



Convergence of Enterprise IT and Embedded Systems

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From the Editor

Today, the IT-driven convergence of previously separated domains is the megatrend across industries. Systems and services become smart by being aware of their environment. Enterprise IT, on the other hand, needs to connect with many distributed devices and systems. Ubiquitous computing and the Internet of Things are transforming and converging entire industries, as is underlined by the slogan that a car is a computer on wheels. Alpana Dubey of Accenture and I provide industry insights and the latest software trends. I look forward to hearing from both readers and prospective department authors regarding the technologies you want to know more about. —Christof Ebert

CONVERGENCE IS CURRENTLY melding entire disciplines to fully new business models and technologies across industries. What used to be embedded systems, on the one hand, with their specific constraints from the physical environments, and IT, on the other hand, are combining.^{1,2} This will impact education programs as well as classic industry boundaries.

What exactly is convergence? It is the awareness that, with increasing connectivity and autonomy, the historic divide of enterprise IT versus

embedded systems no longer makes sense. With industry, home, medical, and automotive applications being major drivers, IT will converge with embedded systems, such as the Internet of Things (IoT). At the same time, embedded industries will evolve toward IT with cloud solutions and dynamic over-the-air services. Take, for example, industry robots, medical surgery systems, or autonomous cars. Their distributed embedded intelligence is connected and driven by cloud-based IT systems. Software is flexibly moving from cloud to embedded devices with a bidirectional data flow. Cloud-based IT systems provide

the intelligence for the embedded devices, while the embedded devices facilitate distributed low-cost sensors, actors, and ubiquitous intelligence.

With enterprise IT being interwoven with embedded systems, it does not make much sense anymore to distinguish the two as separate disciplines. Because of computing power being cheaper, we will often see instances where intelligence will not only be catered by cloud-based computation but also by the edge devices, also known as *embedded systems*,⁵ named the *Internet of Thinking*. Of course, requirements are different depending on how such systems are

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deployed. A nanodevice implanted in a human has different physical, quality, energy, and IT requirements than a server farm. However, it depends on shared software and information, diminishing the previous tangible boundaries between embedded and back office applications.

Figure 1 shows this fast-evolving convergence with the example of automotive IT. The left side shows the three-tier reference architecture, which we will see in all converging systems in the future. These three tiers have fast become a reference as it ties into layered IT structures and allows us to abstract the three major functions of cloud, performance, and devices. In its implementation, these abstract tiers disappear like the seven Open Systems Integration tiers in networks. They help to design efficient systems with strong vertical interconnection.

A case in point is the classic telecommunication industry. It used to be based on distributed embedded technologies. With the advent of the Internet and growing IT services, the discipline simply disappeared some 10 years ago. Once proud industry leaders, such as Alcatel, Lucent, and Motorola, have ceased to exist. Other companies, such as Cisco, Huawei, Nokia, and Siemens, have reinvented themselves and transformed to convergence companies that master both IT and embedded systems. Today, only historians would still speak of telecommunications as an industry segment.

Education programs are keeping pace with this industry convergence. Computer science, once the theoretical arm of software education, and engineering domains, such as mechanical and electrical engineering, are converging to systems and software engineering disciplines with new curricula. Industry is looking

for graduates who master both the software, with algorithms and the underlying theoretical foundations, along with the engineering, as a disciplined approach with empirical methods and systems understanding from domains as diverse as automotive, chemical, medical, and transport. We are witnessing the creation of fully new engineering curricula based on artificial intelligence (AI) and data science applications to embedded technology.

Convergence is the prerequisite for digital transformation and enables the real-time observation and control of infrastructure, services, systems, and processes. It is the link between the real and digital worlds. This includes data acquisition, analysis, and modeling as well as the necessary information technology and networking. Autonomous driving, predictive maintenance, IoT, and Industry 4.0 are current application areas that are all based on convergence.

Such convergence is also pushing businesses toward solutions/products that require agile and scalable business partnerships where each partner provides a set of unique capabilities that, once integrated with others, can lead to disruptive use cases. An example is the Adidas partnership with Siemens for fast production of customized shoes.⁶

Industry Survey: The Two Forces of Competitiveness and Innovation

To better understand how convergence impacts current challenges, let us briefly look at some feedback from an industry survey that Vector Consulting performed in early 2019.³ We asked almost 2,000 decision makers in companies in the worldwide business-to-business (B2B) context about the top three challenges that they face.

