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TNO-rapport

0100109731

Speurwerkprogramma 2015-2018

Thema ICT

Program 2015

Datum 26 september 2014

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Regievoerend Depart. Ministerie EZ
Financierend Depart. Ministerie EZ

Aantal pagina's 15 (incl. bijlagen)

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1 VP ICT

1.1 Introduction

TNO has one of the largest groups of experts working on a wide range of ICT innovations, in the Netherlands. This group was boosted with the acquisition of KPN Research in 2003 – at that time the focal point was telecom networks at large, but the relevance of internet technology was growing extremely fast. The merge of telecom, internet and media gave rise to the development of data science, internet-of-things, and cross-overs to domains where ‘big data’ and sensor networks could act as game changers. Another cross-over dealt with ICT as a vital infrastructure, e.g. in finance.

In recent years the innovation programs have been jointly developed with external stakeholders. This development was along a number of research lines where a cleannational and international ecosystem was present.

- Robustness and agility are key aspects of a vital infrastructure – these aspects can be identified at various levels in a system.
 - *Robust infrastructures* dealt with individual mobile and fixed infrastructures, making them secure, agile and of high quality. Besides a technical perspective, the program also included economic considerations, like optimizing the life-time of infrastructure investments. With the increased (vital!) importance of ICT infrastructure in many new application domains, also the policy perspective became challenging, with questions related to new entrants, open infrastructure and competition.
 - *Quality and reliability* focused on the design of architectural and process perspective – development of new paradigms and technology to enforce service-continuity. Later on network virtualization or software defined networking came up as well.

Partners in this line are telecom and media service providers (KPN, Vodafone, France Telecom, BT, Orange, Ziggo, UPC, Delta, Turksat, NPO), infrastructure vendors (Nokia Siemens Networks, Ericsson, Alcatel-Lucent), financial service providers (ABN AMRO, Rabobank, ING), and R&D partners (iMINDS, SURFnet, Fraunhofer, UvA, IVI, Fox-IT).

- Our physical world gets digitized, and via services build on top of data and information infrastructures we will enable complete new ways of interaction.
 - *Big data evolution* focused on the need to ‘make sense’ of multi-sensor data in various domains like dike-management, cattle-health improvement, and gas/water mains monitoring. In addition, an interoperability framework was developed and applied in these and other domains – such a framework is strongly needed to enable value chain integration. Moreover, the combining of data into information for various stakeholders is becoming an interesting economic activity that is the root of new business.
 - The line *Information Enabled Empowerment* studies the value of information (‘infonomics’) across various domains where trans-sectoral development of new companies is very likely. In addition, new government principles and frameworks are developed and applied that enable decentralized control and decision making while maintaining central leadership.
 - Finally, the line *Privacy and identity* deals with the fact that in an information society, online service provisioning is becoming the standard, hence digital identities need to be carefully treated. Frameworks describing identity attributes and the protocols how to authenticate them, how to assign and

review rights related to the identity are of key importance when it comes to societal adoption of these new possibilities.

Partners in this line are wide-ranging; for more general support we work with domain-agnostic technology partners such as SURFsara, SIDN, and the Big Data Value Center (TNO, Economic Boards of Almere, Amsterdam, Utrecht, eScience Center), industry fora (NESSI) to create support, and knowledge institutes (Radboud University, Tilburg University). The (cross-overs) require more specific partners such as technology suppliers (dikes: AGT, Siemens, ATOS Origin, IBM; health: Almende, Philips, Noldus, Sense OS; telecom: Thales, Alcatel Lucent, Telecom Italia; cattle management: Nedap, S&S Systems, Sentron), knowledge institutes (Univ of Surrey, WUR), and stakeholders that clearly pose a number of challenging and visionary demands (dikes: Dutch water management authorities; health: municipality of Enschede; cattle improvement: FrieslandCampina, CRV; floriculture: Florecom; vegetable industry: Frugicom).

