Roadmap ICT for the top sectors

4.0. Deze versie bevat de input van alle top sectoren betreffende ICT. Omdat de plannen tot vandaag in ontwikkeling zijn, kan er begin januari nog een kleine aanpassing komen naar de definitieve plannen van de top sectoren.

0. This roadmap

This roadmap describes ICT. The Minister of Economic Affairs, Agriculture and Innovation, Maxime Verhagen has appointed Amandus Lundqvist as the skipper for this, the ICT-roadmap for *all* top sectors. The Government has positioned ICT as a theme important to all top sectors following the motion Schaart (VVD) / Verburg (CDA).

The roadmap team exists of Peter Apers, scientific skipper, Aad Veenman, industrial skipper, Arnold Smeulders, scientific secretary, Erik Huizer, innovation secretary, and Peter Mandersloot, civil secretary.

Input to this roadmap comes from the nine top sectors after several interactions with their innovation tables. Other input comes from industry, TNO, organizations like ICT~Office and EIT ICT Labs, and (applied) science partners. And, a third source is the Digital Agenda of the Government.

The ICT roadmap provides an action plan:
- for companies: business with stakeholders in the top sectors for modern and break-through ICT,
- for TNO: applied research and innovation,
- for the Government: the generic elements in the Digital Agenda,
- for NWO, including STW: use-inspired ICT-science,
- for EIT ICT Labs and the universities: breeding a new generation of ICT-entrepreneurs,
- For COMMIT and ICT Office to promote public-private partnerships.

The actors are well positioned to put their international connections of ICT-innovations into action.

The goal of the ICT Roadmap is to identify instances of high-potential ICT-innovation in top sectors. The goal is achieved by a focused approach, selecting 7 ICT-themes common to more than one top sector as carriers of ICT for direct economic benefits. The action lines range from use-inspired fundamental and applied ICT-research to enabling innovation by the application of modern ICT. The impact ranges from immediate ICT-application benefits to large-scale economic and societal innovation in the long run.

The ICT Roadmap goals are:
- priorities and themes for the public-private research and innovation agenda in ICT,
- with the means to reach that goal, and
- a list of themes to implement starting 2012.

More and more top sectors will realize their dependence on the advances in ICT. In 2012, we start with the program in the Roadmap *and* start with the further articulation of ICT-needs of companies in top sectors for future updates, strengthening the relationships even further.

Chapter 1 gives an overview of the broad impact of ICT in all (top)sectors of society. In Chapter 2, the ICT-part of the top sector roadmaps and the Digital Agenda are summarized. On the basis of this demand-inspiration from each top sector, in Chapter 3 follows a list of relevant ICT-themes shared by more than one top sector. In Chapter 4, the means are discussed per stakeholder to implement the roadmap. In Chapter 5, the shared ICT-challenges as collected in Chapter 3 from the input of the top sectors in Chapter 2 are described.

0.A Relationship with the Digital Implementation Agenda

May 2011, the Dutch Digital Agenda [24] has been announced by Dutch Government. It describes the government's policy on value-added use of ICT for (business-)innovation. It also describes the government's goal to reduce the regulatory burden for enterprises for the purpose of enhancing productivity and economic growth for the years 2011 to 2015. The scope covers the complete chain from the ICT-infrastructure at the bottom to a smarter use of modern ICT-tools at the top. The focus of the Agenda is primarily on business-to-government processes. In December, the Digital Implementation Agenda will be published, which, in more detail, describes the approach how the challenges of the Digital Agenda will be met.

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1. ICT, part of all top sectors

The chapter gives an overview of the presence of ICT in all (top)sectors.

ICT is the enabler of innovation in many sectors of our economy. Under the technology waves of ICT, little remains the same. Time and again, the competition is who picks up the viable applications first.

For manufacturing industry the impact of ICT has been enormous. Producing *just in time* and cutting back in large stocks is now a viable strategy. Production is simpeler, logistics far more efficient and creating spare parts on demand (rather than have them in stock) becomes more efficient. And, manufacturing will further profit from the inclusion of modern ICT: for monitoring during production to delivering. The time where all products are connected to services on their condition and content has only just begun. Manufacturers shift from production to production and services. Océ now manages printers remotely as a service rather than selling printers. The functionality of products will profit from more ICT. The users and consumers no longer accept awkward interfacing or uncontrollable machinery. In short: ICT is changing the whole landscape of both the manufacturing in a fast and significant way.

For government, who would have thought 10 years ago that income tax in the Netherlands would be collected via Internet only? In fact, who would have thought just 5 years ago that the Dutch *Belastingdienst* would be filling in your form before sending it to you? The achievement in logistics of systems and data is an indicator of the broad civil acceptance of ICT technology and support internet shopping in the Netherlands.

> *There are so many sources in the world and so much potential gain, the economy and society thrives on gaining insight from data.*

Creative industries practically rose from ICT that did not exist 10 years ago: virtual worlds, interaction, and social media are its key ingredients. These ICT-components deliver a new way of ICT also to other sectors in society, for example to influence the behavior of people in their water, energy, and media consumption.

ICT technology decreases in size every year, which comes in handy for the surveillance of products in logistics and in the food chain. Tiny computers also provide new opportunities in production. Computers and sensors can be employed to supervise individual plants, thus helping industry to improve their products, and to learn how to improve their production in the future.

> *ICT-projects fail sometimes. More insight is needed as to why they fail, what the possibilities and impossibilities are of ICT, and how to practice realism during tendering.*

Modeling energy consumption, logistics route layout or resource planning has become indispensable. ICT and mathematics work hand in hand for innovation. The cargo distribution based on GPS navigation were developed hand in hand by computer scientists and mathematicians and then applied in ICT.

In many parts of society ICT is vital. Health care systems, energy, water, and many other parts of society need ICT systems to function. As a society grows more and more dependent on ICT, it is essential that we invest in the level of trustworthiness of this technology. Trust implies reliable, dependable, safe, and

secure systems. Recent events have shown that trust does not come easy but goes quickly. And, trust is not a technical issue alone. Reliability and dependability of ICT systems need to be developed further, explicitly modeling risks.

ICT is indispensable, so much so that mankind has to be able to rely on it. Secured access and trust cannot be missed in ICT.

Where the reputation of ICT often has been that ICT is capable of everything, time has made clear that reality is different. The ICT-systems have frequently appeared difficult to construct. The fact of the matter is that ICT never has been impeccable, but that it is a discipline like all others: with impossibilities, design failures, and legacies. It is important to know more about design for existing information streams.

For health and many other sectors, the privacy of the individual has to be respected and protected, technically and procedurally. The issue of privacy sensitive data deserves more research. We see examples of ICT-projects that go awry because of privacy concerns.

Most the world's information is digital. The flow of information yet depends on fixing broken chains and matching the information from different sources.

In agro and food, in logistics, and in health, open data from governments, from NGO's or from commercial sources are essential to close the chain of information processing. Standards are a key issue, and at the end of that also interoperability between standards. Systems based on open data in a closed community also offer many a new opportunity.

The Dutch ICT Sector is an important factor in the Dutch economy in its own right. With an annual turnover of 30 B€ it provides 5% of the GDP. And it is growing as ICT is responsible for 20% of the economic growth and 70% of all innovation in The Netherlands. The sector provides over 250.000 highly skilled jobs in only the core of the industry. A manifold is working in ICT elsewhere: in sectors, industries and non-profit institutions. The majority of ICT-companies in the Netherlands with more than 100 employees have based their headquarters in the Netherlands implying a substantial production capacity. The ICT-sector consists of hardware, software, services, telecommunication, and office technology companies, but also media, gaming, logistics, social media. Other information intensive companies will soon merge. Especially the software sector contributes considerably to the Dutch export. The total ICT R&D expenditure equals a surprising 31% of all R&D in the Netherlands. ICT companies spend

ICT is the key to innovation and productivity, more than any other discipline.

approximately 2 B€ on R&D here equivalent to 18,000 jobs. The public R&D expenditure on ICT is $1/8^{th}$ of the private expenditures. In light of the Barcelona objectives, this urges for an increase in the public expenditure to bring it up to par with private expenditure.

In conclusion, time and again the information technological revolution has proved: ICT cannot be missed. ICT plays an important role in technological innovation of the top sectors, and ICT plays an important role in the innovation of businesses and supply chains of not just the top sectors. And ICT plays an important role in social innovation, among others for the reduction of the regulatory pressure. Innovation with ICT implies innovation in ICT. In this ICT-Roadmap we describe the ICT-innovation common to all or most of the top sectors.

2. ICT in top sectors

In this chapter, the ICT-part of the top sector roadmaps and the Digital Agenda are summarized.

2.1 ICT in High Tech Systems makes Intelligent Products

ICT is present almost everywhere in the roadmaps of the top sector High-Tech Systems and Materials [4], ranging from the equipment for communication, aerospace, automotive industry, solar energy, and advanced medical diagnostic and treatment equipment. We select a few highlights here.

Embedded systems Embedded systems are the core and a major component mostly of High Tech Systems, and through them to many other top sectors as Health, Logistics and Agro. Embedded Systems are integrated hardware/software systems built into devices that are not necessarily recognized as computerized devices or computers, however, these embedded processing units do control and actually define the functionality and quality of these devices. Embedded systems are typically not monolithic, but consist of multiple processing units, connected through wired or wireless networks. The size of the system components ranges from tiny battery-powered intelligent sensors and actuators, to large multiple-rack computing devices. Key concern for embedded systems is that they have to fulfill a wide variety of strict resource constraints, ranging from limited energy-usage, memory-footprint and limited processing power to space and weight constraints. At the same time, they have to fulfill strict requirements regarding performance and dependability. The limited resources and strict extra-functional requirements distinguish embedded systems from ICT systems in general. The design of embedded systems is (therefore) intrinsically a multi-disciplinary activity, requiring skills from computer science, electronics and mechatronics and control, next to a thorough understanding and interaction with the application field. Contributing industries are NXP, ASML, Philips, FEI, Vanderlande Industries, Thales, Philips, and many others. The topic is discussed extensively in a separate roadmap in the top sector HTSM.

Security As our reliance on the ICT infrastructure increases, so do concerns about its security. The growing complexity of ICT systems means that bugs and vulnerabilities are harder to avoid, creating new opportunities for increasingly sophisticated attackers. The recent attack on a uranium enrichment facility in Iran by the Stuxnet worm shows that strategic interests can attract cyber-attackers. ICT security issues are no longer limited to traditional computer systems, such as PCs and laptops. Rather, they surface everywhere, from electricity and water supply systems to the health service, from public transport to smart cars, from implants to supply chains, and from banking and logistics to the emergency services. Trust is a *conditio sine qua non* for normal economic transactions and inter-human communication. It is at the core of social order and economic prosperity, and in an increasingly ICT-dependent world, the security of ICT plays an ever more important role here. Addressing cyber security involves many domains of expertise, or disciplines. We do not just need technical expertise to detect and stop attacks - or better still - prevent them. We also need laws and regulations that better cope with computer crime, and we need to better understand the forms and causes of cyber-crime, the effectiveness of measures, including law enforcement, the underground economy, and see where economic drivers for implementing security measures are lacking and

regulation may be needed. Relevant industries are banks, industries operating in the critical infrastructure and utilities.

Automotive   Smart Mobility is focusing on ICT making vehicles more intelligent with the aim to realize safe and efficient traffic solutions. The theme Vehicle Dynamics Control uses mechatronics and software for safety and driver support. Therefore, VDC is also the area of Advanced Driver Assistance Systems (ADAS) and hence the enabling technology for the future of autonomous driving. The theme Connected Car uses wireless technology with other cars and/or infrastructure making new services in the car possible. The priority towards 2020 is to develop applications and large scale implementations to improve traffic flow, CO_2 reduction, safety and comfort. An additional challenge is to create compatibility and standardization through international cooperation on open platforms, testing and valorization. The theme Traffic Management focuses on efficient traffic control based on an integrated system of vehicles and infrastructure. Topics of investigation are both central and de-central control systems. In the focus Smart Mobility many technologies are available, but the real breakthrough is a matter of the realization of large scale applications in the real world.

Healthcare systems   Clinical Decision Support systems will significantly increase productivity and quality accessing data from a remote location via (reliable) internet connections. Low latency high-volume data mining and decision support algorithms in massive image bases enable better understanding of the cause and evolution of diseases, enabling better patient-oriented treatment planning before and after intervention. This all requires effective, large data sharing and managed access as well as interoperability, massive data fusion, storage and transport, and similarly it needs fast extraction of the right information, preferably from a very large data base of biomedical relevant models. It requires the digitization of the vast amount of biomedical data, from general practitioners, vaccine programs, pharmacists, clinical practice as well as clinical research, and advanced IT solutions to find the right information at the right moment, also from a remote perspective using all kinds of (mobile) internet connections. This remote perspective crosses organizational borders requires specific attention to security and privacy for patient data and the setup of trusted networks. Another extension to such networks will be the safe, secure and smooth integration with mobile communication and visualization devices, leading to optimized medical data transmission, modeling and visualization applications for mobile devices.

2.2 Smart Grids for an Energy Future in the top sector Energy

Smart Energy Grids   Apart from an ICT role in the surveillance and prediction, ICT will play a crucial role in future electricity networks and systems with durable energy supply: the smart grids. Due to the large-scale incorporation of uncertain, decentralized, and durable energy sources (like solar, wind, and biogas) as well as new devices with intensive energy consumption (like e-vehicles and heat pumps), the management and control of electricity networks and their users become substantially more complex. In addition, energy consumers will also become producers. This demands for a substantial amount of new ICT techniques for future energy systems, in order to efficiently match the demand with the uncertain supply, in the networks as well as at the side of the users and their devices. Also, in order to work well in real life, the stochastic aspects in the management of Smart Grids will have to be studied closely with stochastic operations research and statistical learning

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from mathematics. In order to enable such smart grids, substantial research is thus required in agent systems, data processing and mining, semantic sensor networks, security and privacy, embedded systems, modeling, control, network theory and optimization techniques. The urgency for enabling smart grids is clearly visible in industry.

