becoming increasingly interdependent and competitive, and financial markets becoming increasingly abstract and uncontrolled; consumer demand moving towards more customised services and imposing contradictory requirements on manufactured goods (such as low-cost quality or ‘glocal’ products); demographics; the pace of technological change, in particular in ICT\textsuperscript{15}. Therefore, EU integration, globalisation, shifting demand and progress in science and technology, and innovation will all have a major impact on how the manufacturing landscape in Europe in terms of location, production and distribution of labour will manifest itself in the future. Change creates opportunities but also brings new threats,

\textsuperscript{13} This is not to say that ‘cyborgs’ are not a reality today, but their nature, role and capabilities are likely to be drastically enhanced by the Internet of Things.


\textsuperscript{15} ICT pervasively intrude people’s lives to the benefit of business, consumer choice and further customisation, education, health and the overall quality of life. Automation and the reorganisation of business processes in combination with auto-ID technologies (e.g. RFID) transform regional and global value networks and supply chains.
especially for Europe, and its peoples. Europe is still a union in the making exposed to considerable internal and international challenges.

Let us face a dismal reality: the trend of a sliding share of manufacturing in value added and employment may not be reversed in the next decades. Manufacturing is no longer the steering engine for Europe's economy and provider of massive employment. The value added applied to manufacturing products, but also the overall share of manufacturing in employment, have decreased in Europe over the last three decades, reflecting structural changes in the economy. However, manufacturing industries in Europe still employ today over 40 million workers, and underpin economic growth, job and wealth creation (productivity rises in industrial sectors are much higher than in services). They are also a source of technological progress and innovation, they create solutions for societal problems and sustainable development, contribute substantially to the equilibrium of Europe's trade balance (industrial goods represent three quarters of Europe’s exports), and drive demand for industry-related services (every industrial job creates two extra jobs in the service sectors).16

Therefore, the future of manufacturing is essential for the economic growth and quality of life in Europe. In 2025 Europe's share in the overall global manufacturing production and trade will be about 20% (higher than its share in population) and manufacturing will contribute more than 15% to value added in Europe17. Manufacturing will remain the most important driver for Europe’s exports. A further strengthening of the internal market and adequate research and innovation policies can have a substantial impact on these shares; both are within reach of EU policy-making.

In order to rise up to the challenge, the EU manufacturing sector, evolving from a product-oriented towards a service-oriented perspective, needs to reduce the complexity and reduce the current limitations of manufacturing systems and processes. Partnerships with cutting-edge players of enterprise software are possible, and even necessary in order to move away from incremental research and spark off deep innovation. Besides investment in, and inclusion of Internet technology to accompany the evolution of the manufacturing sector, the prospects of the sector will also depend on complementary organisational changes, including, in particular, management practices and decentralisation, innovation, and skills development. The ‘digital divide’ between forerunner enterprises (mostly Internet-based) and the manufacture remains large and the manufacturing sector urgently needs to develop its own distinctive approach to innovation, which guides its strengths and capitalises on its values, and fosters a new innovation culture.

The progressive adoption of Internet technology by the manufacture needs to be enhanced by the most promising developments relating to the Sensing Enterprise. Manufacturing enterprises will be supported in the future by smart components providing global and physical awareness to the business systems of the manufacture value chain to enhance their overall context awareness. These components could be sensors, tags, tweets, personal assistants, intelligent agents, smart objects, crowd-sourcing knowledge, natural interfaces, and so on. They should allow a continuous awareness and improvement of business operations in a digital environment. This new kind of enhanced connectivity and information gathering will be such a structuring resource that it will unavoidably change the core of the way the

16 Source: http://www.industrialpolicy.eu/EMF/The-need-for-a-strong-industrial-base-in-Europe
manufacturing enterprise develops, collaborates and links with its stakeholders, giving birth to a new manufacturing enterprise.

Among the trends that can be mentioned as epitomising the pinnacle of progress in the manufacturing industry are the new wave of robots and the emergence of fab labs (FABrication LABoratories).