The description clearly shows the well-established connections with national and international eco-systems. This holds for business, R&D&I programs (FP7/Horizon 2020, EIT ICT Labs, COMMIT, ICT Doorbraakprojecten) and standardization groups or industry fora (ETSI, 3GPP, W3C, HGI, ...). On an expert-level, the group has a number of part-time professors and associate profs, thereby connecting to all relevant Dutch universities in this field. Also on board-level and advisory fora, TNO is well represented (ECP, CTIT, ICT Labs, PI.Lab, High Level Overleg, DG CONNECT Advisory Forum). Last, but not least, many of the PPS-programs are regionally embedded, and it is also at this level that TNO's leadership is present (e.g. Groningen/Drenthe, Noordvleugel, Brabant, The Hague Security Delta).

1.2 Vision on the program 2015-2018

People and technology play a central role in the transformation to a networked information economy and smart society. An integrated approach to technological, human and organisational innovations is the basis of TNO's program "ICT 2015 – 2018". The two research lines as described in the previous chapter will serve as main lines in the portfolio, and will contribute to the (current) roadmap of HTSM/ICT, in particular 'ICT one can rely on', 'ICT systems for monitoring and control', 'ICT for a connected world' and 'Data, data, data'.

Vital ICT Infrastructure

With LTE (4G) just being deployed nationwide, the development of the next generation is already on its way. TNO actively participates in the 5G Infrastructure PPP, and has established leadership on self-organization, M2M and energy efficiency – key ingredients of the 5G infrastructure. For wired infrastructure in (dense) (sub)urban areas, TNO has an internationally renowned reputation for stretching the techno-economic limits of existing infra-structure, and will continue to do so.

The infrastructures for wired and wireless are strongly connected, and so is their future. The home network brings many challenges together, and with the advance of smart homes and evermore demanding residents, many service providers are looking for network-based value propositions. TNO has a strong position in the Home Gateway Initiative and other standardization and industry fora in this field and a track record of highly innovative projects. With so many vital applications across one network, (cyber/service) continuity is of key importance. Since these services are mostly delivered by multiple cooperating providers, the interoperability across the chain and the service governance are important and critical success factors. TNO is one of the leading contributors to the widely supported IT-Capability Maturity

Framework, that clearly describes the value of investments in IT capabilities; this framework gains attention as it serves as a powerful context to organise the governance in complex service-delivery webs. Finally, Software Defined Networking (SDN) or Network Function Virtualization (NFV) can provide an extremely powerful concept to increase robustness, but also increases flexibility and thus improve business case when demand is uncertain or highly irregular.

Big Data, Big Value

Fostered by the growing ubiquity of sensors, processing power and bandwidth, the amount of data that becomes available is steeply increasing. The amount of data becomes so large that the sheer size of the datasets becomes part of the problem (this is the informal definition of 'Big Data' as used by the European Commission), and calls for specific solutions to handle these voluminous datasets. Additionally, the variety of data is an important aspect, this translates to interoperability issues. Thirdly, the velocity of data (in real-time applications) needs attention.

Besides rather technologically-driven 'industrial' applications of big data analysis, based on physical sensors and serving the optimization of systems, many big data applications are based on human-generated data (transactions made by humans, sensors that are carried by humans, textual or visual data that is generated by humans), and consequently these applications will have a deeper impact on how individuals, organizations and society handle data-driven innovations.

The *Big Data, Big Value* research line will address three important advances beyond the current state of the art:

- From predictive maintenance towards (real-time) services.
- From new business based on company-data towards trans-sectoral data-driven innovation.
- From business cases towards value cases based on data/information architectures.

The Big Data Evolution subtheme addresses these questions, where Big Data and its applications are the core, and where selected topics from the Internet of Things and Semantic Technology provide essential elements.

1.3 Background, context, definitions and long term visions

According to Abdul Paliwala, "[...] the idea that we live in a changed universe of information and changed relations of production as a consequence of the information technology revolution is part of the discourse of the sociology of information. There are a variety of approaches ranging from Daniel Bell's 'Post-Industrial Society' to Castell's 'Network Society'. The underlying idea of Castell's Network Society or Network Informational Society is that *networks* replace hierarchized and circumscribed relationships. The nature of work is transformed by the interactive networks as opposed to hierarchized production processes involved in production and exchange. Networks and thus processes of production and exchange have a tendency to extend spatially and be globalised. Benkler has suggested that there have been two information revolutions. The first led to an industrial information economy and the second to a network information economy. The industrial information economy was dominated by the industrial production of information (financial services, accounting, software, science) and cultural (films, music) production, and the manipulation of symbols (i.e. brands, e.g. Nike). The new, the networked information economy is based on a communications environment built on cheap processors interconnected in a pervasively networked, connected environment-typified by the internet."