ICT and the gas infrastructure Measurement and control of quality are essential elements in a decentralized gas-infrastructure. Kema, TNO, GTS, industrial gas-consumers are key companies. For the macro and micro gas-infrastructure, ICT plays an important role in planning and dispatching. Smart energy grids are expected to deliver an important contribution to the dynamic supply and demand of the future. A key company here is IBM. Measurement and quality control are also essential ingredients of *green gas*, to supervise the quality of gas from a distance. The international trade in certificates in fact is an information chain traded in virtual platforms.

Societal awareness for energy consumption For a broad societal awareness of energy consumption, social media are essential. In a manner similar to the creative industries, patterns of use are kept and used for personal feedback as well as feedback on the gas delivery. The aim is to influence consumer choices in the use of energy by smart meters, apps, and personal data displays. Consortia have been formed around *local living lab* test beds like Amsterdam Smart City with among others Alliander, KPN, Cisco and focusing on smart meters. Other initiatives are more experimental like power matching in Hoogkerk with Essent, Humiq, TNO, KEMA addressing core network challenges.

Smart energy Smart Grid systems have layers to abstract hardware infrastructure from the services. In between them is a virtualization layer where ICT is essential for interaction between the layers. An important aspect of the virtual infrastructure is that the real infrastructure can be monitored and controlled at the level of the virtual infrastructure, but that the physical infrastructure does not rely on the virtual infrastructure. If – by whatever cause or through whatever reasons – the link between the virtual and physical infrastructure is severed, the physical infrastructure will revert to a default and secure autonomous mode of operation. Another important aspect of the virtual infrastructure is its distributed nature. There will be no central ICT-platform in the Netherlands to which the entire smart grid, its devices, sensors and displays will be connected. Instead there will be many different ICT-platforms distributed throughout data centers or local computational and communication hubs. This large network of nodes will communicate through the vertical interfaces over the so called Energy Internet - a possibly large variety of communication technologies, enabling parties to make their own choices with respect to realizing their part of the virtual infrastructure. Also note that the exposure of technological components in and connected to the grid depends on the extent to which owning and/or controlling parties want to expose monitoring & control interfaces of their components to others. The more impact a component has on the performance of the smart grid, the more restrictions there are with respect to access to that component. The *Building Brains* consortium led by TNO is working on new concepts. For electronic cars, smart grids have successfully been demonstrated by Enexis and e-Laad. In the Rotterdam area smart grids are being considered around the Clean Tech Delta with Dura Vermeer, Arcadis, Deltalinqs, Eneco and TNO. The Smart Energy Collective with Eneco, Tennet, Essent, and the Gasunie as its members but also IBM, Heijmans, KPN, Kema, and Logica.

ICT in the constructed environment Buildings need flexible ICT-systems for evidence-based monitoring on top of an open-source architecture for energy management. Data and information modeling from districts to the user with useful feedback systems provide inside in how to manage energy supply. Another key element is the information chains around energy consumption and for the relief of regulatory pressure. Energy saving in buildings should be based on sensor measurement and control, improvement of energy efficiency by the availability of modeling tools during *parametric* design, effectiveness by providing ample energy management information to the end-user, and by being conscious of embedded energy at the end of the life time.

2.3 eLogistics for the societal heart beat in the top sector Logistics

The key to success in logistics is to get the flow of data right. The data around the physical movement of goods is complex as there are many data sources each with different owners, and in addition regulations from many sides. The data are unpredictable as logistics is about connecting any good to any organization. And, a major issue is the cargo planning of vehicles as the current load is 50% only. At the same the data are increasingly individualized and real time available. The ICT-Logistics research community is centered around Dinalog and its partners. Interoperability is one of the key ICT issues in this topic. In addition, advanced operations research from the field of mathematics is crucial for optimal scheduling of trains, modeling and management of traffic and optimal transportation of goods even when data are uncertain.

Cross chain control centers provide control for several supply chains simultaneously by information integration and planning under constraints. This does not only affect the logistics of physical goods but also information and financial streams such as forecasting, financial engineering and data management. The aim is to achieve better coordination and better supervision over these transport activities for efficiency, less pressure on the environment and better sustainability in general. In the end this provides a competitive edge over other countries. Companies involved are Kuehne Nagel, Unilever Benelux, Nabuurs, Jan de Rijke Logistics, TNT, Ortec, Ahold, Flora Holland.

Service Logistics is directed towards capital-intensive systems and their maintenance to achieve closed loop supply chains. The aim is to significantly improve the availability at lower cost, lower maintenance and less new materials. ICT is important to remote monitoring and supply chain information systems. The aim is also to become leading in business service management and service logistics. Companies involved are Océ, IBM Nederland, Thales, VanderLande Industries, KLM, ASML, Marel Stork, Fokker Services.

Core Netwerk and ICT Open Platform take care of the national and international logistics connections by standardization and information integration. The international and regional accessibility of mainports, brainports and greenports and the areas they service are all part of the Core Network. The aim is to better match supply to the demand and to build a well-controlled payment chain. Industries involved are: ECT, Havenbedrijf Rotterdam, Combi Terminal Twente, Havenbedrijf Amsterdam, Brabant Intermodal, Portbase, and Customs. The platform aims to provide a well-connected chain of logistic information, including standards, the planning with realistic information. That means, some of the

information may be missing, some of it may be false, some of it may be out-dated. Relevant industries KLM Cargo, Cargonaut, Portbase, Swissport, Tata Steel, Geodis, Amsterdam Harbour.

Supply Chain Finance aims among others to smoothen the international payments, with industrial partners like Control Pay, ING, Rabobank, Philips, ASML, Neways, DSV.

Synchromodality aims to improve reliability, predictability, efficiency and sustainability of streams of goods by flexible planning. This requires information intensive services from a wide variety of sources. Companies involved are ING, Sony, Fuji Film, ECT, Versteijnen, DB Schenker, MCT Terminal Moerdijk, KLM Cargo, Aviapartner.

2.4 Quality of Life for an Aging Population in the top sector Health

Home care, self-management and ICT In the Netherlands, 1.2 Million people are employed in care. Between 2007 and 2025 the work force will shrink by 10% while the need for care increases. The population of Europe is ageing. The older the population, the higher is the frequency of chronic diseases. This poses an increasing burden on healthcare and social service systems and affects the quality of life by inducing both physical disabilities with frequent hospitalizations and social impairment. It has been estimated that for one third of the future population, professional care is at stake in 2025. As a result, new concepts in care and self-reliance is needed as well as a new balance between professional care and supported care. A shift from intramural care to extramural care or even self-care requires more intensive communication, and hence a crucial role for new concepts in care and ICT. The Ambient Assisted Living program in the EU supports the need for a paradigm shift from the specialized care centers to the home as self-care and self-coaching environment. In this vision, person-centric healthcare solution are essential for patients with chronic conditions - especially elderly people – as well as their informal caregivers. This emphasizes the role of the home as care environment, by providing real-time support to patients in order to monitor, self-manage and improve their physical condition according to their specific situation.

Quality of life Increasingly, healthcare insurers are expected to have a prominent steering role in the provision of health care. How can this role be supported by information obtained from the variety of sources? Similarly, how can these data be put to good use? Many questions remain concerning the use of these data sources. What legal, social and ethical issues are at stake? What types of data are useful and how can they be gathered efficiently? What types of analysis and tools are needed to translate the data into relevant information to ultimately decrease costs, and to improve productivity and quality of care?

Medical imaging Medical imaging techniques enable earlier, more accurate and less invasive diagnosis and eliminate the need for unnecessary invasive interventions. Fusion of diagnostic and therapeutic procedures will transform many of the current clinical practices. Imaging applications have become an important integral part of different stages in the care cycle. Imaging technology will become indispensable for treatment planning. In conjunction with increasing technical achievements, these new opportunities will have to be validated with existing technologies and compared with current standards. Unexpected findings further accelerate diagnostic and

therapeutic healthcare costs and induce over-medication: unnecessary treatment of perceived medical conditions in the general population for which thorough Health Technology Assessments (HTA) will be required for containment and where HTA outcomes also take patients' values into account.

Medical data storage   Bio-banking with large-scale medical data storage, patient privacy protection and the interpretation of trends are essential for the further exploration and shortening of clinical trials. In epSOS thirty companies are developing cross border exchange of health information and ambient assisted living solutions. Another initiative, eHealth-nu by TNO, KPN, Philips, Menzis and others targets chronic patients. The Dutch Health Hub is a promising crossover where data search technology from media-sector is applied to the radiology archives, with participation of the AMC, EUR, local hospitals, media companies and data centers.

Mathematics plays an important role in Health: in unraveling the mysteries of DNA and understanding the nature of complex metabolic pathways, in optimal patient scheduling saving millions of euros to helping doctors to process gigabytes of data produced by modern imaging technologies.

2.5 Empowering Individuals in the top sector Creative Industries
Creative Industry is the fastest growing sector in cities like Amsterdam (and also in London and Berlin for that matter). The field is dispersed over many different activities and the notion industry does not have a classical meaning anyway. The essence of the creative field is mostly small and very versatile companies as the frontrunners while larger companies follow. The best perspective for the ICT-connected Creative Industry is a connection between high-content, high-science and high-tech. IIP/CREATE has been the best representative for the ICT-part of the creative field [16]. A collective from industry, SMEs and universities, it has been instrumental in defining the field as an economical sector of innovation. Given the high degree of high-tech SME and the necessary versatility of high-content, forming three regional concentrations dedicated to ICT in CI: one focused in Amsterdam including Hilversum, with a focus on media, data and news, one focused in Eindhoven for life style products including man-machine interaction, and one focused in Utrecht for gaming.

ICT and Media   has identified the following ICT-topics. Smart & Social Media: the advent of new, intelligent technology and the user as prosumer will have an enormous impact on media consumption. Big data will be generated by digitizing all visual and textual data. What is required here is new ways to search and access open and closed data, and new ways to store them. Virtual Interactive worlds will provide interactivity to media. And ICT in cultural heritage is an essential ingredient to provide access to text, picture and sound from past and future.

Gaming   has led to a research agenda for three themes: game worlds, users and interaction, and transfer of gaming. At the same time it has led to innovation program on games in context. These elements are strongly related the ecosystem and project initiatives. Game worlds include engaging virtual worlds and in hybrid environments in which the real and virtual world are intertwined. And game worlds of the future must be populated by meaningful virtual characters. Users should be able to interact with games in intuitive ways. When using games in an applied context, it is important to understand game design principles to obtain the best motivation, flow, and transfer of

gaming and it is important to measure the effectiveness of serious games. Games are focused on the domains of safety, health and education.

Architecture and the built environment has an ICT interest in open data and standardization.

Cultural heritage mentions the large quantities of (media) data, and the (automatic) addition of standardized metadata, including the interoperability and conservation of data and tools for a sustainable future. Technical innovation, consumer innovation by crowd –sourcing and business innovation are of prime importance for cultural heritage. Annotation is important, the incorporation of novel approaches in the archival workflow including media mining technology. For access: user contextualization and recommendation. Contextualization and semantic interoperability delivers semantic interoperability between archives. And interaction with and visualization of large data sets and new services based on archives and location provide new possibilities for storytelling.

The top team for Creative Industry envisions a virtual Creative Industry Top Institute where the emphasis is not on traditional science but rather on creativity and connection. Another variation of high-tech SME parallel to the creative industry, i3B is a set of successful SMEs forming a living lab of SME's in brain, cognition and behavior [14].

2.6 The top sectors Agro & Food and Horticulture ICT

The top sectors Agro&Food and Horticulture have in common that they are high-tech by themselves, already using advanced sensor technologies to monitor crops and stock. Adding more high and medium tech ICT to their diet will offer many opportunities.

Over the years, productivity per capita improves significantly. And, the productivity per kg input - base materials and resources - has improved significantly as well. We look for ICT tools like sensors, embedded systems, decision support systems, location-technology, future internet, robots to improve productivity even further but in a green, clean and lean way. This *smart farming* aims at better and predictable yields in quality and quantity, efficient use of resources and a transparent production system generating information relevant in the chain. Information on the production process is needed for optimizing, for delivery, and for agriculture's compliance to regulations as a license to operate.

ICT is changing the production chain, starting at the farm and through a sequence of processing and handling ending at the consumer. Each partner is challenged to be more efficient, more sustainable and more effective. Information is added to the produce along the chain and producers and customers are increasingly looking beyond one chain-partner back or ahead. Allergy information, fair production and trade, footprints and many other quality characteristics are not only relevant to consumers but in the end all chain-partners need the information.

In the Netherlands opportunities arise in smart farming as a breeding place for integrated ICT applications. This will improve farming and simultaneously offers opportunities for businesses in exporting applications. Agro&Food [3] is active in many ICT-projects AgriXchange, SmartFood, MyPig, Smart Dairy Farming, FieldCopter, E-Track, UNIFARM-FP7, Bioscope ESA, Programma Precisie Landbouw EL&I, I3B-4-Livestock-Agro. WUR is the main science partner with contributions of other universities,

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higher education and TNO. At the same time, EL&I develops a National Satellite Databank to provide weekly imagery for precision agriculture. Agroconnect, VIAS and others bring Dutch specialists together to work on the improvement of ICT-based systems. ICT advances enable the farmer to track the health and welfare of each individual animal (precision livestock farming). AeroVision, Agrometius, Agrovision, BLGG AgroXpertus, Dacom, DLV Plant, eLeaf, Holst IMEC, Lely, Nedap, Noldus, Ordina, Rovecom, SAC, SBG Innovations, TerraSphere, Q-Ray and many more are active. Challenges lay the field of standardization and interoperability, embedded systems and sensor networks. Particular issues in agriculture also comprise the governance of information, privacy and security of data and information.

From an ICT perspective, the top sector Horticulture [1] has similar needs as the ICT for Agro and Food. The sector proposes the establishment of *Tuinbouw Digitaal* as an integral Greenport Digital Community; this program will focus on connecting, accelerating, providing and cross-supply-chain development of knowledge, standards and technology. They propose four activities: A Horticulture-knowledge center for ICT, a business to government agenda, a human capital agenda and an ICT R&D agenda.

