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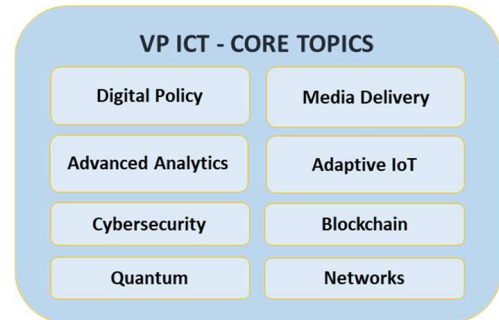
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Summary

TNO Unit ICT aims to guide industrial and societal stakeholders in the digitization of their business or domain, by integrating the identified enablers in national and European ICT agendas in first-time engineering solutions. The Unit propositions focus on stakeholder and customer needs such as data sharing, fast open infrastructures, trusted digital marketplaces, and increasing the efficiency, effectiveness, quality and costs of product development. The VP ICT knowledge program supports these propositions by focusing on eight core topics (see figure on the right).



Until 2022, the main goals for these eight topics are:

- **Adaptive IoT:** to shape Internet-of-Things (IoT) ecosystems in specific domains, such as agriculture, energy and industry by developing technologies for adaptive data processing in complex decentralized systems and for automated software development. In 2019, we develop and deliver infrastructure and technology for adaptive data ecosystems.
- **Advanced Analytics:** to shape ecosystems and platforms for data sharing in domains such as agriculture, energy, health and industry, by developing privacy respecting analytics and explainable, transparent and human aware artificial intelligence (AI) algorithms. In 2019, we deliver privacy respecting tooling to the healthcare domain, and we develop and deliver semantic models for the exchange of company data.
- **Blockchain:** to lead national blockchain developments based on expertise in identity management and blockchain infrastructure, in the deployment of pilots in agrifood, logistics and financials. In 2019, we aim to enlarge our footprint in blockchain ecosystems through EU collaborations, and we deliver a Self-Sovereign Identity Framework to experiment with blockchain infrastructure.
- **Cybersecurity:** to develop threat detection algorithms based on AI and network data, and to integrate such algorithms within an automated cybersecurity platform. The shared research programme on cybersecurity with financials will continue in 2019 and an EU collaboration to develop and implement a security automation and decision support platform will be set up.
- **Digital Policy:** to collaboratively study the societal, economic and policy implications of digital technologies and innovations, to develop innovation strategies and business models for the digital era, and set up a national digital Policy Lab with key academic, governmental, and industrial partners, aiming at policy experimentation using new technologies and data sources.
- **Media Delivery:** to expand TNO's leading international position in end-to-end orchestration technologies for multi-source media streams over hybrid networks towards multiple devices and locations to create a fully immersive, mobile and social video and VR experiences. In 2019, these technologies will be applied to the domain of smart venues and cities, and integrated to deliver orchestration platforms for fan and end-user experiences, primarily in the context of (inter)national collaborations.
- **Networks:** to lead the international development of the 5G standard, by setting up (pre)5G field labs for proof-of-concepts in 5G Verticals (automotive, agriculture, media), investigating the development of radar technology for 5G antennae, and by developing Network Softwareization facilities. For 2019, the main objective is to extend our field lab footprint beyond 5Groningen and Helmond to Amsterdam (the Johan Cruijff ArenA) and the Rotterdam harbour, and to connect these field labs to European 5G testbeds.
- **Quantum:** to become a frontrunner in developing quantum-safe cryptographic solutions and applications for the quantum computer. For 2019, main objectives are to continue the collaboration with QuTech through the quantum applications programme, and to set up an international collaboration around quantum key distribution.

These topics are aligned with national and stakeholder agendas, specifically the *Nederlandse Digitaliseringsstrategie*, the *Kennis en Innovatie Agenda ICT*, the *Actieplan Digitale Connectiviteit*, the *Nederlandse Cyber Security (Research) Agenda* and with stakeholder viewpoints, e.g. expressed in the KPN Technology Book.

In relation to the above mentioned goals, the VP ICT actively engages in stakeholder management on both the national -via the B3C Dutch Blockchain Coalition, COMMIT2DATA, the media *klankbordgroep*, the National Science Agenda Big Data Route, and by supporting the initiative for a national AI programme- and the European level -via the Big Data Value Association (BVDA), 5G (5GPPP), IoT (AIOTI) and the Cybersecurity contractual Public-Private Partnership- with academic partners and partners from industry. Until 2022, our objective is to consolidate this role. Furthermore, we aim to maintain our leading position in ICT standardization and within industry fora, such as within 3GPP, ETIS, ETSI, IETF, ISO and VR-IF.