This pervasiveness has turned networked information into the backbone of our economy and society, and one of the key enabling drivers for the transitions that we

witness in domains such as health, energy, education, manufacturing, ... - the (EU) societal challenges. It has lowered the threshold to innovate and start new business, but it also makes society and business dependable, and vulnerable. The requirements might be perceived as exceptionally high, and business cases will need to be accompanied by (societal) value cases to meet the demands. New roles will emerge and new skills will be needed, as the complexity of the smart and connected systems is no longer easily manageable. These smart systems all have in common that data is the abundant resource, the network is the distribution channel, and information from data is the merchandise. As these networked information streams will grow ever more important across all sectors, our economy is transforming into an Networked Information Economy. This transformation will create great economic opportunities and at the same time enable societal and personal development.

1.4 **Ambition and Impact**

The program aims at public private partnerships where we connect business interest and assets, and public stakeholders such as other TO2 institutes and universities.

For the *Vital ICT infrastructures* research line a strong international perspective is required, because of the ecosystem. Our Dutch partners in this research line expect TNO to be *on-par* with international thought leaders, and to have concrete insight in their business concerns on the mid- to long-term; our ambition is to meet and exceed these expectations.

For the *Big Data, Big Value* research line our ambition is to play a major part in the creation of at least one actual Information Value Provider, where (big) data-based services are delivered and which operates across sectors. This provider will most likely have an launching ecosystem in the Netherlands, but with a clear international business potential. Note that the realization of the Dike Data Service Center took around 8 years to start its first business.

The program portfolio should continually increase TNO's credibility on ICT research, development and innovation. This position enables our principals to act as strategic advisors for business and governmental partners, in the Netherlands, in Brussels, and in Europe.

1.5 **Demand driven interaction**

Besides the extensive existing cooperation with a broad range of private and public stakeholders, a number of stakeholders has been interviewed on the subject of the program. The findings have been incorporated in the vision of the research program as presented above, but some specific remarks are important enough to repeat here:

- *Human capital*: the availability of e.g. data scientists is seen as huge challenge. Especially in the European context this issue is addressed very explicitly.
- *Trans-disciplinary*: most of the programs involve more than technology alone; e.g. big data applications it is not only about producing a model that fits the data, but also about sense making – this involves domain knowledge and organizational skills. TNO is viewed as an organization that is unique in having all these experts in close proximity.
- *Standards*: besides the need for new experts, many stakeholders identified the need for good domain standards with wide support throughout the ecosystem.

TNO is trusted as an organization with the right skills to bring together various perspectives in this process. We will increasingly bring standardization efforts as an integral part into the program.

1.6 TNO applied research in Topsector HTSM Roadmap ICT

The two research lines *Vital ICT Infrastructures* and *Big Data, Big Value* clearly describe challenges that recur at various application domains; as such the business stakeholders that participate in the program have the opportunity to reuse their propositions. This reuse or cross-over of ICT propositions in multiple domains is strongly stimulated within this program. As such, the program actively pursues the use of state-of-the-art ICT expertise in its contribution to tackling societal challenges and economic prosperity.

Within the Topsector HTSM, the contribution to the Smart Industry agenda is obvious. The *Big Data, Big Value* research line contributed to the kick-off document, and will continue to do so.

1.7 Program 2015

The 2015 program has a number of key-contributors: (Dutch) PPPs such as enabled by “TKI toeslag” and budget to stimulate cooperation between TO2 institutes, H2020, ICT Labs, and COMMIT.

More concrete, the program has projects in cooperation with the aforementioned stakeholders on e.g.

