

TNO-rapport**Early Research Programs
Report 2015****Corporate Staforganen**

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1 Introduction

In this report we present the progress made during the first year of TNO's Early Research Program 2015-2018¹. For this program we selected 8 research topics that are at the heart of societal and economical grand challenges where we believe a concerted effort of applied research, fundamental research and future private development will have great impact. We therefore embarked on use case inspired research with equal emphasis on generating cutting edge knowledge and technology, together with research partners from academia, and building research ecosystems with stakeholders and sponsors from industry and public organizations.

In addition to these 8 topics we conducted the seed projects: *Organ Function on a Chip*, and *Submicron Composite Materials*. Both seed projects showed good progress and potential, and are continued in 2016 as part of the ERP portfolio. Together with the University of Twente we explored the potential of a joint innovation effort in *Interaction Robotics*, i.e. all forms of robotics where there is a direct interaction with humans. A mixed UT-TNO team mapped the relevant knowledge positions of both organizations, the needs from industry and other stakeholders, the viability of matching these needs with cutting edge research, and the probability of raising appropriate funding. The findings have been documented², and conclusions are expected to be drawn in the first half of 2016.

The Table below presents the 10 topics and the TNO contact persons.

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9.	Organ Function on a Chip	Evita van de Steeg evita.vandesteeg@tno.nl	Cyrille Krul cyrille.krul@tno.nl
10.	Submicron Composite Materials	Pascal Buskens pascal.buskens@tno.nl	Jaap Lombaers Jaap.Lombaers@tno.nl

The ERP program is focused on building the future knowledge base of TNO. At the same time we look for opportunities to leverage our research with the efforts of others, to gain mass and a higher pace of development. By choosing specific use cases, we invite societal and industrial parties to become stakeholders and sponsors to our research, albeit the research is still in an early stage of

¹ TNO Early Research Program 2015-2018; Annual plan 2015, September 2014

² JIC-Interaction Robotics; Research Report UT-TNO, November 2015

'technology readiness'. To illustrate this the Table below shows the 7 Topsectors where we are building these kind of relations.

ERP	HTSM	Agri-Food	LSH	Energy	Chemis-try	Logis-tics	Water
1. Quantum Computer / Internet	●						
2. Complexity	O	●				●	
3. Personalized Food		O					
4. Energy Storage & Conversion	●			●	●		
5. 3D Nanomanufacturing	●						
6. Structural Integrity	O			●			●
7. Human Enhancement	●						
8. Sense Making from Big Data	●			O		O	
9. Organ Function on Chip			O				
10. BMC-Submicron Composites					O		

● Active relationship; O Relationship under development

Finally we conducted a project on *Orchestrating Innovation* to explore new ways to boost innovation with use case inspired research.

In the next chapters, for each project the results are described.

2 ERP Quantum Computing / Quantum Internet

2.1 Management summary

Research & Technology lines 2015-2018

The envisioned developments cover many TRL's, multiple disciplines, and thereby about 15 years. This will result in a different approach during the subsequent phases of the development. The first phase (2014 – 2017; Proof of Principle) will be dominated by solving the current bottlenecks to accelerate the research, and by making the transition towards the mission-based way of working. The latter includes, amongst others, a better defined goal of the project, working out the project plan, system architectural considerations, and involving third parties.

The second phase (2018 – 2022; Proof of Concept) will be used to demonstrate progress on key technologies (critical milestones), benchmarking, defining the requirements and system architecture, and updating the project plan including contributions by third parties and potential spin-off. Also a relevant and mathematical challenge shall be selected for the demonstration. This challenge shall be mapped to the electronic hardware.

During the third phase of the project (2023 – 2029; working demonstrator) all technologies shall be developed to the level of a working demonstrator. A convincing demonstration shall be executed. Positioning the Dutch industry (by knowledge transfer) is critical during this phase.