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1 Short Description

A **digital transformation** is taking place in every sector of society as a result of artificial intelligence (AI) and the internet of things (IoT). Data and algorithms become increasingly pervasive, and data-driven innovations are important determinants of economic success and societal impact. At the same time, the distinction between the physical and the virtual world is blurring, giving rise to cyber-physical systems (CPS) where professionals and end-users interact through augmented and virtual reality interfaces. For all of these developments, secure, adaptive and robust transmission of data is paramount. VP ICT aims to support the development of knowledge and technologies, with which Unit ICT can guide industrial and societal stakeholders in the digitization of their business or domain. These stakeholders seek to take advantage of new opportunities in data sharing and in the increased efficiency, effectiveness, quality and costs of their product development, but require fast open infrastructures and trusted digital marketplaces to overcome their challenges in operating in a digital ecosystem. These challenges take place in all sectors of society. And at the same time, businesses as well as societal stakeholders are faced with having to reinvent their business models based on data and the emergence of dominant platforms. Law and policies that are able to sustain economic benefits and mitigate negative effects, such as privacy infringement, are necessary. Sectors that have the specific attention of VP ICT are agriculture, telecom providers, government, media, financials and smart industry. **ICT is thus an area of innovation in itself as well as a key enabler for innovation in these domains.** To guide these developments, the VP ICT focuses on eight core topics: adaptive IoT, advanced analytics, blockchain, cybersecurity, digital policy, media delivery, networks and quantum technologies.

The IoT is brought about by connecting a plethora of devices and systems, e.g. home automation systems and measurement sensors, smartphones and wearables, enabling communication and the exchange and processing of their data. TNO shapes IoT ecosystems in specific domains, such as agriculture, energy, health and industry, by developing **adaptive IoT** infrastructures that leverage cloud resources and allow for distributed data processing in complex decentralized systems. The emerging data economy builds heavily on such IoT ecosystems, and on increasingly connected data stores, interoperable data formats, and AI-based **advanced analytics** that is explainable, transparent and human aware. TNO develops infrastructure architectures and semantic models that are becoming important building blocks for data sharing platforms, as well as multi-party computation approaches for privacy-preserving and secure data fusion and processing. The transparency and accountability inherent to **blockchains** allows TNO to work towards the sharing economy, device autonomy en Internet of Things, with a focus on identity management and blockchain infrastructure.

In the context of **cybersecurity**, TNO aims to support organisations (e.g. financials) that aim to improve their own security capability; managed security or transaction service providers that aim to provide better service to their customers; and security vendors that aim to improve and/or extend their product offering. In our concepts, we leverage our broader investments through VP ICT in AI and advanced analytics, blockchain, multi-party computation, software-defined networking and (post-)quantum technologies. In order to take full advantage of these advanced ICT technologies and innovative business models offered by the collaborative economy, governments need to be able to understand and deal with the implications of new digital technologies towards society and industry. Therefore, it is essential that they have the knowledge and skills to develop **digital policy** and actions to foster digital transformation and to accelerate the digital transformation of industry, enterprises and their own governmental bodies. TNO studies and shapes the societal, economic and policy implications of digital technologies and innovations, concerned with innovation strategies and business models, with a special interest in smart industry.

The media landscape is evolving ever faster, and watching linear TV on a big screen nowadays is just one of many consumption modes. Internet-based **media delivery** opens up the media industry for new entrants that do not have the technical and regulatory legacy of traditional players. The industry focus has shifted from only content production and distribution to creating the highest quality media experiences leveraging AR/VR and other ICT disciplines such as AI and blockchain. TNO customers expect us to support them in combining these new technologies with their media services, and in working towards building immersive, interactive and social media experiences. The increasing penetration of Internet of Things devices, mobile systems and Smart Industry ecosystems puts stringent requirements on bandwidth, latency, quality and robustness of 5th generation (5G) wireless communication **networks**. TNO will mainly develop its 5G activities in in the 5Groningen field lab that was established in 2017. This field lab is focused on developing proof of concepts and pilots in different sectors with innovations on mobile access, with specific focus on precision farming.