For more than a decade, companies worldwide have been very successful

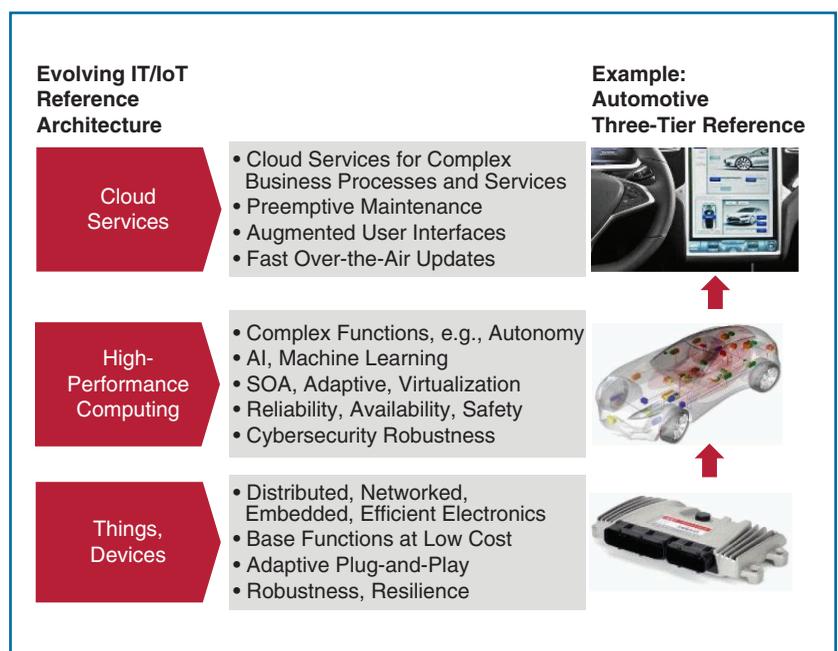


FIGURE 1. The convergence of enterprise IT and embedded systems.

and in continuous growth. Since mid-2018, the global economy has darkened. Global economics are at a turning point. Reasons are manifold, be it global trade restrictions, changes to long-time political relationships, or local industry impacts. In a recent study from the strategy consulting firm McKinsey, more than half of executives say global economic conditions are worse now than six months ago.^{1,4} The picture is similar in developed economies as well as emerging economies. Looking to 2019, economic conditions are forecasted by executives to be lower than they have been during past years, both in their own sectors but also globally speaking.

Such gloomy trends also impact the challenges as they are perceived in our industry survey. Figure 2 provides the survey results of the Vector study. The horizontal axis provides perceived short-term challenges, and the vertical axis shows more midterm challenges. Because each reply allowed up to five challenges in both dimensions, the sum is more than 100%. The validity is given with a response rate of 4% covering different industries worldwide. It thus represents different B2B business models but also regions in the world.

When compared with previous years, we see three significant changes, as underlined by the red arrows in Figure 2, which show the trend direction when compared with our survey from last year.

- Competencies have emerged as the single-most short-term challenge, even in front of efficiency and quality. The reason is simple to grasp. Companies struggle to get the right competencies on board, specifically for the new and challenging topics of IT and embedded systems. We face that in our consulting projects, which increasingly demand competence programs, such as digital transformation and agile software.
- Distributed teams are growing in relevance for all types of development projects. Hardly any product is developed in one place. Instead, most teams capture several sites, often even with heavy time zone differences. Where there were two rather close time zones with, for instance, Europe and India, we now see Europe, the Americas, and China. With such a split, it is hard to find even an appropriate

single hour when all teams would be reachable at the same time. Today, we are coaching many virtual teams to ramp up agile and scale it for the needs of high criticality in distributed projects.

- Compliance has increased its short-term relevance. Although in previous years, companies were still of the opinion that the process acumen of the past was sustainable, it is now obvious that process maturity has decreased. During 2018, we had more client task forces than ever needing to master a fast recuperation from basic flaws such as configuration management and requirements engineering. Often agile development had been used as a synonym for “everything goes,” which translated into reduced process focus. Documentation became insufficient, architecture decisions went undocumented, and test strategies faded. With an increasing risk of product liability, for instance, in functional safety and cybersecurity, our customers now need to quickly recuperate in compliance topics.

When connecting the dots, we see two areas that dominate industry. These two areas—competitiveness and innovation—can be depicted as two forces that determine success in the high-tech sector across industries.