The main issues for ICT research and innovation for the sector are standardization and interoperability along the information chain, support for supply chain management, tools for modeling and visualization, tools for secure online trading and information exchange and single window administration solutions. Business connectivity, seamless interaction with the business processes and system integration (both within organizations as well as across the chain) are essential for the success of *Tuinbouw Digitaal*. To achieve less regulation, the sector urges for process alignment, data alignment and single window administration solutions. A specific suggestion in this regard is to remove person identifiable characteristics and make them available as Open Data to the sector to benefit from. A specific reason for Standardization is to avoid a single solution (single service-supplier) resulting in vendor-lock in. Therefore standards should cover a broad spectrum with several viable options. Research should focus on: e-information standards, e-information integration, e-business to government, e-recognition (online secure identification between organizations) and e-competences.

Internationalization of the standardization, interoperability and service integration is a must. There is a commitment from the Horticulture industry and organizations like Florecom, VKC, VBN, Floraholland, VGB, Frugicom, Edibulb, KAVB, and NAKT.

As growth in a glass house is much better controlled in green houses, Horticulture is more high-tech by nature then *Agro*. In the sector, climate control in greenhouses by PRIVA, Hoogendoorn, GROW-technology are essential as well as energy saving by smart grids. A close connection to *Energy* is obvious. Other important aspects are robotics for harvesting and vision for quality assessment. Monitoring (sensors) along the whole food chain from plants to food in shops is a new but inevitable part of the future of the sector. Food chain monitoring can only be achieved by ICT sensing networks, and ICT embedded tags. In general, ICT Logistics can play an important role in the flower trade for the delivery just in time to the customer. There are contacts with Dinalog on this topic with the companies like Logics Agro, and CODEMA. Internal logistics are covered by AW systems.

2.7 The top sector Water and ICT

ICT is important to Water [6]. 20% of the 70 business cases underlying the sector plan focus on ICT, and a further 20% has an important ICT component. The top sector has noted that IBM might be interested to move her activities on R&D to the Netherlands as part of her Smart World strategy when new initiatives on water and ICT innovation are generated in the Netherlands.

National information infrastructure   Many smaller companies like Alert Solutions, FutureWater, Hydrologic, HKV, will profit from a national ICT infrastructure around water also employing Internet and cloud computing. A recent study of the TUDelft commissioned by I&M demonstrates that 70 companies, from large to small, take an interest in such an infrastructure. The dispersion of data, different styles of data handling, software of various legacies, and restricted compute capacity hamper the development of effective business models. The Digital Delta is a new show case for a national infrastructure for the purpose of acquiring information, simulation, measurement and control and decision support [38].

Open Data   A positive point is the open geo data initiative of EL&I. The top sector expects that this will result in an enormous wave of innovation, including a competitive advantage for foreign markets. Open data will further enhance cooperation along the knowledge chain in the sector. Companies involved are Hansje Brinkers and eLeaf.

Basic level ICT   It is felt that much of the modern ICT is not being employed in Water. There is a world to be gained by education and awareness campaigns.

Two prominent initiatives under this topic of the sector plan are the Digital Delta and the *Convenant Informatieketen Water en Klimaat* [18]. Applications of ICT are needed for water technology, In view of the international opportunities of water technology, investments in ICT state of the art will improve the speed of water quality control, the security of water plants, maritime safety (nautical, terrorist and environmental), and the efficiency of back offices. ICT companies combine smart ICT solutions in public databases on water, creating real time insight in water shortages or surpluses, like Hydralogic.

In Water, mathematics today deals with many of the problems in this discipline: from ship maneuverings to modeling of climate change leading to floods and droughts, to modeling ground salinity, sandbank dynamics and dredging in coastal areas. Modern water management requires advanced numerical mathematics, as well as extended modeling and analysis, both from deterministic and stochastic points of view.

One of the spearheads in Water is *Enabling Deltalife* [20], with close relations to IIP Water & ICT [13]. Maintenance of dikes is a first priority for our low lands, as various disasters throughout the world show. Sensor-enabled smart dikes enable timely maintenance, as a prototype for dike data service centers of the future. These centers will provide advanced services for professionals, like anomaly detection, and enhanced water safety for citizens. IBM has opened two Centres of Excellence in Water Management worldwide, one of which is in Amsterdam for the Dutch Flood Control 2015 Program.

2.8 The top sector Chemistry and ICT

Chemistry [9] is a high-science sector with a direct yet underdeveloped relation with ICT in terms of visualization, data and knowledge management, and large scale data processing.

2.A The digital agenda

The Dutch Digital Agenda [24] focuses on smarter use of ICT to enlarge (business-)innovation and economic growth, mainly for business-to-government (B2G) processes. Many topics of the agenda apply also for the top sectors. In the agenda, which is neatly related to the European Digital Agenda [24], the Dutch government identifies four action lines for making benefits of the economic opportunities of ICT.

Action Line 1: Making enterprises working smarter.
 Use of ICT leads to better efficiency for enterprises as well as creating a government that is small and effective. The government aims at reducing the regulatory burden which will enable enterprises to operate more efficiently.

Financial digital data exchange: the government has opted for the international Standard Business Reporting (SBR) standard for financial reporting leads to cost savings for business enterprises as well as for government within all sectors.

Productivity and Cloud Computing Government sees Cloud Computing as an important development for enlarging economical productivity. Government explores the requirements needed to enable enterprises to exploit the potential of cloud computing. The opportunities of Cloud Computing have been already identified by the Creative Industry. However it is relevant for all top sectors.

Open data Government possesses a lot of data which have considerable economic value once the data can be accessed easily and commercially reused on the basis of open data. Government develops activities on: *Geo-ICT* The government is making its geographical information available through open data platforms which will be developed for this purpose. As a result the Netherlands Space Office will implement a National Satellite databank on which actual satellite-images will become public available. Geo-ICT creates many opportunities initially for all sectors, initially for the sectors Agro&Food, Horticulture and Logistics. An open data pilot will start regarding the use of open data for export regulations of especially the top sector Horticulture. Depending on the success of the pilot, new projects in other fields of export will follow in the coming two years, such as for Agro & Food and Creative Industry.

Standardization and interoperability leads to a reduction of transaction costs and supports business innovation. Focus in Standardization will be on digital transactions (business tot government, business to business). Interoperability solutions abs standards will be developed and implemented in the top sectors Logistics, Horticulture and Agro & Food). Focus in creative industry, life science and energy (smart grids) is on business innovation.

Reduction of regulatory burden for enterprises ICT can substantially reduce the regulatory burden by further digitalize information-exchange between enterprises and government. Government has several programs running: *Electronic Business File*. Government is investing the opportunities to implement the

Electronic Business File in top sectors like Agro & Food, Horticulture en Creative Industry. A report will be available in spring 2012 for the selection of new leading sectors, *Agro & Food*. *Chain approach for sectors.* A program is running with focus on specific public and private cases where ICT might successfully reduce regulatory burden and also contributes to (cost-)efficiency within government. Opportunities for new cases have been identified within the sectors Logistics, Agro& food, Horticulture and Chemistry (case *asbest toezicht*, National Single Window for Trade and Transport). *Compliance and Inspection authorities.* Opportunities have been identified for the sectors Chemistry, Logistics (esp. inland shipping). *Authentication by e-Recognition* offering enterprises one 'key' for authentication at digital governmental offices. It uses different levels of reliability and allows an enterprise to grant authorization to employees.

Action Line 3: Digital security and trust
The focus of this action line is how ICT-services can be provided safely and reliable and can be used with confidence.

Cyber security The key here is confidence in ICT. By the growing use of ICT confidence is undermined by disruptions of networks, services, applications and abuse of ICT, for example in the form of botnets (a network of infected PCs), viruses or breaches of security with personal data. Therefore, Cybersecurity is a generic theme for supporting secure use of ICT.

Action Line 4: Knowledge
Preserving the quality of the ICT research infrastructure for achieving higher return on ICT research together with obtaining sufficient digitally skilled people are main topics.

eSkills Digital Skills for smart use of ICT is gaining more importance. However the supply of skilled employees, as well in numbers as in competence, does not cover the demand. This means that the Netherlands cannot fully profit from the use of ICT. In cooperation with trade and industry, educational organizations the government is realizing more and more compliant e-skilled employees and other decision makers. Through the Human Capital Agendas of especially the top sectors High Tech and Materials and also Creative Industry, Logistics the lack of skilled people will be addressed.

Research on the ICT-infrastructure SURF is acting as the coordinator of the ICT R&D-infrastructure in the Netherlands. The top sector High Tech Systems and Materials is arranging general support by e-Science and the national e-infrastructure for all top sectors. For this purposes a special board will be established with represents from Science and Business-enterprises.

Netherlands: Digital Gateway to Europe The Netherlands has a strong position in physical infrastructure (main ports, roads, waterways and ICT-networks). The Netherlands as an intelligent digital gateway and virtual hub to Europe is a promising concept for generating value added services and more profit with ICT in an international arena. The challenge for success is to generate added value to data by intelligent handling of (inter)national data streams. A digital gateway consists of ICT-infrastructure, standards and services/applications. Good practices of digital gateways are in financial services and logistics on a single window. The keys to success of digital gateways in top sectors are entrepreneurship by the innovative

ICT-sector, talent and eSkills, public-private cooperation and research. Logistics, Horticulture, Creative Industry and Health are most promising for exploration of the digital gateway perspective. These challenges are describes in a recent report [40] on the digital gateway to Europe, supporting the approach of the ICT-roadmap for top sectors.

2.B i-Overheid: data quality, accountability and the *multiplier effect* of ICT

Today's innovation processes are – similar to our present-day society - characterised by the process of interlinking and sharing data and the results of technology-based *reproductive information processes*. As part of many different business and organisational processes (whether in health care, energy supply or the automotive industry) data are circulated and effectively distributed between different actors and partners in chains of networks. It is crucial to have awareness of the consequences of these processes: the multiplier effect of ICT and the constant re-use of data in new business contexts owing to the network character are often not factored into the monitoring of information quality, the accountability for data and information distribution and possible consequences for responsibility and liability. For, increasingly making use of the same *pooled* information of part of e.g. open innovation, open data or other business and governmental strategies and concepts leaves actors with the risk that no one knows precisely who is responsible for the information (or its accuracy). Individual initiatives related to ICT and information sharing are not – or scarcely ever – assessed on the basis of their impact or potential impact on business chains, organisational processes and society as a whole. The most significant omission is the failure or near-failure to view such initiatives within the context of the fast-expanding and rapidly diversifying information flows. It is all too easy for this quality and accountability gap to remain unnoticed, especially in networked situations, without anyone being *to blame*. It is therefore required that businesses become much more aware of various features of a networked economy and information chains than is now the case. If such awareness is not on the innovation agenda, paper-based reality and *real reality* can diverge quite dramatically.

The concern about the quality of and accountability for data should not be limited to the information itself, but should also extend to the metadata. Metadata acts as an indispensable signpost in information management systems. It plays a crucial role in tracing information and identifying the original context and origins of that information. The quality of an information management system depends on the presence of good quality metadata. In addition, the quality of the information depends on such technical, legal and organisational prerequisites as data security, well-designed work processes, and a reliable authentication and identification infrastructure. But this brings e.g. the key question of ownership in metadata on the agenda.

In sum, the quality of the *information factor* in R&D and strategic innovation processes requires strategic attention and consistent policy across the breadth of businesses and partnerships. The assumption that the use of ICT is primarily a matter of technology must be replaced by the realisation that at a (technological or organisational) network level it is networked data that matters as well. This then requires sufficient awareness of the consequences of the multiplier effect of networks and composite information and the challenges owing to the networks. These challenges relate in particular to governance issues on information quality, accountability, ownership and responsibility as well as liability in networks and data chains.

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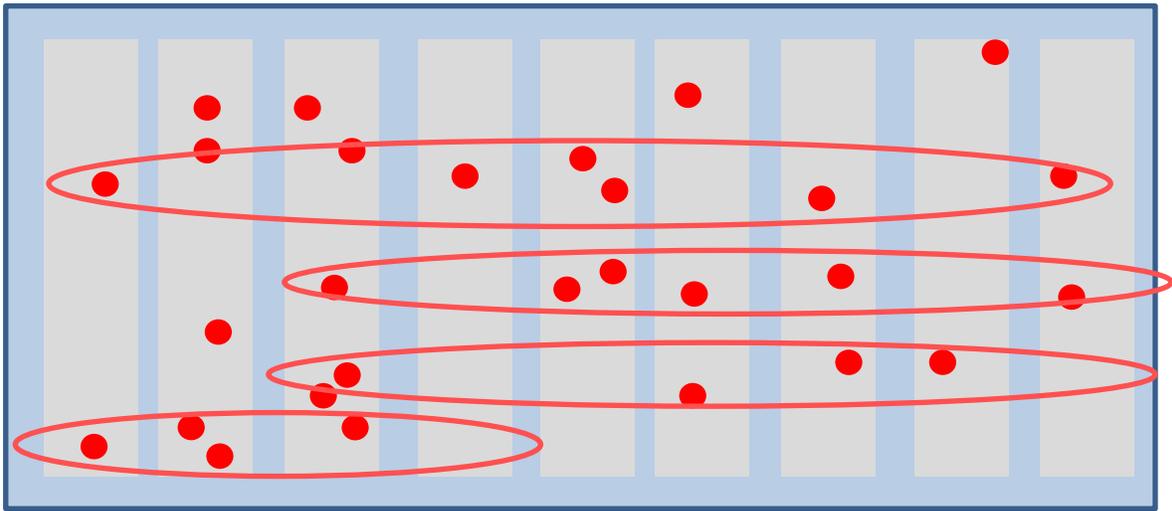
3. ICT research and innovation themes

In this chapter follows a list of relevant ICT-themes shared by more than one top sector.