- G.Fast: next-generation wireline infrastructure
- Self-organization in LTE Advanced
- Cyber-continuity
- ‘Green ICT’
- Smart Dairy Farming (in cooperation with the WUR; including TKI toeslag and TO2 budget)
- COMMIT/SWELL – detection of burn out risks for knowledge workers based on analysis of human sensor data
- iCore – laying the foundation for efficient operation of the Internet of Things, both technologically (discoverability) and business-wise (relevant business models)
- ACCUS – focusing on interoperability of urban data (Internet of Things, Smart Cities)

2 VP ESI

2.1 Introduction

Position – TNO-ESI embedded systems roadmap

The high-tech industry in the Netherlands requires access to an open innovation ecosystem that strongly facilitates strategic innovation. The Topsector High-Tech Systems and Materials (HTSM) has been established to facilitate this ecosystem. A large number of application- and technology-based roadmaps form the heart of HTSM, of which the embedded systems roadmap represents an important building-block. The TNO activities in this area are centered around the business domain 'embedded systems innovation', as represented by the research group TNO-ESI. TNO-ESI is a leading member of the HTSM roadmap team for embedded systems. This guarantees a strong link between the TNO-ESI strategic research agenda and the HTSM roadmap for embedded systems, as well as its broad (industrial and academic) ecosystem of stakeholders and participants.

2.2 Program 2015-2018

Vision on the program 2015-2018

A common denominator in the Dutch High-tech industries is that these companies require access to distinguishing technology innovations, a state-of-the-art product development process, leading capabilities for design and engineering, an effective and efficient supply chain, a highly qualified workforce, and an open innovation ecosystem that strongly facilitates strategic innovation and cooperation. The VP Embedded Systems Innovation supports these needs in a number of important ways:

1. *Design and engineering.* Design and engineering of complex high-tech systems currently relies on fundamentals and models developed in computer science, physics, mathematics, mechanical engineering and electrical engineering over recent decades. The engineering discipline is in strong need to address the heterogeneity and multi-disciplinary aspects of the designs, to scale in the number of cooperating components and sub-systems, as well as to incorporate extra-functional requirements such as system performance and dependability.
2. *Development processes.* There is a significant need for a more fundamental basis of embedded systems engineering to improve on the efficiency, effectiveness, quality and costs of the design/development process. The main needs are for: (i) a significantly increase efficiency of product innovation, (ii) early identification of system level design trade-offs, (iii) significant improvements in multidisciplinary design capabilities, (iv) design for integration and test.
3. *Adaptive systems.* Today's products must be designed for tuning to customer specifications, must provide flawless cooperation with other products and applications (each with their own lifecycle) and be sufficiently future-proof to accommodate continuously changing operating needs during the product lifecycle.

4. *Information centric systems-of-systems.* The emerging application fields for 'internet-of-things', 'systems-of-systems' or 'cyber-physical systems' drive entirely new product design challenges and knowledge needs. This requires access and in-depth understanding of latest communication-, embedded systems- and ICT-innovations, as well as new design strategies and processes for developing such products.
5. *Human capital development.* In terms of human skills, based on the points mentioned above, there is a significantly growing need for systemic investment in education and training to develop the broader capabilities of the high-tech knowledge workers. In the area of embedded systems, this translates into a special need for education in the area of system architecting and multidisciplinary engineering to accelerate the relevant learning curves. But also, with the quickly changing technology base, life-long learning programs must be developed that address these ever changing knowledge needs.

A summary of these needs is presented in Figure 1, where the concept behind most of the roadmaps of today's high-tech OEM industry is summarized.

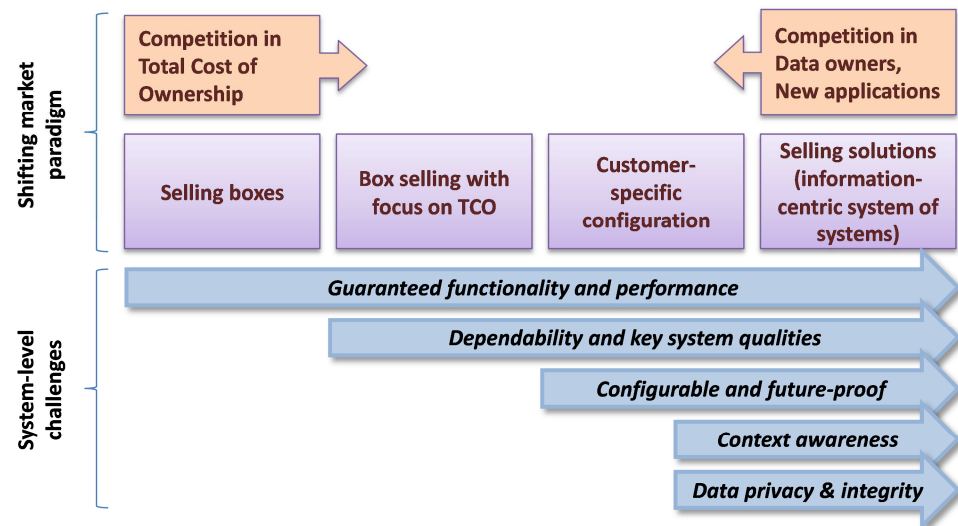


Figure 1: Relationship system-level product challenges and industry needs.