Competitiveness

Competitiveness refers to the urgent need to deliver with competitive cost and quality, while at the same time competing on competencies. This is clearly a short-term need and reflects the currently increasingly perceived economic weakness across sectors. Only with the right amount of quality, efficiency, competencies, and mastering of distributed

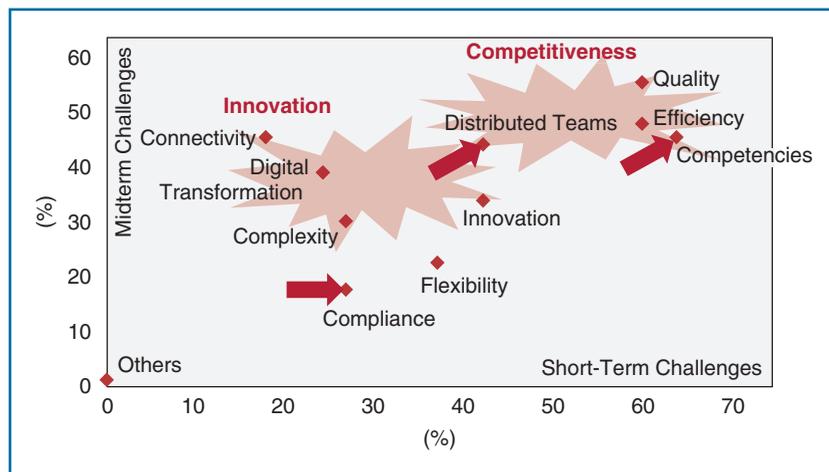


FIGURE 2. Industry challenges in global product development.

teams will companies be able to survive the upcoming tough times.

Innovation

Innovation refers to the demand for new solutions from markets regarding connectivity, autonomy, digital transformation, and so on. Markets expect innovative products. Digital transformation and related technical topics are driven by industry leaders that increasingly have their roots in the classic IT business. Amazon, Apple, Google, and Microsoft all approach the service industries. They will not stop in front of previously incumbent territories, such as Google with its Waymo mobility services and autonomous cars.

Productivity and innovation are mandatory at the same time to survive in uncertainty and competitiveness. Many companies that we talked with reported a push to reduce prices more than 10–20% for the same products year to year. This pattern has been recurring in volatile environments, starting in the late 1960s, but it was also visible, for instance, in the 2008–2009 global industry crisis.

Global product development today is challenged with extreme short-term pressure on both efficiency and cost. This is indicated by the pole at the right side of Figure 2, where efficiency and cost are by far the biggest short-term challenges. Companies spend a lot of energy to become faster and stay competitive in the costs of product development. Virtual teams and short-term allocation facilitate time and cost advantages in an increasingly competitive market but demand a sustainable agile setup.

The real challenge is quality, here emphasized with two major quality drivers, i.e., safety and security. We have chosen these two because they are pivotal in this converging software

industry. Cybersecurity is mandatory to ensure reliable and trusted connectivity and related mobile and distributed services. Functional safety represents the growing awareness of product liability where specifically embedded devices must ensure the absence of hazards to users and environment. The recent growth of lawsuits in medical, transportation, and industry shows that the relevance of functional safety is growing fast. Understanding that there is no safety in distributed IT systems without cybersecurity makes this pair of qualities indispensable.

It is important to balance the two poles of efficiency versus innovation. This is where product management meets product development to identify the best technical solutions that satisfy market needs.

Connecting Competitiveness and Innovation

Convergence drives competitiveness and innovation. The two forces of competitiveness and innovation from our survey create challenges that demand fully new solutions in business, R&D, and engineering. We have never seen such a strong simultaneous push for efficiency, quality, and competency. Convergence leverages the two forces of competitiveness and innovation toward sustainable business prospects for technology companies. Innovation with IT convergence needs a focus on different topics, which we will briefly highlight here.

Business Models

Markets today want to have sustainable networks of suppliers. The traditional concept of the *supply chain* is disappearing. Suppliers are subject to continuous replacement where necessary. The success of a supplier depends on how well it can create communities and business models together with

customers and other suppliers. For instance, software has such low entry levels that a new competitor is simply a mouse click away. Friction-free deliveries further add to this competitive trap. Crowdsourcing with networks of stakeholders developing and maintaining components and wikinomics to efficiently get access to and manage big data are two recent examples.

Value With Customers

Value-oriented engineering will grow rapidly, i.e., improving the evaluation of requirements within a business case from a portfolio management perspective. This implies dynamic segmentation down to the single buyer. It is about speed to needs. Customers are not interested in features but in satisfying their needs. Customers' relationships with organizations will not end at the delivery or sale of the product or service. Instead, an organization would need to continuously cocreate value for the customers.