ICT one can rely on

*Secure and Vital IC*T are important to many top sectors, HTSM, Health, Logistics, Horticulture, Energy and Water. Two primary areas of security challenges to address are: *security and trust of citizens* including security of mobile services, data and policy management, and accountability, and *security and trustworthiness of Infrastructure*, including malware detection and removal, intrusion detection and prevention, trustworthiness of networks and hardware, software security, security of industrial control systems, secure exchange of business information and administration, and secure operating systems. The two primary areas of vital ICT challenges are *technical robust infrastructures* and *quality and reliability*. The first challenge aims at the creation of robust fixed and mobile networks. The second challenge aims at the quality and reliability through design and process management. Robustness of ICT-systems should be built in the architecture from the moment of design onwards. Secure and vital ICT is promoted by RABO, ABN, Aliander, CPNI.nl, and KEMA, Vodafone, KPN, Ericsson, Eurocontrol, and Translink.

Privacy is important in many top sectors like Creative Industry and Health. Privacy is the protection of user-related data possibly during their use on the network. Privacy forms an increasing problem in the digital society. Larger databases imply more vulnerable data that about people, their credit cards, their habits and their lives. ICT secure technology protects privacy. For one, privacy of mobile telephone calls ask for advances in cryptography. *e-Identity* is the identity users deploy on the network. Identities are often only protected with plain-text passwords, making it easy for others to capture those identities and perhaps misuse them as recently with DigiD. TNO works closely in this area with Thales, Atos, Philips, Irdeto, Buurtlink, Tastelink and SIDN as well as with IBM, Vodafone en Nokia.

ICT systems for Monitoring and Control

Control is an important aspect of ICT-systems. *Embedded system* developers face many and sometimes conflicting challenges. To increase efficiency and to drive down hardware cost, they must aim for ever higher levels of system integration. But to keep applications manageable and scaleable, they need solutions that are as general and modular as possible. At the same time, embedded system complexity rises, quality standards go up and development time needs to decrease. With such opposing forces, how can the development of embedded systems still remain successful, maintainable and reliable? Embedded can be found in many top sector disciplines: in diagnostic equipment in medicine, in uitlities like water and energy to reliably control processes, and of course in HTSM. Companies like ASML, Philips and Océ are working on solutions for the future of real time embedded systems for example for lighting, consumer and health care systems.

Monitoring and sensor networks have an impact in High Tech Systems, but can also be of crucial importance to Health, Agro & Food, Horticulture, and Water. All types of sensors are measuring the

state and the presence of things. They pass the data to one another and the rest of the world with a potential impact in the way we live, work, and do business. Examples are found in smart mobility by cooperate driving, in safety & security for reconfigurable sensor networks, and in intelligent camera-networks. Other applications lie in energy in the Couperus Smart Grid Consortium. Monitoring for properties surveillance is also a topic covered by quite a few SMEs.

ICT for a Connected world

Four top sectors mention *the need for information chains* for the innovation of their businesses: Health, Agro&Food, Horticulture, and Water. *Standardization* helps to make the information flow between various elements in the supply chain more efficient,. *Open data*, making large (government and non-government) databases available to the public with a standardized API, is part of the Digital Agenda. And, open data are endorsed by TNO, Logica, and IBM and many others. Relief of regulation may be facilitated by open ICT with proper standardization. They might be made available after removal of any sensitive data in the form of Public Census. *Services* are used in 70% of Dutch commercial activities. The essence is in the pricing per use rather than per product. Services turn traditional product-oriented industries into ICT-driven service industries, as recognized in EU-program FP8 [19]. Geo-ICT is an emerging, yet important aspect of open data and new services.

Data, data, data

All around us, small data grow to *big data*. Not just in the Internet but in science, in industry, and in life style by recording all interactions and sensor data, data grow to unprecedented amounts. E-science is the software infrastructure to model or to access big data. This is a support function for science and medicine. *Cloud computing* provides the hardware and the data storage backbone, important to the top sectors like Creative Industries, Energy, and High Tech Systems. Making computational power and storage online available gives businesses the opportunity to use ICT in a flexible way, weighing down less on investments. Companies like Microsoft, Google, Philips, and Amazon deliver cloud computing solutions, and software companies like SAP, AFAS, and Exact deliver cloud-software.

Data and content exploration is critical for the competitive position of all top sectors, in particular Agro&Food, Creative Industries, High Tech Systems, to name just three. Society drives on data and content. Social data, informal data, formal data, written data, observed data. The more we know about the data, the better we are able to predict them, or to communicate them to a controller, or to protect them, the better we master the stuff progress in society is made of. Companies are found in publishers like Elsevier and Wolters Kluwer, in new data-intensive services like Ziuz, and WCC. Data mining is a key issue in Elsevier, Marktplaats, Hyves, Bol.com, and Philips.

Value and information chains

ICT is the driving force behind innovation, not only transforming topic by topic and top sector by top sector, but also transforming business models and value chains. For an agile society it is important to act on opportunities by forming new business chains and by developing the skills for rapid business model innovation. For global ambitions in top sectors, the only relevant frame for business is the

international theater. Therefore, international networks are vital to develop businesses. And, to reduce the regulatory pressures on administration it is important the obstacles to a smooth flow of information.

Human and societal capital

An agile and entrepreneurial workforce is key to success in global competition. This pertains to breeding ICT top talent from current educational programs, but also to attracting talent from abroad, and rendering the current workforces agile and entrepreneurial. In addition, ICT provides also capital to society as it shepherds all information and all knowledge.

Future themes

The ICT roadmap is not static. Topics to consider for future roadmaps are games, social media, man-machine interaction, software engineering, and bio-informatics. They are among the themes which will connect between more than one top sectors. The ICT Roadmap will be reviewed every year for the urgency of its themes.

4. ICT research and innovation implementation drivers

In this chapter, the means per stakeholder are being discussed to implement the roadmap.

4.1 EIT ICT Labs

A sustained transformation in innovation through the integration of education, research, and business
EIT ICT Labs is a European public-private initiative intended to turn Europe into the global leader in ICT innovation:
- Breed entrepreneurial ICT top talent via the transformation of higher education to promote creativity and entrepreneurial spirit
- Speed up ICT innovation through ICT Labs for researchers, innovators and entrepreneurs
- Generate world-class ICT business via broader and faster industrialization of research results.

EIT ICT Labs offers a joint program of international master Schools, doctorate schools and professional schools as well as thematic action lines, research action lines and business action lines. All action lines integrate the knowledge triangle of education, research and business, and are co-located in Berlin, Paris, Eindhoven, Stockholm and Helsinki. Core industrial members are Philips, Siemens, Nokia, Ericsson, Alcatel, SAP, Deutsche Telekom and France Telecom, where also 3TU plays a key role.

EIT ICT Labs mobilizes the Entrepreneurial Support Systems as currently organized by the Dutch (technical) universities and research institutes into an *international business strategy*. In a similar way, EIT ICT Labs leverages educational programs to boost international mobility and entrepreneurship, through its partner network of academia and large enterprises. Public-private research & development projects such as COMMIT, FP7-8 and ITEA2 projects, serve as important carrier projects for the EIT ICT Labs activities, especially in health and well-being and smart energy systems.

Netherlands focus
The Dutch partnership in EIT ICT Labs has a focus on ICT technology for Health & Wellbeing, new business creation and professional and life-long learning. In 2011, EIT ICT Labs has established an international business coaching infrastructure to support ICT spin-offs and SMEs. In 2012, EIT ICT Labs will launch the first year of the international Master School, and the Doctoral Training Centers. In 2013, EIT ICT Labs will launch the program to address the educational needs of professionals. All programs feature international mobility, exchanges between enterprises and academia, and entrepreneurship.

4.2 COMMIT

COMMIT is the public–private program for research in the ICT. It is the most experienced current vehicle to express the interest of companies in public-private research in ICT having registered 25 M€ in contributions in programs topically preceding the ones listed here. ESI, one of the key participants in COMMIT, has registered a substantial amount of company support. Also GATE, the Utrecht-centered program for gaming, another participant in COMMIT, has registered a substantial amount of additional company support. Support in the Roadmap ICT of companies will be arranged in public-private partnership -contracts under the COMMIT consortium agreement.

4.3 TNO

The TNO contribution to the ICT roadmap is in the form of research-capacity. Part of the budget of TNO will be allocated to subjects described in this roadmap, always in programs together with industry from the top sectors and from the ICT-sector. The exact amount is to be discussed between TNO and EL&I and is dependent on TNO budget reductions that are foreseen in the period 2013-2016. TNO instruments to be used in the context of the ICT-roadmap are diverse.

Small Business Innovation Program

In the Small Business Innovation Program [31] innovative businesses are being challenged to combine their market knowledge and entrepreneurship with innovative technologies of TNO develop new products or services and bring them to market. TNO supports SME in their process to market with technological and financial means 25 K€ for feasibility and max 250 K€ for product development.

Co-financing

This is an investment instrument [32] based on policy and applied research means funded by the Ministry of EL&I. The total yearly amount is 23.5 M€. To increase effectiveness for top sectors a small adjustment is desired. It allows for co-financers to contribute in kind. This is a good instrument for pre competitive knowledge development and research that can be used as a basis instrument for PPP programs.

Branch Innovation Contracts and Innovatie Prestatie Contracten

TNO research means up to 4 M€ are available for the realization of BIC's. The BIC with iMMovator is an example in the Creative Industry sector. BIC's target knowledge transfer and network capacity building.

FP7/8 en PPP's

TNO participates in approximately 1/3 of all European ICT-research programs. Given the nature and topic of the specific research programs, consortia are being formed which often include private companies. Example projects are found in the creative industry like Fascinate [33] for media and ICT and Open garments in the textile industry [34]. The European Commission also uses public-private partnerships, like Future Internet [35] to collaborate with (local) authorities, civil society and companies.

4.4 ICT Office

Since the publication of the top sector plans, analysis has shown that ICT has a role in every single sector. The role is either explicitly stated in the ambitions, or implied in the plans as an enabling technology to become reality. ICT Office and TNO have developed the Innovation Accelerator to clearly define the ICT ambitions and needs of the sector, the steps needed to reach those goals, and the opportunities and threats the sector faces. The result of the accelerator is a plan for the short, middle and long term where ICT goals are being laid out, including spillover effects to other sectors. The Innovation Accelerator will give sectors insight in their ICT needs. It will provide a clear business opportunities for ICT companies and research goals for knowledge institutes.

4.5 NWO

NWO is responsible for enhancing the quality and innovative nature of scientific research and for stimulating new developments in scientific research. NWO furthermore facilitates the dissemination of

knowledge. The ICT-roadmap is implemented along two lines both in a national competition: supporting talented researchers/fundamental research and public-private partnership research programs. Each line will be strengthened by valorization activities and may be supported by an international component.

Supporting Talent and Fundamental Research
Supporting talented researchers in their scientific career is a vital condition for scientific innovation. Encouraging the development of groundbreaking ideas is a key aspect of NWO policy. At the same time, reinforcing the knowledge chain from the start at fundamental research will return economic benefit, as countries around us recognize. Therefore, NWO will allocate budget for a *free competition*, with the only constraint that the research topic has to fit within this ICT-roadmap. A similar construction might be foreseen with the Talent Line of NWO (a top sector *Vernieuwingsimpuls*). Financial commitment from companies will not be required for this implementation line. Establishing active connections between scientists and companies through e.g. user committees is part of this scheme.

Public-private partnership research programs
NWO has a long-standing tradition in public-private partnership programs, the thematic programs such as Jacquard with several sequential calls and the STW *Perspectief* program. The goal here is to be inspired and to inspire research. Also, the education of future personnel is a key motivation for the participation of the sector. The actual implementation in this line is by competition where public-private partnerships will be invited to submit a proposal under one of the themes of the ICT-roadmap. As selection is on the quality of research and the quality of use-inspiration, some themes may have more than one project, whereas other themes may have none. In public-private-programs, dissemination is a key activity for which part of the budget will be reserved. Additional schemes, such as the Valorisation Grant or the *kenniswerkersregeling*, may be used for this as well.

The industry participation in the use-inspired or insight-inspired research is warranted by an in-kind active or an in-cash contribution of at least 25% of the program. The private commitment in the NWO programs will be arranged on a per-program basis. The actual participation of a specific company may be on the project level, in order to ensure maximum interest and benefit. In use-inspired or rather insight-inspired research, private partners will be invited to take the lead in the selection of the topic, similar to the standing practice in the successful ICT-FES programs, the STW *Perspectief* program and the NWO Technology Areas. Similar to COMMIT, the theme is defined by industry. But unlike COMMIT, and similar to *Perspectief* and Technology Areas, the competition is open. The arrangement warrants the best proposition in competition as is customary in science.

International activities
Science is international by nature. A strong embedding and benchmarking against international programs will ensure a maximum return for the Dutch science and industry communities. Furthermore, European schemes (EIT, FET, Horizon 2020, ERC) may provide additional financial matching for the national programs. NWO has a co-operation with ministries and science foundations in strong research nations like China, India and the United States. These agreements lead to international cooperation by joint workshops, student and staff exchange and research programs (including public-private programs).

Relations with other disciplines
Given its large impact in society, it is essential to engage other disciplines in the top agendas. Design of wind turbines and management of energy networks are based on complex mathematics. In the future, mathematics will also help to reduce energy consumption in homes, by some estimates, up to 30%. Shorter innovation cycles and the complexity of modern products demand wide-scale application of modeling, simulation and optimization techniques. Mathematics is instrumental in bridging various scales: from nano to macro. Comprehensive mathematical models are used routinely already. Future developments like sensor networks will require development of a new mathematical foundation.

The impact on the foundations of public and private life is simply too big to leave it to the ICT alone. Who owns the data on a social website? In an i-Phone? Your moods? Your body language? The commercial interest of these questions is the foundation of all social media. One could argue that data on a social website are completely private, and probably at the surface they are. But what level of anonymisation is needed to protect one's privacy? The discussion may be relevant and interesting here, but it is no less than life-essential in countries of repression. Philosophy and ethics should answer these questions and provide the grounds for a firm judicial foundation, and behavioral sciences provide a commercial basis: what will be the limits of practical use?