TNO-ESI 2015-2018 Research Agenda

The 2015-2018 TNO-ESI research agenda addresses a number of key system-level challenges in multidisciplinary system architecting, design and engineering. It emphasizes the fact the ever increasing complexity of high-tech system design cannot be dealt with by the current, mainly mono-disciplinary design methods and tools. It comprises four key lines of innovation that are embedded in the system level challenges of the HTSM embedded systems roadmap. These are:

1. *System performance.* This research area focuses on quantitative design criteria for embedded applications and their resource utilization in trade-off with costs. Design for system performance focuses on satisfying the (often conflicting) extra-functional requirements and is determined by a complex coordination and balancing of inter-related events in subsystems and components. Achieving the desired system performance involves trade-offs between all disciplines involved in the design. The outcome of the TNO-ESI research program in this field can

be used in a wide variety of application areas, leading to more reliable and robust products. The long-term goal is to realize multidisciplinary design approaches that realize full 'performance-by-construction'.

2. *System quality and reliability.* Research in this area focuses on the relation to the correct functioning and overall behavior of a high-tech system. Quality means that a system is 'fit-for-purpose', meeting the explicit and implicit requirements that are set for its operational deployment. Reliability is the likelihood that a system will perform as agreed and will do so during its operational life. Design for system quality and reliability focuses on deployment of architectural principles, rules and patterns that focus on preventing design flaws and ensuring robust system operation. The TNO-ESI research in system quality and reliability focuses, amongst others, on methods and techniques for early system validation and certification, such as model-based methods for integration and test. These incorporate techniques for validation of highly configurable and adaptive systems-of-systems. Such systems are not under control of a single system integrator and are subject to continuous change.
3. *Future-proof systems.* The research focuses on the design of systems that allow for easy modification and upgrade during their operational life. A system is considered *future-proof* when it anticipates future user needs, so that action can be taken to minimize possible negative consequences. Future proof systems allow for the accommodation of changing application needs, the ability to incorporate additional functionality, extend connectivity and incorporate new technology or components. Future-proof system designs are based upon platforms of design components or libraries of compatible hardware and software virtual component, intended to maximize operational upgrades and thereby reduce investment risk and prolong a system's useful economical life. The TNO-ESI research program also addresses methods and techniques for re-use of design assets, such as for system modularization, component and object-based architectures, run-time techniques, and methods for system configuration, maintenance and upgrade.
4. *Systems in context.* Research focuses on the design of systems that are context-aware and incorporate adaptive behavior. These technologies are applied in various fields of application to address pressing societal concerns, e.g. for smart buildings, intelligent traffic, pollution control, smart manufacturing and situational awareness. It tightly links information processing with monitoring and control, as well as decision making, interweaving 'embedded systems applications' with 'communication technology' and high-level 'information processing'.

In the field of systems in context, the TNO-ESI research program focuses on information-centric architectures in which embedded intelligence reflects and reasons on the system's own operations and the interaction with its environment. Additional research areas incorporate dynamic system re-configuration, situation-dependent behavior and control, cross-domain system interoperability and interaction in systems-of-systems, as well as data/information driven decision making, including aspects of trustworthiness, integrity and data-privacy.

2.3 Ambition and Impact

Embedded systems are at the heart of most technological advances. Embedded systems technology plays a prominent role in most state-of-the-art products, applications and services, such as in cars, mobile phones, advanced manufacturing systems (e.g. 'Smart Industry'), medical equipment and public infrastructures. Also societal innovations incorporate application of technology in one form or another, as to improve quality-of-life or enhance effectiveness and efficiency of service. Therefore, societal innovation has become ever more reliant on latest innovations in embedded systems technology.