Artificial Intelligence

AI is the technology trend dominating all others. Although they have been around for decades, converging IT systems can now allow AI to control ubiquitous distributed embedded systems. Each software engineer must ramp up the necessary AI competencies and connect with his or her respective industry domains. Topics such as data science and machine learning facilitate new services, such as predictive maintenance, and tailored solutions for a single-buyer segment. This demands data quality (see "Data Quality"), trusted data sources along cybersecurity and transparency. Algorithmic transparency will be demanded by policy makers for autonomous systems and machine learning to ensure fairness and compliance with laws. To support this, AI experts must become socially responsible and,

DATA QUALITY



Data are the new oil. Data fuel industries and are impacting all business models. Let us look as a case in point to the enterprise-embedded convergence and its impacts in the automotive market. More than 100 embedded controllers, real-time connectivity, cloud services, and increasing autonomous functions make automotive software the most complex across all of today's industries. Automotive original equipment manufacturers are equipping next-generation production processes and vehicles with connected embedded sensors and actuators to obtain better intelligence and control. They adopt information and communication technology workflow from their IT systems to each single car. With a car becoming a computer on wheels, the sanity of data is becoming ever more important.

Because of businesses and even society being dependent on data for critical functions, the risk of data being manipulated is ever increasing. Artificial intelligence models trained on biased data have already shown unfairness and a lack of inclusive practices. According to a survey performed by the Accenture Technology Vision team, 79% of executives feel that many of the critical functions of the organizations are based on data, yet there is not much investment on verifying the truth within the data. This leads to wrong insights and a further wrong set of decisions and actions.

Ensuring safety and security implies that the AI models, used for performing critical functions, are trained from the right data. In our data science projects, such as for predictive maintenance or testing of autonomous vehicles, Accenture and Vector are looking to several parameters, namely, provenance, i.e., verifying the history of data from its origin through its lifecycle, context-considering circumstance around data use, and its integrity.

ensure cybersecurity, performance, and functional safety. High-potential employees prefer challenging assignments that provide opportunities for learning and growth. In previous years, such challenging assignments along with continuous learning were key success factors for retaining good engineers. Even with weaker economic conditions, the most valuable employees should still feel from their assignments and learning that they can grow.

Knowledge Management

Knowledge is the currency of the 21st century. With global development teams and constantly changing markets, techniques for capturing widespread knowledge on customers, markets, products, and technologies are necessary. Competencies and knowledge are our primary assets. Their management must depend on people to mature products and product management in an ever-changing environment. Appropriate data sanitization and debiasing, at scale, would be required. Organizations would need to build a provenance into the models they train from the data. The models along with the data used for training need to be curated and labeled.

The convergence of IT and embedded systems allows value generation by innovatively combining state-of-the-art communication technologies using AI, data analytics, and big data. It is opening the doors for technology innovation, new business models, and collaboration schemes across industries. Multimodal mobility will connect previously separated domains such as cars and public transportation. New services, such as sharing, create completely new ecosystems and business models that are far away from the classic buy-your-own-product approach.

Convergence will transform once isolated systems, such as a car or a medical implant, into a distributed IT

at the same time, deliver algorithms that are explainable.

Quality

The increasing amount of IT for sophisticated services and autonomous systems raises the bar for quality. This includes safety and cybersecurity but also performance and usability. Product liability will force strict governance rules to prove that quality standards have been observed. Quality is a habit that must continuously evolve. Last year's best practices might still meet standards but may not be safe in the future or most efficient. We often face companies that

even move backward, assuming that once they implement high process maturity, it will last forever. The result is degrading quality, specifically in the quest to save engineering capacity.

Competence

In a world of fast-paced, innovation-driven change, the criticality of learning will continue to grow. Learning must be continuous and blend foundations with hands-on experiences. Convergence means a fully new skill set ranging from systems engineering to architecture of both enterprise and embedded systems, down to implementation, technologies, and a wealth of methods to

system with cloud access, over-the-air functional upgrades, and high-bandwidth access to map services, media content, other devices, and surrounding infrastructure (see “IEEE International Conference on Global Software Engineering”).

Although all companies will struggle against the weak economic outlook, technological advances are consistently changing in the world, while some companies are not making any progress. Success is not guaranteed for those who invest in R&D, but it may be for those who balance the two forces of competitiveness and innovation. Technology strategist Hermann Kahn observed several decades ago: “Everybody can learn from the past. Today it’s important to learn from the future.” This is the wake-up call to use convergence against the weak economic outlook. One who takes no ownership nor risks will not survive in our competitive business.

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IEEE INTERNATIONAL CONFERENCE ON GLOBAL SOFTWARE ENGINEERING



The annual IEEE International Conference on Global Software Engineering (ICGSE) brings together worldwide industry and research leaders in distributed software development. The 2018 conference had participants from more than 20 countries with one-third of the papers from industry. ICGSE 2019 will take place in Montréal, Canada, colocated with the International Conference on Agile Software Development and International Conference on Software Engineering conferences, 24–26 May. Join the conference and learn how to succeed with distributed software projects. For more information, see www.icgse.org.

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