On one hand, in the future, Internet of Things enabled robots will be to industrial robots what the personal computer was to the mainframe and the minicomputer, or the iPhone was to the traditional phone. What we could call 'robiots' – cheap, easy-to-use robots that will be 'informed' by smart things about how to use them – will bring robots to the factory, business and even home, and will in particular take over multiple tasks for small manufacturers, who cannot afford traditional, expensive robots. While traditional robots are not flexible and require a long time to program for one repeatable task, future 'robiots' will be taught not only by humans but also by various sensing objects at business or factory level about the specific task which they need to do and, through a learning process, they would re-programme themselves for new tasks.

On the other hand, fab labs - i.e. small-scale workshops equipped with an array of flexible computer controlled tools that cover several different length scales and various materials - will be part of, and support the trend towards the Sensing Manufacture. The idea is as simple as its application is difficult: if all cans, books, shoes or parts of cars are equipped with tiny identifying devices, a new paradigm of manufacturing will soon unfold. Things like running out of stock or wasted products will no longer exist as we will know from sensing objects (and perhaps 'robiots') exactly what is being consumed on the other side of the globe. The Internet of Things will actually be used for the collaborative development of everyday objects and will allow tracking the product-cycle of these objects in order to increase their efficiency and sustainability. In the long run, the fab lab phenomenon will obviously not substitute to mass production but will complement it and intensify and expand the shift from the ‘walled manufacture’ to the ‘liquid manufacture’. By enabling ‘almost anyone’ to make ‘almost anything’, including using smart sensors realised with Micro Electro Mechanical Systems (MEMS) and Nano Electro Mechanical Systems (NEMS), we will be approaching the vision of the Future Enterprise, at the confluence of the ‘liquid enterprise’ and the ‘sensing enterprise’.

Europe needs to create smarter businesses, newly exploiting one of the human dimensions of intelligence brought by the latest developments in the Internet of Things: the sensing capacity. A concept like ‘Sensing Manufacture’ should be explored through investments in specifically targeted research, while at the same time benefiting from the results achieved in the Future Internet activities. The ultimate impact expected, as suggested by the Innovation Union Communication and the Interim Assessment of the Future Internet PPP, is a globally more

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18 Source: from frequent and extensive discussions between Gérald Santucci and Rob van Kranenburg, founder of Council. Today the fab lab concept is an anticipative fantasy - domestic 3D printers generally using plastic, silicon sealant, chemical reactant or even chocolate (http://www.chocedge.com/) can print a vase but not yet a car!


sustainable and competitive European industry through the optimisation of resource exploitation and, eventually, improvement of innovation capacity. At stake is a myriad of opportunities for countless actors in the business landscape in Europe.

In 20 years and more, successful organisations, in particular enterprises, will be those capable of quickly adopting the new paradigm of intelligent sensing virtuality in their business and organisational strategy – mobility, adaptability and context-awareness will appear at the forefront of business innovation. Europe needs to research and develop a new generation of sensing networked systems going beyond current enterprise systems to fully exploit the potential of the next generation Internet and its capacity to support new notions of business behaviours, forms, and values.  

We need to support research and development activities but also targeted innovation in order to attain WYSIWYG (*What You Sense is What You Get*) systems at design-time and a dynamic proactive collaboration of intelligent hardware/software components at runtime. Smart components will provide global awareness to the systems and eventually empower the business people using them. These components could be personal assistants, tags, intelligent agents, intelligent social networks and crowd-sourcing knowledge media in the area of Open Innovation, allowing a continuous awareness and improvement of enterprise systems. Additionally, interoperability between these systems is required.

We need technology aimed at ‘hiding’ technology. With smart objects interacting with the environment, among themselves, with people, on the network and on behalf of the enterprise, and augmented and virtual reality becoming more and more present, the interface between humans and technology is steadily moving away from the keyboard-terminal model. This is not only an opportunity for enhancing smart objects, but mostly a chance to simplify contact with technology, make it more intuitive, more natural to the human mind-set and reduce the digital divide. Furthermore, this refocuses (human) intelligence on value-producing activities.