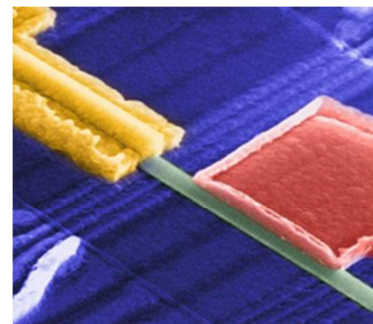
QuTech works according to Roadmaps. The most critical enabling technologies that will be developed during the coming years are incorporated in the most relevant Roadmap. The State-of-the-art, knowledge gaps, and planned developments will be described per Roadmap. (Beyond 2018 Roadmaps will likely be organized according to components and modules of the quantum computer or setups for secure quantum internet.)

Roadmap A: Topologically protected quantum computing

So called zero state- or Majorana qubits have the potential of very long coherence times. The most convincing experiments on the demonstration of the appearance of Majorana quasi-particles have been performed by the TUD in 2012/2013. This was done on devices based on InSb nanowires in which superconductivity is induced by a connected superconductor. A qubit based on Majorana quasi-particles actually requires braiding of those Majorana particles which in turn requires the integration of a few nanowire crosses (instead of nanowires) in combination with a few Josephson Junctions.

The research in this Roadmap is focused first on improvements in materials, device technology, and measurement techniques. Improvements in materials are needed to reach higher electron mobility in the nanowires/nanocrosses. A new process flow shall lead to better control/prevention of contamination, and in-vacuum growth of superconductor and semiconductor material shall lead to ultimately well-defined interfaces. Several properties of the current superconductor material NbTiN, like the quasi-particle density of states within the superconducting gap, are unknown. This material will therefore be characterized better by means of tunneling studies.

The interface between the semiconductor and superconductor materials is the most critical and very sensitive to imperfections like oxidation, dangling bonds, chemical residues, or non-homogeneous coverage. To improve this interface we will investigate etch recipes which are more gentle than the current Ar sputtering (needed to remove native oxides that show up due to transport of the nanowires from the growth chamber at TU/e to the deposition



1. SEM image of Majorana device (false colours; TUD).

chamber at TUD). High-resolution electron microscopy will be used to investigate the precise interface coverage. Deposition of the superconductor material by means of sputtering maybe replaced by other techniques or materials. A new deposition tool will be installed and a new process flow will be develop to ultimately execute all material growth and deposition steps in one system without breaking vacuum. The device is grown on top of an insulating Si substrate with gate pattern. This 'gate chip' will be improved by better planarization (even CMP seems to result in too rough surfaces), and selection of a dielectric material which is both high quality (no charge noise on timescales of days at low temperatures) and enables a non-reactive and hydrophobic surface to avoid reactivity in ambient conditions.

TNO will work on most of the challenges mentioned above: TNO's experience with nano-fabrication and contamination control will be required. Also the new deposition tool will be installed in the cleanroom of TNO and a specialist in this technology will be hired. Finally TNO will execute simulations on multiscale physics to understand, amongst others, the effects of stress induced in the nanowires by cooling down from room temperature to 15 mK on electron mobility.

Beyond these developments this Roadmap will focus more on the development of so called Majorana-Cooper pair Boxes (MCPB), superconducting-insulating-superconducting (SIS) junctions, integration into a circuit, and finally the actual braiding of Majorana's.

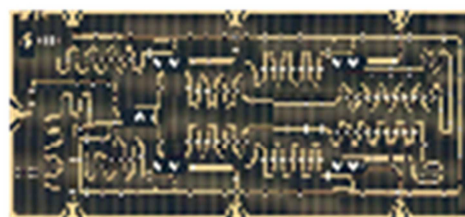
Roadmap B: Fault- tolerant quantum computing

The transmon qubits are relatively speaking the most mature type of qubits. Circuits with 5 qubits with controlled interaction are currently being studied. The activities over the next few years will be dedicated to the development of a 17-qubit design. This is the smallest set of qubits required to demonstrate surface code protection. This protection against decoherence is based on a set of primary qubits plus ancillary qubits. The latter will be used to probe decoherence at the primary qubits (parity check), followed by repair of the states of the primary qubits.