This universal application of embedded systems technology in all segments of industry and society has created challenging new opportunities for the Dutch high-tech industry. New industrial products, with enhanced functionality and better cost-performance represent a key element of the competitive position of our high-tech industry.

To address these developments in the TNO-ESI research agenda, a number of key trends need to be distinguished:

- *Product innovation as a competitive discriminator.* In design of high-tech systems, there is a clear shift away from basic engineering (which is being outsourced globally) towards a need for enhanced capabilities in system-level architecting, design and integration. It is here that that latest capabilities for embedded systems architecting and design will be required to play a predominant role. They need to address the strict requirements regarding (real-time) performance, dependability, data-privacy, security and integrity, (networked) integration and system interoperability, at earliest possible development stage. At the same time extensive attention need to be paid to the trade-offs associated to resource constraints, such as for limited energy-usage, memory-footprint, processing or bandwidth resources and constraints for space, weight and environment. These strict extra-functional requirements and limited resources distinguish embedded systems technology from ICT in general.

The design of embedded system applications (therefore) is intrinsically a multi-disciplinary activity, requiring skills from computer science, electronics, communication technology, mechatronics and control, as well as a thorough understanding of- and interaction with the application field in which these systems are being deployed.

- *Towards a connected world.* More and more technology systems are integrated and connected by means of intelligent networks, wireless communications and data-processing means to perform value added user functions and work-flow processes. This provides for entirely new applications and services, such as for real-time road traffic monitoring and control, distributed energy provisions, outbound patient care and highly adaptive emergency services. With an ever-growing dependency on these applications, both for our personal, societal and economic needs, embedded systems technology has become a key enabler in emerging applications for 'internet-of-things', 'information-centric systems-of-systems' or 'cyber-physical systems'.
- *market and product propositions.* A further key development is found in the way in which companies position themselves in the *value chain*. The traditional business model of 'selling boxes' is steadily becoming obsolete. Today's market requires products that satisfy a broad variety of customers, can be tuned and configured to specific needs, and flawlessly integrate with other (networked) products and applications, often from different manufacturers. This means that today's product must be designed for adaptability to individual needs, allow

flawless interoperability with other products and services, and be sufficiently future-proof to accommodate changing needs during its operating lifecycle. A further step in this evolving business position is that companies not only provide these products to their customers, but also are expected to deliver total integrated solutions as a service.

As a result of the above developments, and the speed by which today's innovations take place, a continuously growing gap has emerged between the available technologies and the professional capabilities to effectively leverage on those. The bottleneck for future products is in *efficiently and effectively* developing highly intelligent, well-performing and adaptive systems, where embedded systems technology acts as the key integrating discipline. This requires special attention to be paid to system engineering practices for product innovation, the accommodation of requirements from operational use, but also to the appropriate education and training of knowledge workers.

2.4 Demand driven interaction

The applications of embedded systems technology in the various industrial and societal fields, all rely on comparable technology building-blocks, methods and techniques. Because the management of complexity, functionality and interoperability of embedded systems is almost always at the heart of a technology concern, it is of utmost importance that new knowledge is not only generated for individual products or applications, but that opportunities for synergy and knowledge exchange are fostered. Such a coherent approach leads to a faster and more efficient build-up of knowledge, with sharing of solution strategies, architectures, platforms, best practices, education, etc. This provides benefits to all parties through a 'knowledge multiplier' and an 'investment multiplier'. For successful innovation and value take-up by the ecosystem, it is essential that systematic attention is given to all required elements of the knowledge chain. TNO-ESI follows a process of 3 key steps, where each step adds value and depth to the previous step (see Figure 2):

1. *Programming*. This incorporates the translation of industrial and societal requirements into the TNO-ESI research agenda, programs and projects. This incorporates active support to national and international initiatives for setting up related research agendas, in particular for the HTSM embedded systems roadmap.
2. *Research & Development*. This incorporates the execution of applied research programs that are driven by strategic research questions from industry and society. This includes the capture and generalization of research results into a sustainable knowledge base for general (re)use by the stakeholders in the TNO-ESI ecosystem.
3. *Innovation Support*. This incorporates the transfer of knowledge through collaboration with industry, network activities, seminars, workshops, events, publications, special interest groups and training. Furthermore an extensive competence development program for life-long learning is executed, addressing the development of professional competences for system architecting and engineering.