Waves of technology will induce waves of social innovation, when the impact is broad. And in case of ICT the impact is broad, as is also the case for bio and (expected) for nano. To some, ICT is social innovation, and quite rightly so. As ICT has shifted from automation to information, and information is the stuff power is made of, ICT has transformed the societal relations. Therefore, an essential political, sociological and psychological element comes with the current state of ICT. Study is needed to improve the ergonomics of interfaces, to predict user acceptance, and to summarize the influence on decision effectiveness in governments.

Democracy changes under ICT and digital media. A key notion in the digital agenda of Europe and the Dutch government promote measures to avoid a digital divide. That does not only raise questions for ICT research in simplicity of man-machine interfaces, but also to demography research of computer use in the population, and the conditions thereof.

ICT-theme, selective use and insight-inspired competition
The competition is within one, NWO-broad ICT-theme. Selection is on the quality of research and the quality of use-inspiration.
   a. The roadmap is supported by a very broad and diverse set of industries with more than 25MEuro in cash and in kind.
   b. Among the many themes suggested, when no endorsing companies could be found, the theme has been removed from the list of themes.
   c. It has been verified that the selected ICT themes have the consent of the top sectors, and that they are each useful to more than one top sector.
   d. The implementation is by competition inviting public-private partnerships to submit a proposal under one of the themes. Industry participation in the use- and insight-inspired research is warranted by an active in-kind or an in-cash contribution of at least 25% of the program.

As selection is on the use-inspired question *and* the scientific quality, some themes may have more than one project, whereas other themes may have none.

5. ICT Roadmap Action Lines

The action lines along the ICT-themes are described in this chapter.

For each of the common ICT themes, the stage in the knowledge chain is indicated by:

    immediate application of modern ICT,

    the application of ICT-science,

    use-inspired, fundamental ICT-science.

These are marks on a continuum of stages of knowledge as it becomes more and more practical during its development. For each theme, a tailored approach is chosen. Some common ICT-themes require immediate solutions and these solutions exist in principle. For other themes, the distance between science and application is short, for example in cryptology for security. This is the preferred solution as the time-to-market for new ideas is shortest. Yet other themes require a longer incubation of science before it can be put into practice, yet the future need may be equally urgent. An example here is content exploration of the very databases which grow everywhere. In such cases an intermediate step from science to application needs to be taken care of.

For the 2012 action plan, see chapter 7.

5.1 ICT one can rely on

5.1.1 Secure and vital ICT

Security is a multidisciplinary field that cannot be approached from the technological viewpoint only, and requires taking into consideration human, regulatory, and legal aspects as well. Specific topics that will be covered are: identity, privacy and trust management, malware, forensics, data management, cybercrime, risk management, secure design. The topics range from scientific study to tooling and engineering. The National Cyber Security Research Agenda has been adopted by the Dutch Cyber Security Council. Under the umbrella of this agenda several research programs will be proposed with stakeholders who have demonstrated their support to the agenda both in the private and public sector and ranging from applied to fundamental use-inspired research. Specific technical and scientific challenges include improving malware detection, prevention and removal. Also, finding usable solutions for privacy preserving identity management and for usage control of sensitive data and improving forensics tools and implementing accountability of users in distributed systems are key elements. And, improving the security of the critical infrastructure as well as analyzing the economics of security and the evolution of cybercrime. Realizing security and privacy by design as well as better tools supporting writing secure software and analyzing the security of software and hardware is important too. Finally, it is important to study the link between cyber-security, economics, risk management and regulations and the secure exchange of business information and administration, e.g. e-recognition. Industries interested in the topics include: NvB, Rabobank, ABN-Amro, ING, Alliander, TNO, Riscure , Ericsson, Novay, SecurityMatters, Irdeto, Fox-IT, Civolution.

Vital ICT, we observe that actions in this field are mostly triggered by incidents which rather erodes than increases the trust in ICT-services by society, government and organizations [42]. Vital ICT also is a

multidisciplinary field, which combines expertise on networking, architecture and process design and service, continuity and security management. Specific topics that need to be tackled include reliable internet infrastructure, ICT-robustness, reliable ad-hoc communication infrastructures, trustworthy internet banking, and reliable sensor-based mobility management. Apart from acting against (cyber) attacks, vital ICT also reduces the effects of system failures in general. Service continuity is a key notion here. The strategic research agenda for Vital ICT is broadly supported by industry. Six out of ten strategic research themes identified by KPN are in secure and vital ICT. The strategic agenda of *IIP Vitale ICT*, is supported by Thales, Eurocontrol, Alliander, Belastingsdienst, DNB, DBC Onderhoud, IBM Nederland, Philips Research Lab, Rabobank, SIDN, Strukton, SURFnet and Wiser Consultancy.

5.1.2 Privacy and e-Identity

Personal data is the new currency of the data society, according to a recent report of the World Economic Forum. Through the intense use of social media, of search engines and mobile services, people collect and share relevant data and services while leaving traces of personal data. Important societal activities, such as health (electronic patient records), energy (smart metering), and mobility (road pricing) depend on personal data, yet face problems in implementation due to inadequate handling of privacy and data protection issues. Adequate safeguarding and managing of privacy and personal identities facilitates acceptance and adoption of online services and commodities. Transparency measures, offering a clear perspective on what data are collected, for what purposes, and how they are used, are required to increase trust in the online world. Confronted with the need to control identity information in a multitude of situations, tools that help in managing personal profiles and identities encourage uptake of services that are based on personal data. Measures to promote privacy and to increase transparency of processes in which personal data are used, will enable the spread and uptake of innovative ICT-based services. Several top sectors acknowledge this by urging for appropriate approaches and solutions on privacy and identity measures.

The enabling features of privacy and identity management systems for furthering information society services require research investments in technologies, business processes, systems architectures, consumer behavior and institutional issues. A grand challenge in the application of science is the creation of a nationwide, trustworthy, interoperable, privacy-friendly identity management infrastructure, allowing for secure authentication and identification services, and supporting digital signatures. Especially challenging is the implementation of revocation mechanisms and building the system without relying on a single point-of-trust, issues which are not only relevant for identity management of individuals but for business activities of commercial organizations as well. This infrastructure would foster trust in other infrastructures that are built on top of this, such as in health (electronic health records), and iGovernment (online tax forms, *Digitaal Loket*); it is key in realizing the ambitions of the Digital Agenda, and supports various top sectors.

The uptake of privacy and identity management solutions depends on the appropriate understanding of business and administrative drivers and barriers and the role of legacy systems. This challenge is enhanced by the need to understand consumers' behavior vis-a-vis privacy issues on a broad spectrum of applications, running from social media to e-commerce and transactional services and understanding the effects and possibilities of regulatory interventions.

Challenges related to use-inspired science address new approaches towards privacy and identity management. Physical infrastructures (utility, transport and logistics) critically depend on ICT. Dedicated ICT infrastructures (increasingly mobile, such as mobile payment systems), underlie most if not all societal activities. The design of these ICT infrastructures determines, at a fundamental level, the privacy and trustworthiness properties of all services built on top of them. These values must therefore be incorporated into the design from the start. The challenge is to develop new techniques and business methods to apply privacy by design and data protection by design, while maintaining security, accountability and functionality at the infrastructure layer. This involves the development of privacy design patterns and privacy enhancing technologies, and further developing the concept of revocable privacy and privacy impact assessments, among others. These techniques are fundamental to achieving the goals of top sectors High Tech Systems - Security, Energy - Smart Energy Grids, and Health - Quality of Life.

The confluence of cyberspace and physical space into one ambient intelligent system based on the Internet of Things poses fundamental research challenges in the area of privacy and trustworthy services. The challenge is to empower users to exert control over the implicit construction of their identities by this infrastructure, for example in a smart living scenario. Development of new lightweight cryptographic protocols, and new intuitive security paradigms that are user friendly are part of new research to be undertaken. This challenge applies to top sectors Creative Industries - Empowering Individuals and Health - Quality of Life.

Industries ready to invest in privacy and e-identity include KPN, SNS, Rabo, SIDN, Google Nederland, QIY, and COLLIS.

5.2 ICT Systems for monitoring and control

5.2.1 Control and embedded systems
Many ICT-systems exercise *control* over a function. *Embedded systems* are integrated hardware / software systems built into devices that are not necessarily recognized as computers. However, these embedded systems do control and actually define the functionality and quality of these systems. Embedded systems consist of multiple processing units, connected through wired or wireless networks. The size of the system components ranges from tiny battery-powered intelligent sensors and actuators, to large multiple-rack computing devices. Key concern for embedded systems is that they have to fulfill a wide variety of strict resource constraints on energy-usage, memory-footprint, processing power, space and weight. At the same time, they have to fulfill strict requirements regarding performance and dependability. The limited resources and strict extra-functional requirements distinguish embedded systems from ICT systems in general. Embedded systems occur everywhere: transport infrastructure and transport means; advanced systems for leisure and lifestyle; healthcare and well-being; dependable and secure communications; production; environment. Embedded systems play a key role in society, in and outside the top sectors.

Design challenges for embedded systems   The design process creates, starting from system requirements, step-by-step the concrete system components. Key challenge here is to make the last

step of design, the mapping onto the hardware, more systematic and less costly; in current practice, well over 50% of system development costs are spent in this phase. Furthermore, dynamic integration is a new and important issue, especially for systems of systems.

Scientific challenges for embedded systems   System design refines high-level system architectures by decomposing them into smaller components, finally leading to system realization. This requires many design decisions, covering multiple disciplines, and a careful trade-off between extra-functional concerns regarding performance, reliability, evolvability, resource usage, energy usage, and costs. Key developments are necessary to come up with new methods to assess multi-disciplinary design alternatives and new techniques to enable large-scale system implementation (hardware, software). A first set of challenges relates to the use of models throughout the entire system design process, from the very early stages of requirements capturing to system integration, system test, and system evolution: How to manage and relate many different models? Which models are cost effective in which phases of the design and development process? A second set of scientific challenges, relates to the type of models being used, in particular, to the required classes of models and analysis techniques, such as to really support the design process, what are appropriate types of models? How to systematically combine and use different types of models multi-domain? How to cope with complexity and scalability?

The design and scientific challenges as described above, are treated in more detail in the more specialized roadmap for Embedded Systems, as part of the HTSM top sector plans. Companies supporting that roadmap include Philips, NXP, Thales, ASML, Vodafone, KPN, Vanderlande Industries, FEI Company, Océ, Grass Valley, Sioux, Assembleon, and many more.

5.2.2 Monitoring and sensor networks

Monitoring is a key element in the modern worlds of surveillance, production and logistics. In real world applications like the monitoring of pipelines, windmill farms, and subsea installations, large scale, internet-based ICT-infrastructure is needed to process the data, to make sense of it and to initiate actions. In the past few years we have seen the powerful ICT infrastructures arise, mostly using cloud technologies.

Another type of monitoring is protection, advances in real-time signal and image processing and pattern classification enable the development of systems that automatically detect suspicious behaviour. The emphasis is shifting from sensors, communication and data logistics to sense making, data driven modeling, interpretation and reasoning.

Sensors and actuators embedded in physical objects — from containers to pacemakers — are linked through both wired and wireless networks to the Internet. When objects can sense the environment, interpret the data, and communicate with each other, they become tools for understanding complexity and for responding to events and irregularities swiftly. The real world in which sensor networks operate in is difficult to operate in. Challenges include interpretation of real world observations, and complexity when dealing with a large number of devices.

Pervasive deployment in increasingly networked sensing systems requires the use of tools, which are necessary to turn special-purpose solutions into generic network facilities, which can be applied for a

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variety of purposes and in different operating conditions. There is a strong need to be able to rapidly develop sense-making applications through common tools, programming models, and development support. It is imperative to design and develop energy efficient and miniaturized hardware, for integrated and multi-functional sensing, for analogue and digital signal processing, and for effective actuation. Ease of deployment and accurate control will be provided through the design and development of energy efficient communication, synchronization, collaboration, and artificial intelligence techniques.

For use-inspired science, the development in the top sectors indicates grand challenges for sensor-based surveillance, large-scale sensor network communication, and the coupling of heterogeneous sensor networks, including the use of smart phones. As systems become more dynamic and more diverse, system engineering at all levels of the sensing system becomes important. A platform approach is needed that aims at a service architecture, tooling and middleware independent of the hardware platform, supporting a wide range networking paradigms and applications. The in-system processing of distributed data, leading to decisions based on incomplete and unreliable knowledge, will prove to be important for achieving reliability, efficiency and scalability. Efficient and robust radio technologies are needed to collaboratively use the scarce spectrum reliably.

Companies investing in the technology are among others Ten Cate, Volker Wessels Telecom, Siemens, Thales, IBM, Shell/NAM, FUGRO, Witteveen en Bos and Arcadis.

5.3 ICT for a Connected world

5.3.1 Standardization and interoperability
Several top sectors have indicated a need for interoperable (data and) information chains in their sector to innovate the business. Achieving interoperability, high on the priority list of CIOs, is essential for organizations to be effective into the dynamic and connected world. Today, in an increasingly interconnected world, interoperability is more important than ever, and solving problems caused by non-interoperability turns out to be very costly. Studies of the US automobile sector, for example, estimate that insufficient interoperability in the supply chain adds at least 1 B$ to operating costs, of which 86% is attributable to data exchange problems [43]. Later studies mention five billion dollars for the US automotive industry and 3.9 B$ for the electro technical industry, both an impressive 1.2% of the value of shipments in each industry [44]. The adoption of standards to improve interoperability in the automotive, logistics, aerospace, shipbuilding and other sectors could save billions [45].

The European Commission is emphasizing the role of standards [46]. Standards for ICT will play a more prominent role in the EU in an effort to stimulate innovation, cut administrative costs, and encourage interoperability between devices, applications, data repositories, services, and networks. The Commission will demand that European standards for innovative products and services be quickly elaborated and adopted. In addition, recent EU-programs on PPPs have stimulated the interaction between specific application domains and generic internet functionalities. The interaction should stimulate the efficient use of and influence on generic ICT-technology to improve up-take of new services in various application domains, thanks to alignment with large ICT-industry back-up using the

economy of scale, and alignment with user-behavior. Domains in the PPP-Future Internet program include logistics, mobility, agriculture and smart cities.