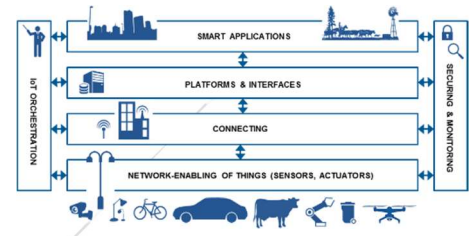
Quantum technology will disrupt the way we handle communication, impacting asymmetric cryptography, cloud computing and networking. Quantum computers will be able to break through public key encryption schemes and disrupt the way we communicate and trust across the internet. The quantum computer will also bring new business opportunities, of which the shape and form is not yet known. TNO aims to support organisations in preparing for the inevitable arrival of (a network of) quantum computers, both from a security and an application point of view. We have established a solid collaboration with Delft University of Technology (DUT) in the QuTech research centre, and seek new collaborations with the QuSoft research centre on quantum software.

2 Results 2019

For each of the eight topics, within the context of the VP ICT, specific results are defined for 2019.

2.1 Adaptive IoT

TNO has gained a good position in setting up the infrastructure for complex and multi-stakeholder data and IoT ecosystems. In 2019 VP ICT will focus on infrastructure virtualization through containerization and use of microservices, automated platforms, data locality and the design for auditability. Having a stronger focus on technology development in addition to shaping these data and IoT ecosystems, should allow us to gain a stronger position in this field. In 2019, VP ICT will support at least the following activities in the context of adaptive IoT:



- the ECSEL project Productive 4.0 will continue, in which we develop and deliver ICT solutions for Lot-1 production and zero-defect manufacturing in industrial factories of the future;
- the H2020 project Cerbero will continue, where we design and deliver an environment for CPS based on cross-layer model based approach to describe, optimize, and analyse the system and all its different views concurrently, and on an advanced adaptivity support based on a multi-layer autonomous engine;
- the ITEA project TESTOMAT will continue, in which we develop and deliver a test automation improvement model for continuous integration.

2.2 Advanced Analytics

The privacy respecting architecture and tooling that have been developed over the last few years, based on homomorphic encryption and secure multi-party computation will be integrated into data sharing platforms in a variety of domains. AI and semantic technologies will be developed and integrated into smart agri platforms, and the SAREF standard will be brought to collaborations in the energy domain. In 2019, VP ICT will support at least the following activities in the context of advanced analytics:

- the coordination action on Big Data in Europe will continue, where we provide coordination and support for the current and future H2020 projects within the Big Data Value Public-Private Partnership;
- the H2020 project TOOP will continue, where we create and deliver interoperability modules and interfaces between building blocks via the 'Once Only Principle', thereby creating seamless service delivery between EU governments;
- the H2020 project Big Medilytics will continue, in which we realize cost savings in healthcare by delivering an infrastructure for data sharing;
- an EU collaboration will be set up, to develop artificial intelligence and semantics technologies for data-driven decision support systems in agriculture, enabling key stakeholders to share vital information between them;
- an EU collaboration will be set up, to adapt the SAREF reference language for energy-related data, and deliver a semantic model for interoperable and smart homes and grids;
- a dedicated effort on AI from 2018 will continue, extending the work in three use case domains (agri, safety, mobility) to health and energy.

2.3 Blockchain

The TNO Blockchain Lab can be used to develop proof-of-concepts of blockchain activities across TNO. Within the context of the Dutch Blockchain Coalition (DBC), TNO will continue to shape a national Blockchain research agenda. Furthermore, based on this research agenda the VP ICT will also continue to shape national ecosystems, such as the Techruption in Heerlen, as well as other field labs that allow for experimentation and development of blockchain applications, for example in the field of Smart Industry. In 2019, EU collaborations will be set up to strengthen our Self-Sovereign Identity Framework, and to deliver it to partners to experiment with blockchain infrastructure; we apply our knowledge in pilots in agrifood, logistics and financials, resulting in concrete deployment of blockchain technologies in 2019. In addition, TNO will be investing in the integration of semantics with blockchain technology to allow the representation of business logic without the dangers of immutable smart contracts.

2.4 Cybersecurity

Aligned with the programme areas described in VP Cyber Risk Management and System Resilience, VP ICT specifically supports the development of threat detection algorithms, the integration of such algorithms within an automated cybersecurity platform, and privacy preserving post-quantum systems from advanced cryptographic mechanisms. In 2019, VP ICT will support at least the following activities in the context of cybersecurity:

- the Shared Research Program (SRP) Cybersecurity will continue , focusing on developing and delivering innovative cybersecurity solutions for the financial sector;
- the H2020 project Prometheus will continue, where we develop and deliver privacy preserving post-quantum systems from advanced cryptographic mechanisms;
- an EU collaboration will be set up, to develop and deliver threat detection algorithms based on AI and network data, and to integrate these algorithms within a security automation and decision support platform.