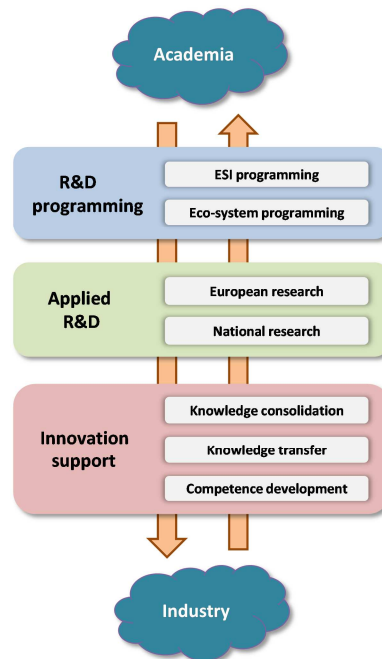


Figure 2: The TNO-ESI demand driven interaction based on a workflow (programming, knowledge development, knowledge valorization) that connects academia and industry.

TNO-ESI and its academic partners work in close cooperation with their industrial counterparts, often at the physical location of the industrial partner. This direct collaboration between industrial and research partners gives a much better insight, understanding and appreciation of the particular problems at hand. It allows the research findings to be directly validated by application to the realistic complexity of industrial cases. In other words, valorization is pre-built into the process.

The TNO-ESI research and development results are expressed in terms of methods, techniques and, if necessary, supporting SW-tools. Application of TNO-ESI results requires these methods to be incorporated into industrial development processes, including the adequate training of personnel. Without this explicit attention to the transfer and adoption of knowledge, the added-value of the results of the research projects may be lost.

2.5 Cooperation

Target groups

TNO-ESI works in long-term programs with a restricted but highly loyal stakeholders, mainly focusing on high-tech OEM industry and their (SME) suppliers. These customers span a wide range of markets and applications.

Through its innovation support activities, TNO-ESI supports a much wider range of stakeholders in the embedded systems ecosystem, categorized as follows:

1. *OEM companies.* These are the industrial OEM's, including large international companies ASML, Océ, Philips, NXP and Thales.
2. *Industrial suppliers.* These are the large, middle, small partners and suppliers of the larger OEM's, such as Prodrive and VDL-ETG.

3. *Academia*. These are the universities that are involved in research and teaching in topics relevant to the embedded systems domain, such as TUD, TU/e, UT, RU, VU and UvA.
4. *Public and societal organizations*. These include the public bodies and industrial branches that are involved with high-tech industry. Our key contacts include, amongst others, HTSM Topteam, TKI team, Holland High Tech, High-Tech NL, BOM, Oost NV and FME.

2.6 Program 2015

The 2015 research program of TNO-ESI is depicted in Figure 3. As can be seen from this figure, the research activities are arranged around the four research themes: 'system performance', 'system quality & reliability', 'future-proof systems' and 'systems-in-context'. For each research theme and in close cooperation with the industrial stakeholders (ASML, Thales, NXP, Philips, Océ, FEI and their industrial supplier network), specific applications are selected to serve as practical use-cases. The VP program for embedded systems will also be arranged along these 4 key program lines.