The importance of standards and interoperability will continue to grow. Networked business models are a reality in today's economy [47]. For governments it is also essential for reducing the administrative burden on companies. A new challenge is *semantic* interoperability, for which many semantic (industry) standards are developed, or need to be developed. Standards contribute to achieving interoperability. However the benefits of standardization are not fully achieved yet. To grasp the full potential more and improved development and usage of standards is needed. Solutions like methods, tools and techniques are needed, just like setting up public-private partnerships for standardization. An example is e-invoicing, where both industry and government work together on standardization to achieve the full benefits of e-invoicing and the government goals on this subject.

Different sectors have developed different solutions, some more successful than others. Some sectors are re-inventing the wheel because of lack of knowledge from what has been developed in other sectors. An essential role is foreseen for the *Informatie Knooppunt Interoperabiliteit*. IKI is meant for development, (re-)use and dissemination of solutions across sector, and together with both industry and government. General methods for standardization, MOSES for the creation of standards, and BOMOS for development and maintenance are available. Also quality of standards needs attention, along with improving the adoption and use of standards. The IKI platform will become the bridge to provide the knowhow into the sectors. And finally, solutions are needed for achieving large-scale semantic interoperability in complex settings across different sectors. The IKI will gather experiences of standardization in science and society for dissemination between government and businesses.

For the application of science the issue of interoperability of information is already an actual and fundamental issue for developments within the government [24], healthcare met e-health, disaster and crisis response and in transport and logistics [5]. The advent of new technologies and economic developments such as the Internet of Things demands new scientific knowledge to support public and private sector organizations with expertise in dealing with the organizational and managerial problems that arise from these new combinations of organizing and technology. This research domain - which combines Enterprise Interoperability, Enterprise Collaboration and Digital Ecosystems supported by the European Commission over a number of years - is one important element of the overall research field of the Future Internet, and has a specific research focus on ICT adoption and usage by enterprises.

5.3.2 Open data and services

On December 12th, 2011, the European Commission announced its strategy on Open data in the Open data directive [48]. Based on a potential market value of tens of billions of Euro the EC took a major step in signalling administrations to free up their data as to stimulate innovation, transparency and quality of service. Also a national master plan Open ICT-platform is needed providing a template for chains of information where efficiency through standardization is the key. A try-out is planned for the logistics sector, later followed by one for the agricultural and horticultural sectors. Dutch companies participate in international consortia on standardisation for interoperable smart solutions as CONTINUA e-Health and Smart Grids in Energy. More focus will be on horizontal dissemination of knowledge and experience

with standardisation strategy and valorisation. Companies and government work together on open standards for electronic transactions as invoicing, Standard Business Reporting and an electronic Company File for less administrative costs, see section 5.5 below. An annual meeting between government and business on the re-use of open standards will also be organized.

And there is more. In a narrow sense, open data may be defined as freely accessible, structured and machine readable datasets. Innovation is aimed at the disclosure of these datasets and combining them to new perspectives on existing information services like *Buienradar*. In a broad sense, open data may be viewed as the re-use of large public and private data files, opening many possibilities. Examples are the aggregated data of pension- and payroll service providers. Research on open data should include economic and societal perspectives, policy and governance in a service based economy. Research topics encompass interoperability and data service management, visualisation technology, heuristics and content retrieval. Finally, open data requires research from the human perspective: how is the empowered citizen involved? How may user generated data support governments and how does this affect the way citizens interact with their local and national governments?

And, open data may are enabler for a service-based economy. Today services constitute an increasing part of the Dutch and EU's economic activity, being around 70% of total employment as well as of the gross value-added generated by EU27 (Pro Inno Europe 2010). For the most part, the share of services of the GDP is growing all around the world. The ongoing transition from a manufacturing economy to a service economy and from goods-oriented suppliers to service providers is gaining momentum. This change does not concern only industry, but society as a whole. However, these developments do not automatically sustain a sound economic development.

Services do have real potential to contribute. Deloitte, a consultancy firm, concluded in 2006 in its study of services in the manufacturing industry that *the average profitability of the service businesses benchmarked is more than 75 per cent higher than overall business unit profitability, and accounts for an estimated 46 per cent of total profits generated today*. Deloitte also concluded that *in many manufacturing companies there would be little or no profitability without the service business [49]*. By offering services companies are pursuing to facilitate product sales, to expand the scope and the life time of their customer accounts, to lengthen product life cycles, to create new growth possibilities on already partly saturated markets, and also to respond to customer demands.

This, however, raises critical questions with respect to IT-support of service based business. Common aspects of services are that in general they are executed within a specific timeframe, are people based and information intense. Digitizing services have increased the potential for efficient, customer centric services. In practice a lot of servitization has resulted in failed IT-projects, budget overspending and a loss of trust in the value of IT. Research should focus on the support of services by agile, smart technology that empowers the efficient execution of service processes. Challenges in service science and innovation are agent technology, service distribution, interoperability and standards, semantics, trust- and data management. Relevant fields include transport and logistics, e-health, disaster and crisis response, and government. Relevant here from an ICT-perspective is a restructuring of the software, converting it into a software-as-a-service, SAAS. Companies are ABN AMRO, Achmea, ING, Rabobank,

Exact, RBS, APG, IBM, Cap Gemini, KPMG. Other companies interested in service software are: ACE, Centric, Exact, Layar, Unit4, VitalHealth, en Yuki to name just a few.

5.4 Data, data, data

5.4.1 Big Data

As hidden worlds were revealed through Van Leeuwenhoek's lenses, innovative data management reveals the hidden worlds within data. In our modern world the stakes are high. To truly understand the complexities of global warming, gene diversity, and industrial complexity, flexible eScience-infrastructures to dissect and manipulate Terabytes to Petabytes of raw facts are indispensable. The route forward is marked with better compute infrastructures, modern database management and software innovations.

Compute infrastructure Modern compute infrastructures seek a balance between commodity, easy to deploy, (public) clouds and privately owned powerful compute/storage clusters. The infrastructures consist of modern many core processors and use virtual machine technology, which isolates many of the hardware/operating system specifics. The innovation agenda includes data storage location and data movements in large-scale, distributed data centers (e.g. SARA); optimal allocation and execution of software to reduce the center's energy footprint; remote visualization using high-speed optical networks; best-practice guidance for software development (e.g. NLeSC). Examples: The potential use is wide spread and applies to various top sectors. In healthcare, for instance, for accurate medical history evaluation and care plan analysis, in logistics, for better search answers to queries on scenario alternatives or in finance, telecom, life sciences, security, and many social networks.

Database management Next generation database systems for business intelligence and science exploration are in high demand. The sheer data size creates query result sets which are often too large to interpret. Instead, the user should be given the means to stepwise explore deeper and deeper into the database, and stop when the result and quality reaches his satisfaction point. Response times should be close to instant, to allow for interactive explorations of Petabytes of data. Innovations required span the complete software stack, e.g. one-minute database kernels; blending science file repositories with declarative query processing; post-processing result-sets using data mining; informative summarization to aid in finding the right query; optimization against emerging hardware (Solid State Disks), many core machines (Graphics Processing Units) and distributed compute infrastructures. Examples: Queries terms are mathematical equations rather than search keywords. Social networks (Hyves) and market places (eBay) may grind more than 1 Terabyte/minute for marketing opportunities and potential (spam) attacks and frauds.

Software innovations Software innovations are needed to deal with the data explosion, the scaling of simulation models, and with the complexity of the underlying distributed infrastructure. The sheer size of the data can be partly addressed with modern open source tools (and industry standards) like the Hadoop MapReduce framework. A challenge is how to extend those systems to support more complex functionality, like multi-model simulations, (un)supervised learning, querying

and reasoning. In addition, software innovations in the base toolkit (e.g. domain specific languages) are needed to take advantage of modern infrastructure: tools to program complicated many core machines (e.g. GPUs), adaptive schedulers to allow on-demand scaling in clouds and robust tools to harvest the potentials of many cloud resources. Examples: enabling peak compute loads for water simulations during a crisis; coupling different models (atmosphere, water, land) in climate simulations.

Companies interested in the theme are Philips, MonetDB, Vancis, SIG, Serious Toys and high-tech SMEs.

5.4.2 Data and content exploration

More and more of everyday life is being digitized. This results in large and heterogeneous user data and user generated content streams. In digital data and content knowledge is stored, very large amounts of it. The challenge is to create intelligence, to take better decisions, and to learn what the customer wants from streams of user data and content: to extract and exploit knowledge for individuals and organization across the various forms of information: text, sound, speech, image, and videos.

So far the world was dominated by official content produced for a purpose: forms to fill in, media, new papers, written, books, rules and regulations. In a networked and sensor-rich world now also accidental content is being observed: about humans, about growing stock in agriculture, about traffic in logistics. What is needed in the long run are intelligent algorithms that combine these sources of content with human centric interaction and intuitive user interfaces. It is important to track information over time to detect trends, to make predictions and to adapt to our environment.

At the level of implementation, the application of intelligent lighting solutions is a good example of integrating ICT in our living environment. Recent developments in solid state lighting technologies open opportunities for the development of intelligent lighting solutions. Future lighting systems will consist of wirelessly connected distributed networks of small lighting devices that are controlled by smart sensor networks and intelligent algorithms that combine context information with human centric interaction concepts embedded in intuitive user interfaces. How does light affect the brain? How do people interaction with light as a computer interface? How does lighting combine with outdoor clothing? How does ambient lighting optimize well-being and well-working? Can we contribute intelligence to light design?

For the application of science, linked open data is key. A frequently perceived hurdle for the widespread usage of open data in the top sectors is the lack of standard formats and interfaces. The challenge is to automatically generate wrappers around open collections of spoken text, written text, image collections, video collections and/or sensory data so that they can be queried. Linked data describes a method of publishing structured data so that it can be interlinked and become more useful. Linked open data uses open datasets to provide meaning to mentions of entities and locations in text, audio or video. The challenge of large-scale linking is to develop algorithms based on machine learning that automatically fuse spatio-temporal data in heterogeneous streams.

For use inspired science, the top sectors ask for semantic and cognitively plausible exploration solutions that are self-learning. The challenge is to transition access to information from a document-centric paradigm focused on returning disconnected atomic pieces to a truly semantic aggregation paradigm,

eventually leading to devices and environments that understand a user's intent, discover and organize facts, and identify opinions and experiences around them. Manual ways of turning omnipresent streams of human signals into meaningful information are beyond the capabilities of most organizations. The challenge is to design exploration methods based on self-learning algorithms that exploit social signals to improve their functioning. Information is both a unifying scientific theme and a key resource. The challenge is to understand how the representation of external information aligns with internal (neural, intuitive, social) representations as these can now be observed through fMRI scans, internet-wide sentiment analysis or cognitive studies. The goal is to arrive at fundamentally new exploration methods at the level of human cognition.

Companies interested in the theme are Philips, Noldus, Euvision, Treezir, and many high-tech SMEs.

5.5 Value and information chains

5.5.1 Business value chains

To implement the solutions as proposed by the top sectors, new approaches to innovation are required. Innovation chains are no longer organized in a linear or top-down fashion. In many cases, high-tech SMEs have become knowledge providers, competing with universities for state-of-the-art knowledge. Start-ups from universities, high tech SMEs and large companies should work closely together in both competitive and non-competitive settings, and in multidisciplinary teams. What is needed is a *networked innovation model* to match invention, innovation domain and business. To support the new innovation models, EIT ICT Labs supports the creation and growth of *new companies*, as well as the innovation in *existing value chains*, e.g. through higher involvement of high-tech SMEs.

New Business Creation will receive integrated support for new, young research-based, market driven ventures. Entrepreneurship Support Systems stimulate the birth and growth of new and young ventures. EIT ICT-Labs builds upon and improves existing regional activities and provides international opportunities for growth , among others by giving access to an EIT ICT Labs wide network of cooperating business developers. Its main goals are:
- Creating larger ICT-based spin-offs / spin-outs
- Fast and international growth.

In 2012, EIT ICT Labs will launch four new instruments:
- *Embedded coaching:* Embedded coaching supports young SMEs in their business approach and help them to realize more global market propositions.
- *Soft landing places for companies and ideas:* Implement a roadmap to receive the soft landing NBIA accreditation or to develop a similar soft-landing EIT-label for the European market.
- *Specific training modules:* Aim of this training – which has to be developed - is preparing entrepreneurs for doing business on a European scale.
- *Recruiting potential serial entrepreneurs and board members:* Increase the success of new ventures and their international growth by keeping a database with serial entrepreneurs and experienced board members.

Innovation in Established Companies & Value chains   The underlying idea is to make the large companies more flexible and agile by using the SME ecosystem, and to strengthen the SMEs through the R&D resources of large companies or university expertise. EIT ICT Labs will provide:

-    Access to new business models and experts: Business Modeling Catalyst
-    Access to new partners in Europe: Business Club Catalyst
-    Access to new technologies: Technology Transfer Program Catalyst

In 2012, the focus is on:

1. *Platform & services:* Provide a tool box for SMEs and large companies for business models, scenario techniques, collaborative business modeling, and road mapping.
2. *Networking:* Reinforce links between EIT ICT labs and the main actors of business development in each country focusing on high-growth corporations by Cross Cluster and Business Club Catalysts.
3. *Technology transfer:* Toolbox to detect, stimulate and support Technology Transfer opportunities between academic research organizations and industry.

A new instrument is *SME's and soft landing services* for SME's desiring to grow to new markets in Europe.

5.5.2 Accelerating Innovation

As the ICT Roadmap is not fixed, the look beyond 2012 requires a constant update to stay in tune with the needs of the top sectors as they are developing. One means to achieve that is to organize a dialogue with the top sectors throughout 2012 and further years to get insight in the developing demands for ICT in the top sectors. By organizing Innovation Accelerators per top sector, the current and future ICT needs of the top sectors may be articulated. The Innovation Accelerator will point at ICT business opportunities of each top sector. This way the top sectors can be stimulated to view beyond the horizon and develop new visions on how ICT can help them innovate to a new level and added to the ICT Roadmap for 2013.