The final outcome would be the development of a new infrastructure for networked systems, a new generation of technologies in support of applying Internet to the business space (beyond ‘Enterprise 3.0’), methods and tools to support knowledge sharing within business ecosystems (clouds, clusters, etc.) and new scientific foundations to produce enterprise system offerings that are rested on and subject to the rigour of science.

3. **Reaping the benefits of the Sensing Enterprise: a challenge for Europe**

The innovative vision on the Sensing Enterprise – if properly encouraged- is expected to have huge impact at economic and societal levels in Europe, and elsewhere. In the words of Brian Arthur, a *second economy* ‘is silently forming – vast, interconnected, and extraordinarily productive.’ It is a digital economy built by sensors and machines that communicate with one another without the intervention of humans. Not only is this economy extremely fast growing, but it is also producing value, intangible value, that needs to be – and partially is – valued. ‘In fact, I’m beginning to think of this second economy, which is under the surface of the physical economy, as a huge interconnected root system, very much like the root system for

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aspen trees. For every acre of aspen trees above the ground, there's about ten miles of roots underneath, all interconnected with one another, 'communicating' with each other. (...) In 2025 the second economy will be as large as the 1995 physical economy. (...) In two to three decades, it will surpass the physical economy in size.’ Posing a new question now, that is ‘what will the word ‘οἰκονόμος’ (‘economy’ in Greek standing for ‘household management’) mean if the household is virtual and its management pervasive?’

The particularity of the second (sensing) economy is its capacity to self-reconfigure on the fly and to create new connections at any point. In this context, new business values need to be considered and valuated, of both tangible and intangible nature. Thus, by using the Internet of Things to its full capacity, enterprises can respond intelligently to their environment and make use of new resources otherwise latent. Multiple dimensions and multiple stakeholders add to this sensing perspective, coming from the sensing net, the web-based net, the mobile-net, the virtual-net. Similarly, multiple research and market actors are contemplated (users, applications, agents, objects, data providers, etc.) to create exponential possibilities of innovative business. Innovative software companies, current infrastructure owners, as well as Future Internet players exploiting the full potential of the Internet of Things, the Internet of Services and the Internet of Media will be involved in the development of the Sensing Enterprise, and convert its promises into wealth.

But even if Europe reaps the benefits of the sensing economy, it will continue to face the challenge of employment provision (or continuous employment?). Arthur puts it bluntly: ‘The second economy will certainly be the engine of growth and the provider of prosperity for the rest of this century and beyond, but it may not provide jobs, so there may be prosperity without full access for many. This suggests to me that the main challenge of the economy is shifting from producing prosperity to distributing prosperity.’

At the organisation level, as we said above, the Internet of (Nano-)Things will have disruptive effects on business processes, manufacturing and production. It will be a ‘hybrid reality’ that will be as huge as the previous various stages of the industrial revolution. Once it is up and running there will be no return. Data will no longer belong to an organisation, be it a public administration, a corporation or some other institution. It will not be limited to a layer of digital connectivity atop existing infrastructure and objects but will imply instead a ‘severely disruptive convergence’ unmanageable with current tools. The challenge is therefore to anticipate this technological revolution by making organisations, primarily companies, redefine and adapt their core functions.

The European Union should aim at developing public-private partnership projects with clear scientific roadmaps in order to achieve a breakthrough related to the Sensing Enterprise. At stake is a significant part of the future European industry capability. These projects should support an activity involving users/providers pursuing a joint and systemically defined technological goal. A major requirement is to foster cross-disciplinary, cross-industry approaches (not limited to software providers) with a long-term vision (at least 10 years).

Such partnership projects will be supported by several research and innovation instruments, in particular the Horizon 2020 programme (2014-2020). They should be seen as accelerators towards the Sensing Enterprise and as a stepping stone to boost – and maintain – sustainable competitiveness of the EU industry at global level.