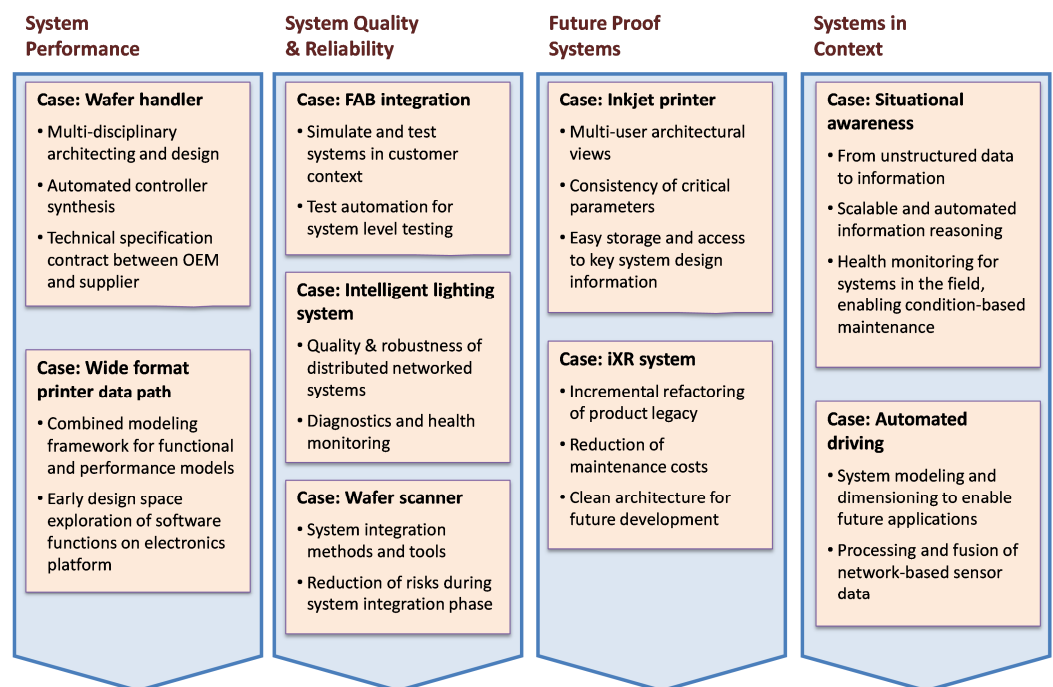


Figure 3: Summary of 2015 TNO-ESI research program.

As a next step and an important step to maximize valorization impact, the research results obtained from each of these use-cases are generalized for redeployment in other application areas and are incorporated in training and education material. As such it form the basis for an extensive TNO-ESI program for knowledge dissemination, education and training, executed on a B2B basis. Please refer to Figure 4 for details.

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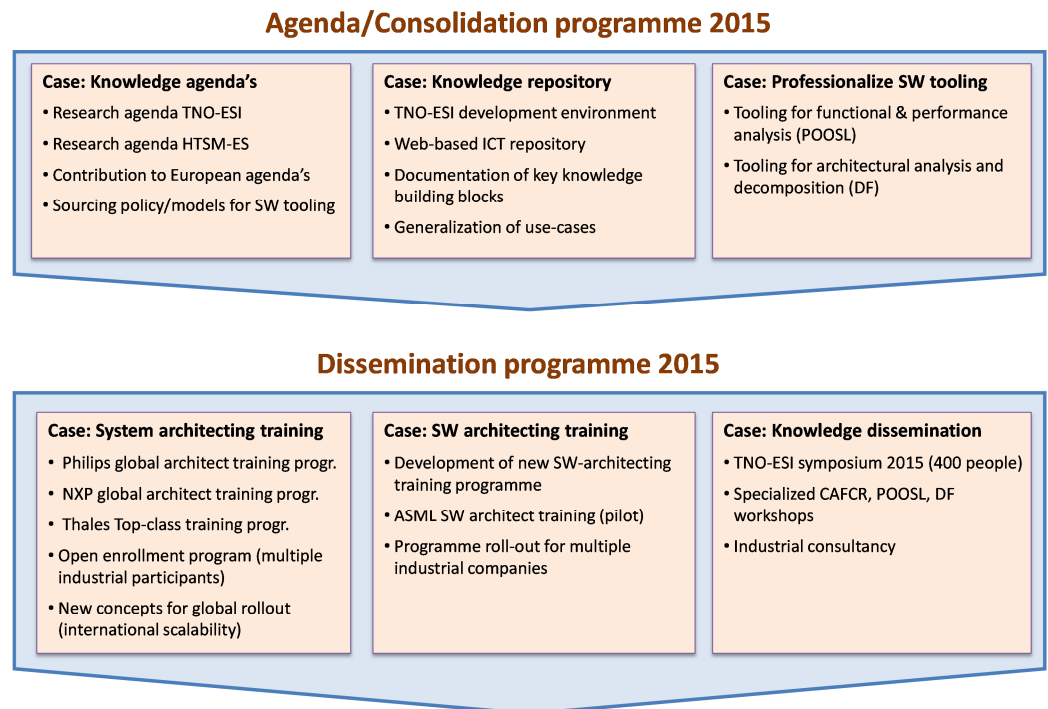


Figure 4: Summary of 2015 TNO-ESI knowledge consolidation and dissemination program.