5.5.3 Cost reduction by ICT process innovations

The regulatory burden can be substantially reduced if the flow of information between public organizations and companies based on laws would be handled electronically. ICT-solutions may support process-innovations by *chain reversal*. A higher reduction of the regulatory burden is achieved by simplifying data transmission by standardization. Currently, the government is running projects with companies for nationwide roll-out of Standard Business Reporting, e-recognition and e-Invoicing for business-to-government processes.

Bottlenecks in the information chain do not simply vanish and cannot be removed by individual companies. Therefore chain reversal and chain optimization with public and private partners are necessary focusing on cooperation, business cases, standardization and ICT-solutions with added value. In this approach companies can fully focus on their core-competence: doing business. Public organizations can be organized more neatly and the inspection of compliance with laws can be renewed. Two public-private programs have been set up to achieve an electronic and more simple flow of information to reduce regulatory costs: Company File (OD) and smartly connected, smoothly organized.

The purpose of the program Company File is that information entered once by a company can be used repeatedly by public authorities. The simplification of data exchange within a chain and the introduction of a electronic business file could reduce the administrative costs by at least 15% for companies involved. Implementation of the Company File started in the fourth quarter of 2011. The Company File will be introduced in de hospitality and recreation sectors and in the rubber and plastic industry. Following an evaluation, a decision will be made in de second quarter of 2012 on broadening of the introduction of the Company File during the period 2012-2014. The government will launch a study on the possibilities of introducing the Company File in leading sectors as AgroFood, Horticulture and Creative Industry.

The program smartly connected, smoothly organized (SGGV) facilitates organizations which are operating under tight control chains to communicate more efficiently by appropriate ICT-solutions (chain optimization). This could reduce the administrative costs of 10 – 30% for companies involved. Keys for success are commitment of chain-partners, demand driven solutions, reuse of information and public-private partnerships. There are several successful cases, based on a positive business case - of public and private organizations working together to cut red tape and performance better. These cases provide a solid basis for further optimization in a sector by the chain partners themselves. This approach is successful: more than 100 companies, 20 branch-organizations such as VNO-NCW and MKB Nederland, departments, provinces, municipalities and inspections are involved.

Running and closed cases are in the sectors AgroFood (administration of calves, e-Journal fishing), Logistics (import of flowers and plants by air, import of veterinary goods Schiphol), Creative Industry (licences for events) and Construction sector (supervision on handling of asbestos). Cases in research for reducing regulatory burden by chain optimization are identified: registration and usage of herbicides (Horticulture), registration of emissions (Energy) and registration of substances in REACH (Chemistry).

A *National Single Window for Trade and Transport* will be launched soon, allowing companies to supply information once for repeated use by various public organizations, thereby increasing the efficiency of freight transport and, consequently, strengthening the competitiveness of the Dutch logistics sector.

Furthermore the Ministry of Economic Affairs, Agriculture and Innovation carries out an investigation for chain optimizations specifically for the top sectors AgroFood and Horticulture. As a result the investigation identifies specific bottlenecks and solutions - by means of the use of ICT – for further reduce regulatory burden in these sectors. Results will be available during 2012.

The entrepreneur plaza will be the portal for companies through which e-transactions can be made with the government. The first phase of this portal will be realized in 2012 and it will be in full operation in 2015.

The pervasiveness of ICT and its immediate impact, which does stop at borders, it is important for the success of the ICT-Roadmap to invest in the international orientation of entrepreneurs and the societal capital of ICT.

Personal and societal capital

Personal capital
EIT ICT-Lab equips students, researchers and professionals with creativity and entrepreneurial capacity by seeding and breeding entrepreneurial skills and attitude, craftsmanship and knowledge of innovative technologies. Guiding principles are robust entrepreneurship education, stake-holder involvement in educational programs, hands-on experience on innovation and entrepreneurship, and international mobility. In 2012, EIT ICT Labs will start new programs through the Master School, the Doctoral School and the Professional Learning Program. *Co-location centers* will be the nucleation points for co-operation between various stakeholders.

EIT ICT Labs Master in ICT Innovation   Students will be enrolled in international master programs in *ICT innovation* in which they will be awarded an EIT ICT Labs labeled degree referencing EIT ICT Labs specific learning outcomes. The Master School will have a uniform structure:
- a set of technical majors that include a common technical competence base and a specialization/ thesis part that has a thematic area focus (90 ECTS)
- a fully standardized minor in Innovation and Entrepreneurship (30 ECTS)
- thematic workshops and Summer Schools in societal sectors of interest, such as Smart Energy Systems, Health and Wellbeing and Intelligent Transport Systems.
The Master School consists of 7 technical majors: Human Computer Interaction and Design, Digital Media Technology, Service Design and Engineering, Internet Technology and Architecture, Distributed Systems and Services, Security and Privacy, Embedded Systems. Students will be provided with real hands-on experience through extensive embedded project work with external projects owners. Innovation, entrepreneurship and industrial embedding are key components.

EIT ICT Labs Doctoral School   The EIT ICT Labs Doctoral School will address the needs of PhD-students through the set-up of environments where young doctors may grow business projects founded on their thesis research, inspired by the British *doctoral training centers* experience, that integrate industrial involvement and MBA like studies in ICT innovation and entrepreneurship. In Eindhoven, a Doctoral Training Centre will be started in the focus area of Health and Wellbeing.

Professional and Life-long Learning   The need to attract and foster talent is not limited to students and researchers at the PhD-level. Companies like ASML, Philips, OCE, and Thales need to install entrepreneurship in their current workforce,

and also need an influx of insightful, talented people to speed up innovation processes and to enter new products and services domains. EIT ICT Labs will outline a *professional learning program* to make professionals more dynamic through thematic workshops, summer schools, specific courses and exchange programs. This program will feature inspiration from new technologies and different domain contexts, as well as Innovation and entrepreneurship competencies, and quality in ICT through certification. Change of (professional) context, as possible through the international EIT ICT Labs partnership, is a recurring element of this program.

Societal capital

The multiplier effect of ICT   The *information factor* in R&D and strategic innovation processes will be researched on its strategic merit. It is a most important enabler of business and partnerships. The research will take away the emphasis of ICT primarily as a matter of technology in favour of the realisation that information is the stuff by which networks (organisational, productional, innovative) are defined. Hence, this intrinsic network quality matters as well. It is important how sufficient awareness of the consequences of the multiplier effect of networks and composite information and the challenges owing to the networks is reached. Is it by transparency? By standards and precision? By an evolutionary process? These challenges relate in particular to governance issues on information quality, accountability, ownership and responsibility as well as liability in networks and data chains.

Philosophical aspects of ICT   Other aspects of ICT in society cover the philosophical issue what information in fact is. Information grows in its use. And, the meaning of information is not strict but highly context-defined. A systematic semantic and ontological meaning is of importance as the grounding of future generations of complex information systems. In times where new media fall under digital interpretation, what is the essence of the information content pictures as it differs from categorical information? When someone enters social information, who is the owner? Is the consumer or is it the industry providing the service? If the latter choice is preferred, what ethical and moral consequences are connected to the transferral of the most intimate data. These are just a few practical, philosophical questions to be studied now for the benefit of future generations of information system users.

6. Operational issues

This chapter discusses the governance, budget and IPR.

6.1 Governance
The funding of the roadmap is from private and public sources: government, companies, NWO, STW and TNO. Investments in general purpose technology, as ICT is, will stall when others than the driving company have an unreasonable advantage. Therefore, it is generally accepted that investment in ICT-research and ICT-infrastructure needs public support.

TKI for ICT   For the exchange of experience, which is an important part of ICT-knowledge, a TKI is the preferred form of cooperation. We adopt the model developed in Bio-Based Economy [41], another top sector transecting roadmap. The development towards a broad coverage of modern ICT in all top sectors is dynamic and highly interactive. The process will involve participation of industries, knowledge institutions and governments in a public-private partnership or partnerships. The core should be use-inspired research or the application of research. The model of governance should allow for a flexible and ad-hoc definitions of partnerships geared towards the shortest time-to-market. It should balance an instant response to opportunities and the time and tranquility it may take to study a hard problem. It should be capable to be steered by commercial consideration without jeopardizing the academic integrity, which in the end serves the best interest of the industry as well. All of this leads to new coalitions all the time. The governance of the top sector is geared towards the innovative and open dynamics on the basis of the following principles:

- Strategic choices will be supervised from the *ICT-Raad*, see below, identifying new opportunities and recommending new chances to the stakeholders to form new coalitions.
- Attention will be paid to the scouting of new uses, to be delivered as new forms of use-inspired research items on the agenda.
- Attention will be paid to technical and scientific themes, up for reconsideration and possible renewal every year.
- Attention will be paid to the aspects of human capital, business development including business model innovation to which ICT is so prone, and ICT-aspects affecting society at large.
- Shelter will be provided for the high-tech SME, as well as for the data-intensive SMEs in their transition towards an ICT-intensive company. The shelter will aim to accelerate business opportunities when the science is at too high a level to be ready for market.
- The TKI will be grounded on a joint effort as laid down in a consortium manifesto directed towards the joint development.

Part of a TKI is a concentration of all knowledge institutes aimed at high-tech SME's from the same branch where the innovation and connection of expertise is essential to survive competition. The core of the rotating-door institute would be academic expertise and the combined know-what of the companies. The purpose would be to research and provide technology to fill the technology gaps of companies. An example would be to provide software design technology for game companies to make their design processes more efficient. Another example would be to provide search engines on digital

databases replacing the need for manual annotation. The contribution to the institute is in cash in exchange for providing a fellowship to the contributing company. The ownership of the know-how is provided to the company on a non-exclusive basis.

ICT-Raad Ownership and Governance go hand in hand. Primary owners of the ICT-Roadmap part-by-part those are organizations that contribute to the funding of this Roadmap. They are:
1. NWO/STW/IPN: fundamental and application-oriented research
2. TNO: applied and innovation-oriented research, accelerator
3. EIT ICT Labs: education and mobility with a European dimension
4. Digital Agenda (Min EL&I) : reduction of rules
5. Companies: cash contribution to research (still to be identified)

Secondary owners are those that contribute in kind, large Public-Private Partnerships, or as matching. They are:
6. Academic organizations (NIRICT/CWI/Non-tech universities): research
7. Companies: in kind contribution (still to be identified), demand-articulation
8. ICT~Office/CIO Platform: representative of ICT providers, producers, and users, accelerator
9. Surfnet/e-Science: universal ICT infrastructure
10. PPP hosting organization: COMMIT+

The ICT-Raad will be formed consisting of the primary owners and representatives of the various secondary owners. The ICT-Raad will be chaired by an independent chairman with a strong background in ICT. All yearly and multi-annual plans require approval of the ICT Raad.

6.2 Budget
The budget for the execution of the ICT Roadmap is drawn from several sources as required below.

Companies, large and small, have signed a public-private contract or letter of intent. They are motivated to spend their R&D-activities in the context of this roadmap in return for participation in the ICT-Roadmap TKI. The industry turn-over in R&D in the Netherlands for ICT covers 10 – 50% of all top sectors. On average it is estimated at 30%. For a total estimated participation to the top sectors of 1 BEuro / year, this boils down to 300 MEuro each year in ICT, a part of which will go to ICT innovation.

For one, the industry and non-profit organizations part of COMMIT are prepared to support the use-inspired research after its conversion to a TKI under this Roadmap. The topics covered in COMMIT comply with the action lines 5.2 Embedded Systems, and 5.4 Data in the Roadmap. The Roadmap will offer new possibilities to the partners of COMMIT and the use-inspired research it endorses.

Funding from the EU is estimated to be 10 – 15 MEuro each year, mostly to universities and knowledge institutions.

The partners of TNO have indicated they are prepared to participate in the application of science under the Roadmap. They have indicated to increase their R&D-budgets spend on topics of this research

agenda. For one, KPN has announced it considers spending in access of 6 M / year on R&D activities in TNO's institute. The Roadmap offers new opportunities for these industries.

(in MEuro)	2012	2013	2014	2015	2016 & beyond	

Companies
   40% cash & kind
	50	60	70	80	90	Estimated for
						   COMMIT TKI

EU - funding	12	12	15	15	15	Estimated current

EU-EIT ICT-Labs
      / person
      / business
	5	7	8	8	8	Conditionally
						   committed
						   by EU-EIT

NWO incl STW
   / current
   / additional
   for ICT Roadmap
	10
	
	10
		10
		
		15
			10
			
			20
				10
				
				20
					10
					
					20
						Required for
						   2012, under
						   negotiation
						   for later yrs

TNO	6	6	6	6	6	Required
Digital Agenda	8				8	Required

Research institutes
   10% cash & kind
	9	10	11	11	11	Convenant
						   Roadmap

Total	110	120	140	150	168	

The companies connected to ICT Office are prepared to help executing the implementation of the Roadmap, especially where they see opportunities to accelerate the innovation per top sector.

EIT – ICT – Labs is a large EU – funded enterprise for the acceleration of innovation and know-how in ICT, where the Netherlands is one of five nodes, next to France, Germany, Finland, and Great Britain. Their participation in the Roadmap activities provides an excellent forum for the EU-connectivity of research and emerging business from the Roadmap. The EU – funding requires 75% co-funding from the national funding, either in cash or in kind.

Apart from transecting top sectors, the Roadmap is also aligned with the implementation of the *Digital Agenda* of the Netherlands, molded after the European Digital Agenda by EU – commissioner N. Kroes. The Roadmap includes action lines for relieving the regulatory administrative burden by information integration along the information chain, applicable to many top sectors. For the Digital Agenda the PRIMA-regulations will demand 50% co-financing.

NWO increases its investments dedicated to ICT-research for the action lines in this Roadmap.