2.5 Digital Policy

Digital transformation is characterized by a fusion of advanced technologies and the integration of physical and digital systems, the predominance of innovative business models and new processes, and the creation of smart products and services. TNO is European thought leader on combined methodologies for digital innovation strategy and policy, such as the Digital Innovation Hubs (DIH) envisaged by the European Commission, and we aim to set up a policy lab as a joint innovation environment for incorporating new digital technologies and data sources into policy making. In 2019, VP ICT will support at least the following activities in the context of digital policy:

- the H2020 project SmartAgriHubs will start, where we develop and deliver a capability (self-) assessment tool for the DIH to coordinate the digital ecosystem and aim to realise the digital transformation in agriculture with a focus on innovative technologies which needs to be customised, integrated, tested and validated not only by technology developers but also the farming community (including government actors) before being released on the market;
- the H2020 project Connected Factories will continue, where we establish and deliver a structured overview of available and upcoming technological approaches and best practices for the digitisation of manufacturing, including concepts such as 'Industrial Internet', 'digital manufacturing platforms' and the IoT;
- Policy development, modelling and monitoring, leveraging AI and data analytics will primarily take place through the policy lab and in collaboration with the municipality of Rotterdam, Ministry of the Interior and CBS. In 2019 the aim is to extend these activities to other municipalities and topics.

2.6 Media Delivery

TNO has an outstanding international position in media delivery with a leading role in international standardization and a substantial and a steadily growing IP portfolio, with strategic partner KPN. In 2019, VP ICT will support at least the following activities in the context of media delivery:

- the ITEA3 MOS2S project will continue, where we develop and deliver a flexible video orchestration platform within a smart venue;
- the H2020 VR-Together project on social VR will continue, in which a scalable and web-based platform is developed and delivered for networked collaborate VR experiences;
- the H2020 FLAME project will start, in which we create and deliver localized crowdsourced video production and distribution workflows for prosumer content, and demonstrate these in 5G-enabled smart cities.



Building on results from a 2018 seed project, we explore an EU collaboration to develop tactile Internet technology, to transfer multisensory data, e.g. touch and feeling across the internet, for example when operating an exoskeleton.

2.7 Networks

Research within the 5Groningen field lab in 2019 focuses on two main technological developments in softwarized networking, i.e. slicing and mobile edge computing (MEC), based on Software-Defined Networking (SDN) and Network Function Virtualization (NFV) concepts. TNO is also involved in the 5G field lab automated driving, in which automatic driving with 5G technology will be piloted. In 2019, VP ICT will support at least the following activities in the context of networks:

- EU collaborations for advanced 5G validation trials across multiple vertical industries (in particular media and logistics) will be sought, aimed at connecting national fieldlabs to European-wide testbeds and delivering integrated platforms for these verticals;
- the 5Groningen initiative will continue, focussing on use-case driven development of the TNO Hi5 platform. It will deliver a platform update in which we adopt 3GPP Release 15 architecture for the core and the OpenAirInterface 5G gNodeB ready;
- Furthermore, two H2020 projects will continue; Sat5G and Clear5G, concerned with integrating satellite into 5G and delivering a 5G wireless network for Smart Industry respectively;
- We extend our work in the 2018 TRIANGLE project on 5G network orchestration to i) enable highly efficient management of applications and deliver high quality experience to users using network information and ii) to support multiple concurrent users;
- In a collaboration with quantum computing experts, we develop and deliver SDN/NFV concepts to realize transitioning network techniques, to protect networks that are incapable of quantum-safe encryption from attacks on encryption by Quantum Computers.

2.8 Quantum Technology

VP ICT enables knowledge build up and technology development on i) secure quantum communication and key distribution, ii) quantum algorithms and applications, and iii) post-quantum crypto. The work in sub-topics i) and ii) is aligned with the corresponding QuTech research and technology roadmaps. In the field of quantum technology, research on (post) quantum cryptography will continue in 2019, as well as research following the worldwide developments in quantum information processing and quantum communication and networks, identifying opportunities for TNO to create a knowledge position in the field of quantum technology. In particular, we expect the following results in 2019:

- the collaboration with DUT in QuTech will continue in 2019, where we deliver quantum key distribution solutions and quantum algorithms.
- a quantum technology research roadmap will be added to the Techruption programme;
- an NWA project on improving the security of financials with quantum computing will be set up;
- work on a post-quantum cryptography testbed from 2018 will be used in developing a quantum-safe network proxy. Here, post-quantum crypto and network programmability will be combined to deliver a network proxy that enables legacy systems to operate in a quantum-safe manner.