Important technological developments on which TNO will work include the development of electronics architectures for circuits with more than 8 qubits, more compact resonator designs (to make devices with more than 17 qubits fit on one chip), and FPGA- and RF technology for fast electronic feedback control.

Spin qubits may intrinsically have longer coherence times. Still surface code protection is required. Current research topics include scaling to circuits of 5 qubits, and integration on the devices of the superconducting transmon qubits.

Important technological developments on which TNO will work include investigation of potential 2D architectures (required for scaling beyond about 5 qubits), a PCB/interposer for connection of about 100 DC-, RF-, and microwave signals to/from the circuit, nano-lithography and contamination control for higher quality devices and miniaturized qubits (to reduce the number of imperfections in the device which limit the coherence times).



1. Circuit with multiple transmon qubits (TUD).

Roadmap C: Secure Quantum Internet

The fourth type of qubit is based on the N-V color centers in diamond. One of the advantages of this type of qubit is the possibility to read the state of this qubit by means of visible photons. This makes this type of qubit attractive for applications in encryption and communication via glass fibers. Entanglement over 3 meters distance has been demonstrated by the TUD last year.

Challenges include the efficiency in coupling light to the fibers, wavelength conversion (from the intrinsic wavelength of N-V centers near 637nm to the wavelengths used for telecommunication,

needed to make use of known technologies and reduce the transmission losses in fibers), generation of arrays of color centers in a controlled way.

2.2 Progress of the project

A. Plan of Work:

Fragments copied from 2015 proposal:

Roadmap A

For the topological protected qubits it is most critical to get the new cluster tool up and running.

Multiple colleagues will work on the development of extremely flat basis devices with embedded bottom gates.

Thirdly, simulations on nanowires and their environment will continue to develop better understanding of the relationship between stress and electrical performance.

Roadmap B

The colleagues of TNO will focus on implementation of feedback control based on FPGA's (the design thereof is ongoing since mid of 2014).

During 2014 TNO realized the first demonstrators for RF multiplexing for qubit control. In 2015 this technology shall be improved and extended to larger numbers of in- and outputs.

TNO will also improve the contamination control for the device manufacturing of these transmon qubit devices.

Roadmap C

When future circuits contain more than a few qubits the initiation will take weeks. TNO aims to develop a machine learning algorithm to automate this process.

TNO will investigate the possibilities and limitations in nano-fabrication to reduce the impact by defects.

Finally, TNO will work on the connectivity for spin qubit circuits. Ideas exist to develop a multipurpose connectivity board ('interposer') to deal with this challenge independently from the configurations/generations of qubit circuits.

Roadmap D

During 2015 colleagues of TUD and TNO will work on a demonstration of such wavelength conversion with sufficient efficiency to meet the requirements for this application.

Experiments in 2015 shall show the improvements due to this adaptive optics and may raise new challenges.

TNO will work on the controlled positioning of arrays of N-V centers in 2014-2015. The lead time of this research is large.

The development of fiber arrays will be started in 2015.

B. Progress realized

Organisation, Managerial, Commercial:

- The 'partnerconvenant' was signed by TNO, TUD, departments of EZ and OCW, NWO (incl. FOM, STW), and Topsector HTSM/TKI in June 2015. The agreements add up to about 135 million euro commitments, giving QuTech a firm basis for the first 10 years.
- Only foreseen within a few years from the start of QuTech, a contract with a large commercial partner was closed in September 2015 already. Intel will support research at QuTech with over 50 million dollars plus expertise of Intel in the fields of material sciences, nanofabrication, and computer architectures. (picture centre: J.S. Clarke and VP M. Mayberry of Intel, minister of Economic Affairs NL H. Kamp, Prof. L. Vandersypen and Prof. L. Kouwenhoven of QuTech)