TNO deploys several instruments for funding applied research, valorization projects and proof of concept projects. The instruments include Small Business Innovation Program, Branch Innovation Contracts and the EL&I co-finance program. All programs suit specific types of innovation. TNO has been invited by the Minister of EL&I to apply ICT-funding to the order of 6.2 MEuro a year to the ICT-roadmap

and the top sectors for the next 5 years. The 6.2 Meuro is partly EL&I co-finance to be matched by industry, and partly it is knowledge building funds to be applied with less matching funding. For 2012 and 2013, part of the budget is assigned in FP7 programs and COMMIT. Most of these long-term obligations match with the scope of the ICT-roadmap. Part of the remaining funds will be allocated to top sector specific ICT-projects, see chapter 2, and aimed at the Creative Industry, HTSM, Water, Energy and alike. The other part of the budget will be allocated to generic ICT-subjects described, see chapter 5. However, the budget is insufficient to meet the requested budget based on the combined requirements of the top sectors as voiced in this roadmap. Therefore, the final allocation of the budget will be done by TNO together with EL&I, taking other TNO contributions to top sectors in account.

In this stage we register the well-motivated intent of top sectors indicating the relevance of ICT, the motivation of the stake holders such as NWO, TNO, companies and their representatives, and the Government. When projects are concrete, a conditional factor in the selection of projects is the commitment of companies *for that project*. Only when projects are sufficiently concrete (including IPR), the various stakeholders sign a contract.

6.3 Intellectual Property Rights
The intellectual property in ICT takes several forms.

One variant is a contribution of cash in exchange for the IPR potentially developed in the program. In another variant, the contribution of cash is used to invite a scientist to contribute specific know-how to the industry. In practice, these two variants may be combined leading to the exchange of IPR for know-what and cash in proportion to the added value. These variants will work for the larger industries with well protected knowledge in a R&D unit of the company.

At the same time it is often the case in ICT, that advanced *know-how* is the key-ingredient of the competitive edge. ICT new ideas often have a broad impact and they are difficult to police. Therefore, ICT differs considerably in their handling of IPR compared to other disciplines where the protection of IPR in patents is the key to success.

On the basis of these observations, for the publicly funded part of the roadmap, the default option is to create open and open-source standards enabling the free exchange of information between more than one vendor.

For the NWO-part of the roadmap, we will follow the IPR-statement of NWO, developed for the HTSM top sector [39]. The statement describes a tailor-made solution to IPR differentiating among cash and in-kind contributions, and enabling industrial innovation by regulating the limits of the free flow of knowledge and know-how. The purpose is to enhance innovation in a short time-to-market by open communication in the consortium while safeguarding the legitimate rights on the use. Open communication in a limited environment is the best way to fundamental, use-inspired research of top quality. As a standard policy all partners in a public-private consortium under this roadmap will agree on IPR as part of the consortium agreement, which will include an agreement on licensing, the ownership and handling rights of patents, and an agreement on the commercial validation of the research results.

7. Roadmap 2012

7.1 The 2012 roadmap actions

1. ICT one can rely on

In 2012, given the need for ICT industry and utilities can rely on, the Roadmap will initiate programs of science, and the application of science in secure and vital ICT, as well as on privacy and e-identity. Science projects will be run on the basis of competition by NWO / STW on the combined quality of industry inspiration and the quality of the proposed solution. The projects will start in the first half of 2012. Application of science projects will be run at the newly formed TNO-institute for privacy and e-identity. And, implementation projects will be run as part of the implementation of the Digital Agenda, implementing parts on security and e-identity.

2. ICT Systems for Monitoring and Control

In 2012, embedded systems will be part of the execution of the roadmap Embedded Systems in the HTSM top sector agenda. For monitoring and sensor networks NWO / STW on the combined quality of industry inspiration and the quality of the proposed solution. The projects will start in the first half of 2012.

3. ICT for a Connected World

In 2012, embedded systems will be part of the execution of the roadmap Embedded Systems in the HTSM top sector agenda. For monitoring and sensor networks NWO / STW on the combined quality of industry inspiration and the quality of the proposed solution. The projects will start in the first half of 2012.

4. Data, data, data

In 2012, given the need to do something with large amounts of information and data everywhere, the Roadmap will initiate programs of science, and the application of science in big data and cloud computing as well as in content exploration. Science projects will be run on the basis of competition by NWO / STW on the combined quality of industry inspiration and the quality of the proposed solution. The projects will start in the first half of 2012. Application of science projects will be continued to run at the eScience-Centre and SARA and industrial labs.

5. Value and information chains

In 2012, the Roadmap will employ by EIT ICT Labs four activities on new business development: embedded coaching, soft landing places for companies and ideas, specific training modules and recruiting potential serial entrepreneurs and board members. And, for the innovation of established companies and value chains, the roadmap by means of the EIT ICT Labs will commence platform & services, networking and technology transfer. In addition, for the reduction of the regulatory burden, the first phase of the entrepreneur plaza and the pilots on information chain optimization will be ready by 2012. By an Innovation Accelerator to be organized per top sector in 2012, the current and future ICT needs of the top sectors will be articulated. The result of Innovation Accelerators will point at the ICT-business opportunities and research needs of each top sector. A budget is required of 250 KEuro.

7.2 The 2012 financial planning

The following budget needs are indicated.

Plan 2012 (in KEuro)	1 ICT one can rely on	2 System for control & monitor	3 ICT for a Connected world	4 Data, data, data	5 Value and Information chains	ICT and society
Companies for ICT Roadmap	8000	8000	8000	14000	8000	6000
EU funds	2000	2000	2000	6000		
NWO incl STW current + additional for ICT Roadmap	5000	5000	2500	7500		
TNO	2000	1000	1000	1000	1000	
ICT Labs personal + business					3000	2000
Digital Agenda	1000			1000	4000	2000
Research institutes 10% in cash & kind	3000	3000		3000		
total	17600	13800	5400	15800	17000	9200

8. Conclusion

8.1 Summary

ICT is an important ingredient in all top sectors. The estimated level of activities in ICT is 10 – 50% of all activities. It is safe to conclude that 30% of all innovation is ICT-involved involved innovation, also supported by evidence from other sources. ICT is by far the largest technical discipline of innovation.

All top sectors underline the importance of ICT for their plans. The activities sort according to 4 different ICT-themes:

1. ICT one can rely on
2. ICT systems for monitoring and control
3. ICT for a connected world
4. Data, data, data

Next to these technical and scientific themes, attention needs to be paid to

5. Value and information chains

And another theme as part of the human capital roadmap, or specific for ICT the theme

Personal and societal capital

is also important.

Top sectors have shared their vision. For the ICT part of the vision, the top sectors may profit from innovation acceleration to further articulate their ICT innovation needs.

All signs indicate an increase is required for the ICT research and innovation budget by a substantial amount to respond to the overwhelming interest in all top sectors. As the public budget for ICT research and development is growing, so should the public budget to warrant long-term ICT research.

Attention is needed for the high-tech SME as part of the execution of this Roadmap.

The Roadmap aligns with the goals of the Digital Agenda.

A few new aspects of ICT: software engineering, social media, games, man-machine interaction, to name just a few elements, is not yet on the radar of the top sectors at large. More dissemination is to be done.

8.2 The further impact of ICT

ICT delivers. It is the driver of innovation, disruption and productivity. While in the past ICT has been primarily *supportive* to render societal and economic processes more efficient and effective, we have witnessed in recent years that innovations in ICT are increasingly *disruptive*. Fiber broadband connections have enabled large scale outsourcing to emerging societies. Business models for a 100-year old music industry have been turned up-side down within a two-year timeframe through 'cloud'-like services like iTunes. Immediate interconnected control in the financial industry is at the root of recent financial turbulences. And in politics, global interconnectivity causes turmoil when information-empowered individuals take little for granted. Hence, ICT is also the driver of *social innovation*. Did you read your email in the last hour?

And, as the next step, all things will receive an internet address. They will participate in the information connected world. Stores with RFID-stock, all goods labeled from production to consummation. And even prior to that, all goods exist as an information entity at the moment of ordering. Mass individualization is the result, from conception to the end of its lifetime. Investing in mass individualized information will pay off immediately as soon it is the standard level of expectation. The consumer is taking over the driver seat. New business models and new businesses are necessary to adjust to these new developments.

ICT contributes to sustainability in production, service offerings and products themselves. Smarter energy by ICT almost always is a direct saver of cost matching efficiency to sustainability. Smarter observations by sensor networks will evolve to the standard in a society where everyone wants to be informed immediately. And last but not least the ICT-systems themselves need to be greener in order to make sure that ICT worldwide starts to consume less energy.

Personal data can help our society where bicycles are used to gather information on noise, air-pollution and travel-times in Copenhagen [29]. The essence of this innovation is information, everywhere, attached to everything. All that data allows for data storage in the cloud, modeling and monitoring all in real time. This will help to increase the quality of life in terms of comfort, ease and safety. But data has more uses. It is hard to imagine that any business will do without customer profile data 5 years from now. Businesses will analyze their customers routinely, from video, from profiles, from sales. Production and service delivery chains will be shortened and individualized by ICT and ICT only.

ICT innovation is getting closer to the human and closer to the skin. Man-machine interaction is improved by every new generation of systems, is improved by sensors everywhere, and it has improved by going mobile. Man-machine interaction by voice and video will come soon. Deploying efficient man-machine interaction [15] has demonstrated to be a driver of new ICT-businesses.

Increasing the trustworthiness of ICT is hampered because of the complexity of today's software and ICT systems. Software legacy is a key problem in the operations of businesses. The science of software engineering, the science of information management and the science of systems of systems prevent the disasters of failing large-scale system introductions we have seen too often in the past.

The recent success in the service industry has been largely driven by ICT. To continue this path, radical changes are required in the software systems that are keys to agile service compositions. The components of many popular services contain a limited number of generic and re-useable components, such as *location*, *payment*, and *connectivity*. Hence, it is expected that the launch of new services does not require a design-from-scratch, resulting in short lead-times.

And, yet, all of this is just the beginning. It was argued by Ray Kurzweil [38] that technological capabilities increase exponentially in time from their very nature. Intelligence is part of web crawlers indexing the internet, stock-

54
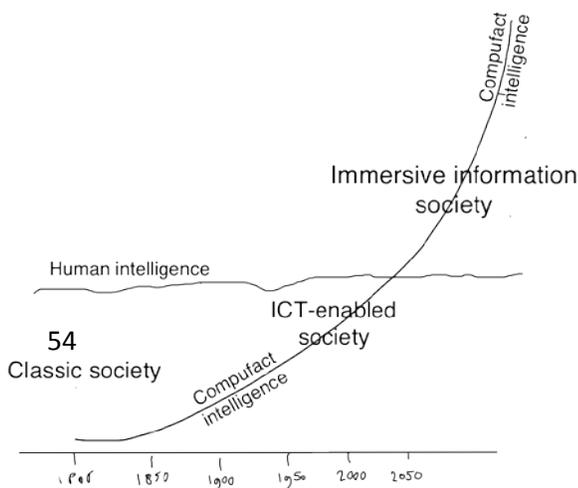
market transaction systems, camera surveillance systems with violence detection analysis. Information goes beyond the boundaries of specific hardware systems, and at the same time beyond the boundaries of countries and companies. Some processes will monitor or control other for specific purpose processes. In short, the information society will become *an organic information society*. An intelligence similar to that of humans (as illustrated by the defeat of world champion Kasparov by the Deep Blue computer) marks another new era.

ICT delivers and will continue to deliver. It is the driver of innovation, disruption and productivity. In an OECD study, almost 60% of the economic growth in 1985 − 2000 is deduced from the application of ICT [26]. And, also in the US, it has been demonstrated time and again [10] that investing in ICT improves productivity, more than anything else and increasingly more than expected previously.

9. References, organizations and contributors

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List of participating in the making of the ICT-Roadmap

1. ICT Office — Branch organization for ICT-industry
2. CIO — Platform organization for CIO professionals
3. NWO — National (funding) agency for research
4. STW — National (funding) agency for technological research
5. TNO — National organization for the application of sciences
6. EIT ICT-Labs — Knowledge Centre for the ICT economy sponsored by EU
7. IPN — National platform for the advancement of ICT Science
8. NIRICT — The 3 Technical Universities cooperative institute for ICT
9. CWI — National research institute for Computer Science and Math
10. eSC — National center for the soft infrastructure for arts and sciences
11. SARA — National compute center for the arts and sciences
12. SURF — National network infrastructure for the arts and sciences

List of organizations currently engaged in public-private partnerships for ICT

1. Almende
2. Ambient Systems
3. ANP
4. Arcadis
5. Auxilium
6. Axini
7. Broadfield Security Services
8. Capgemini
9. Centric Tsolve
10. Cinop
11. CIT
12. Cybermind Interactive
13. Devlab
14. Elsevier
15. Ericsson Telecommunicatie
16. EUVision
17. Europeana
18. Food & Biobased Research

19. GridLine
20. Hyves
21. Irdeto
22. KITT Engineering
23. Korps Landelijke Politiediensten
24. KNMI
25. Koninklijke Bibliotheek
26. Logica Nederland
27. Motek Medical
28. Eurocottage
29. MonetDB
30. Nederlands Centrum Sociale Innovatie
31. Beeld en Geluid
32. Noldus Information Technology
33. De Persgroep Printing Amsterdam
34. Philips Research

35. Politie Regio Gelderland Zuid
36. Re-Lion
37. Roessingh Research and Development
38. Serious Toys
39. Talking Trends
40. Teezir
41. Textkernel
42. Thales NL
43. ThirdSight
44. TomTom
45. TrendLight
46. VicarVision
47. Video Dock
48. Waag Society
49. WCC Development

Industries who have signed a Letter of Intent to this Roadmap:

50. AARVO
51. Adepticon
52. Beijer Automotive
53. Better.be
54. Bicore
55. Blue4Green
56. Bronkhorst
57. Bruco
58. Demcon
59. eTech Connect
60. INQA
61. InRoads
    Irdeto*
62. MobiHealth
    MonetDB*
63. Noldus Information Technology*
64. Oce
65. Personal Space
66. Philips
67. Phuntronix
68. Prodrive

   Re-Lion*
69. Recore Systems
70. Salland Engineering
71. Security Matters
72. SIDN
73. Siqura
74. Software Improvement Group
75. SolidSourceIT
76. SURF
77. Synerscope
78. Target Holding
79. Technolutions
80. TechToBizz
    Thales NL*
81. ViNotion
82. Vipsnet
83. Vital Health Software
84. WMC
    *also COMMIT
… and still counting…