26 From the words ‘οῖκος’ – house and ‘νόμος’ – the law, or management, in ancient Greek.
27 Quoted from Rob van Kranenburg.
In parallel, the European Union should identify and explore new and emerging technological trends that will affect the sensing capabilities of enterprise systems in the future. In order to analyse emerging technologies and to evaluate their effect on research, smaller open projects are required to explore options not constrained by conventional roadmaps in a fast and freewheeling way.

EU priorities need to work on the ‘horizon of possibilities’ for European business in a systemic way, i.e. creating the conditions for more optimisation, more cooptetition, more skilled users/enterprises, and more flexible entities, providing user-centric, customised access to all kinds of knowledge, regenerating the European business fabric, reinforcing citizen-community-government-private networks. Only at European level can we effectively look at the issues posed by the new paradigm described above and its possible consequences in terms of global governance, complexity, interoperability, impact on the innovation culture, privacy, intellectual property rights, and well-being.

The 2013 FP7-ICT Work Programme will support a new scientific and technological approach to business systems through the optimisation of any kind of resources for enterprises with a view to fostering constant anticipation of enterprise performances, of the context, of the technology, as well as of the markets, and to supporting continuous (preferably open) innovation. The official Call text reads:

<table>
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<th>Applications for the Sensing Enterprise</th>
<th>to enhance the global and physical context awareness of business systems through the development of applications services and solutions for the ‘Sensing Enterprise’ supported by smart components.</th>
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<td>These components may be sensors, tags, intelligent agents, smart objects, etc. enabling a continuous awareness and improvement of business operations in a digital environment that will bring new business trends and models not possible otherwise. Europe cannot afford to ignore all these potential developments and research is much needed in this field, may it be concerning technologies, business models and values accompanying the sensing capabilities of the enterprise, specific applications and use cases and so on.</td>
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**Conclusion**

The Sensing Enterprise was born in 2011 from the intuition that the Internet of Things would necessarily affect companies, the way they conduct business, they run enterprise business systems and automate factory-floor production. The FInES Cluster and DG CONNECT of the European Commission, joined rapidly by a growing number of international experts from the manufacturing and production world, coined the phrase Sensing Enterprise to describe a business environment in which all assets are endowed with sensing capabilities and connected to networks to ‘treat’ information, generate new knowledge, help quick and effective decision making and, in so doing, make the Future Enterprise a new entity characterised by disruptive Qualities of Being.  

In less than two years, along a path marked out by several passionate discussions at European events, the concept of *Sensing Enterprise* has grown up from blissful ignorance and denial to curiosity and critical interest. This is a signal that it may rapidly move up to acceptance, understanding and enlightenment!

As the authors wrote in the introduction, this paper is the first attempt to crystallise in writing the state of thinking, admittedly crude, scanty and informal, hence questionable, on the *Sensing Enterprise* concept, its adherence to enterprise challenges, its relevance to prospective solutions, and its impact on the breadth and depth of innovative thinking for redefining the place and the role of the enterprise in the digital economy. Several scenarios have been explored here. Much remains to be done yet to improve the theoretical foundations, structure the issues and the logical links among them, clarify the notion of ‘object’ in the enterprise context, establish the connections between the concept of *Sensing Enterprise* and the neighbouring concepts that exist or emerge at the confluence of the Internet and Business worlds. We believe that the cause is good and we hope that the discussions will develop further, initiated in Europe but open to the rest of the world as well.

It is difficult to conclude on something that is just beginning, even more so when the implications, though unshaped, are believed to be far-reaching. Let us just take one example. The move to the *Sensing Enterprise* – should the latter be a ‘smart business’, a ‘fab lab’, any other Future Enterprise concept, or any combination of those appellations – might sketch out a new social organisation taking the form of an *overclass*, as defined by French economist and scholar Jacques Attali[^29], of which Europe could be the herald: ‘The acceptance of novelty as a good news, of precariousness as a value, of instability as an urgency and of interbreeding as a sign of wealth’ and the development of ‘nomadic tribes incessantly adaptable, unleashing multiple energies and bearing original solidarities’. Over-optimism? Naïvety? Perhaps. But let us join 19th century’s English poet Robert Browning when he writes: ‘Ah, but a man's reach should exceed his grasp, or what's a heaven for?’