2.9 Stakeholder management and standardization

The main objective for 2019 is to consolidate TNO's role in international research communities, standardization and business fora. The COST Actions IRACON, on radio communication for 5G, and RECODIS, on cybersecurity, continue in 2019. Important objectives are to support these developments via stakeholder management and standardization, to maintain connections with national and international ecosystems, such as the Dutch Blockchain Coalition, the media *klankbordgroep*, the initiative for a national AI programme, and R&D&I programs (Horizon2020, ITEA, ECSEL, COMMIT2DATA) and standardization groups and industry fora (e.g. ETIS, ETSI, 3GPP, ISO and IETF). Several part-time professors are associated with the program, to connect to relevant Dutch universities (Rijksuniversiteit Groningen, Universiteit Twente, Universiteit Leiden and Universiteit Maastricht). TNO is also represented on a board level in advisory fora, including 5GPPP, AIOTI, BVDA, PI.lab and VR-IF. Furthermore, TNO has a long track record in contributing to the development of standards, and these efforts are increasingly presented and undertaken as an integral part of the program.

2.10 Links to external agendas and roadmaps

In the report *Maak Waar!*¹, and the subsequent agendas of the ministry of Economic affairs and Climate, *Nederlandse Digitaliseringsstrategie*² and *Actieplan Digitale connectiviteit*³, the Dutch government stresses the importance of innovation in, and experimentation with, new ICT technologies such as AI and blockchain in the context of policy and public services, in iterative and permanent beta manners. While (inter)national funding programmes provide only few opportunities for media-related research and development, strategic partner KPN explicitly mentions AR and VR experiences in their Technology Book⁴, as a driving force for networks that are capable of massive data transfers, with large bandwidth capacity at low latency. The Ministry of Education, Culture and Science, in their first reaction to the *Sectoradvies Audiovisueel*⁵, recognizes the main challenges that stakeholders of the national media ecosystem face, and how these challenges arise from technological developments and the mediatization of society. In the *Nederlandse Digitaliseringsstrategie* from June 2018, Action Line 5 gives explicit attention to establishing and trialing with a world-class fast and open digital infrastructure. 5G receives explicit attention in the *Kennis en Innovatie Agenda* ICT⁶. More concretely, the 2018 *Actieplan digitale connectiviteit* outlines the goal of supplying citizens with at least 100 Mbps mobile bandwidth by 2025. Virtual reality and connected cars are referred to as applications of particular interest, and the 5Groningen and Johan Cruijff ArenA fieldlabs are mentioned as precursors for 5G innovation. A 5G innovation network shall be established in order to connect the various initiatives and to foster knowledge sharing and transfer. In the *Nederlandse Digitaliseringsstrategie* from June 2018, explicit attention is given to establishing public-private partnerships on quantum computing; Action line 6, on quantum computing and quantum software, aims to intensify the collaborations in and with QuTech, with a focus on practical applications through collaboration with QuSoft.

¹ <https://www.rijksoverheid.nl/documenten/rapporten/2017/04/18/rapport-van-de-studiegroep-informatiesamenleving-en-overheid-maak-waar>

² <https://www.rijksoverheid.nl/documenten/rapporten/2018/06/01/nederlandse-digitaliseringsstrategie>

³ <https://www.rijksoverheid.nl/documenten/rapporten/2018/07/03/actieplan-digitale-connectiviteit>

⁴ <https://overons.kpn.nl/kpn-voor-nederland/innovatie/het-technology-book>

⁵ <https://www.rijksoverheid.nl/regering/bewindspersonen/arie-slob/documenten/kamerstukken/2018/07/02/kamerbrief-met-eerste-reactie-op-sectoradvies-audiovisueel>

⁶ <https://www.dutchdigitaldelta.nl/actieplan>

3 Dynamics

No significant deviations from the 2018 plan are foreseen; knowledge buildup and technology development continues on all eight topics within VP ICT, and a healthy portfolio of multi-year projects ensures continuation of research.

In 2018, a dedicated programme on AI was started. In 2019, this programme will continue, offering new opportunities for strategic collaborations with national and European stakeholders, and providing emphasis on explainability and responsibility of AI algorithms. TNO will support an initiative for a national AI programme, in collaboration with key national stakeholders.

In the context of cybersecurity, the dynamics are described in detail in section 3.4 of VP Cyber Risk Management & System Resilience 2019-2022. In setting up the Techruption 2.0 programme, more attention for topics beyond blockchain will be sought, e.g. cybersecurity (and in particular quantum).

4 Ondertekening

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