**Acknowledgements**

Writing this paper would not have been possible without the ‘invisible army’ of helping hands that unknowingly offered their inspiration and dedicated their knowledge to make this ambitious and risky initiative a hopeful move. Among the countless people who inspired us for this work, we would like to give a special thanks to all the individual members of the Future Internet Enterprise Systems (FInES) Cluster and to the other stakeholders who contributed their precious time, valuable efforts and contagious enthusiasm in the series of events where the concept of *Sensing Enterprise* was tested and challenged in 2011 and 2012. All these people will recognise themselves in the paper. Finally, we would like to commend Man-Sze Li, Co-chair of the FInES Cluster, for her hard work and stupendous commitment to the development and promotion of the concept; without her presence, devotion and insight, this paper would simply not exist.

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Annex: Previous references to the Sensing Enterprise

The concept was coined for the first time in the previously mentioned 2011 FInES Position Paper30 published in March 2011. The proposed definition was: ‘Sensing Enterprise: an enterprise anticipating future decisions by using multi-dimensional information captured by physical and virtual objects and providing added value information to enhance its global context awareness.’31

Several events followed, putting into perspective the applicability, as well as the interest of the concept, and touching upon various specific domains. In these events, (mentioned in annex/notes/reference/bibliography of this article), the concept has been presented to and debated with various audiences in Europe.

1. The Future Internet Week32 in Poznań, Poland, in October 2011. Users, manufacturers and policymakers debated a conceptual approach to the Sensing Enterprise in a ‘Internet of Things’ Workshop: what benefits does the Internet of Things bring about for businesses? Are EU enterprises in general, and manufacturing enterprises in particular, prepared for the proliferation of the IoT? What needs to be done in order for EU businesses to adopt the new paradigm of intelligent sensing virtuality in their business and organisational strategy? Cristina Martinez, one of the authors of this paper, first introduced the concept in a session where Rikardo Bueno33 (for the manufacturing sector) and Man-Sze Li34 (for the research community) were each invited to describe this topic from their perspective.

2. ID World International Congress 2011 in Milan, Italy (November 2011)35. Another author of this paper, Gérald Santucci, introduced the concept of Sensing Enterprise before a large audience of auto-ID technology stakeholders during his presentation on the Internet of Things.

3. I-ESA 2012 in Valencia, Spain (March 2012)36. Gérald Santucci presented his view of the Sensing Enterprise in a context where the Internet of Things allows connecting everything and everyone everywhere, thus opening up the way for the continuous tracking and monitoring of various types of inventory and business assets.

4. The Business Innovation Workshop on ‘Translating Knowledge into Growth: Views from ICT Research to support Future Business Competitiveness’ in Aalborg, Denmark (May 2012)37 was chaired by Cristina Martinez, and organised by the FInES cluster in

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31 Ibid., p. 10
33 Director for the Scientific Policy, Fatronik Tecnalia, co-chair of the Ad-hoc Industrial Advisory Group (AIAG) of the Factories of the Future Public-Private Partnership (FoF PPP).
34 Director IC Focus, FInES Cluster Co-Chair.
collaboration with the European Factories of the Future Association (EFFRA) and Aalborg University. One of the sessions, moderated by Man-Sze Li, discussed the concept in the wider perspective of business innovation prospects for Europe. The panel included Oscar Lázaro (Innovalia Association), Jochen Rode (SAP), John Soldatos (Athens Information Technology) and Rob van Kranenburg (Council, IoT Forum). The speakers discussed several application areas of Sensing Enterprise, but also the challenges that it may raise from a technological, societal and business points of view.