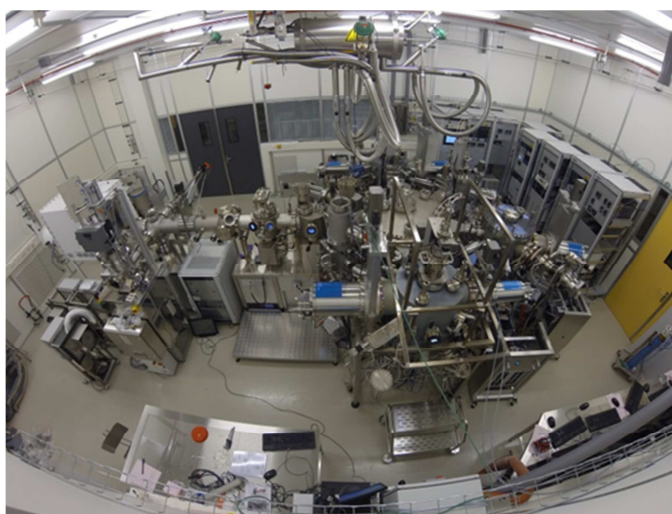
- Both events mentioned above have generated a very extensive media coverage. QuTech and TNO have been mentioned in NOS and RTL4 new bulletins, Volkskrant and other newspapers, New Scientist, Signalement, and others, Radio5, and even the New York Times (picture left).
- QuTech has been invited for negotiations with IARPA on its proposal on logical transmon qubit development.



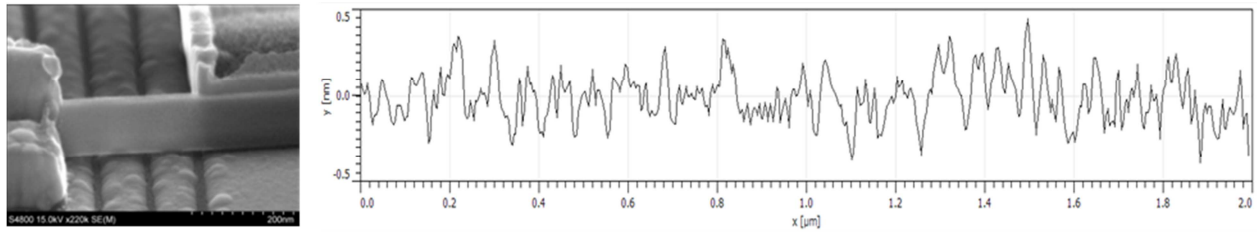
- Ministers Kamp and Bussemaker (picture right) as well as Euro-commissioner Oettinger have visited QuTech. QuTech/TNO is well connected to Innovate UK and the UK department of BIS in our joint effort to generate activities and funding from the European Commission / European Parliament / and H2020.
- Two new colleagues are hired by TNO and seconded to QuTech. Three more vacancies are currently (end of 2015) open.
- QuTech/TNO is still in contact with ASM, ASML, Fox-IT, SURF, KPN, and other companies about potential cooperation and/or joint efforts towards European projects.

Scientific & engineering progress:

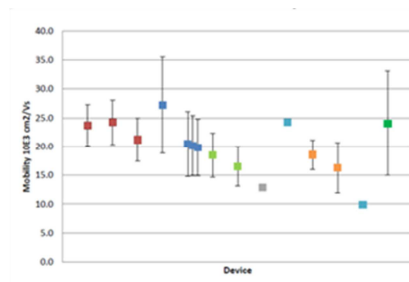
An enormously complex and costly MBE cluster tool (picture left) has been installed in the cleanroom of TNO, which was thoroughly reconfigured for this purpose. This unique tool shall enable growth of high-quality nanowires for Majorana zero state qubits.



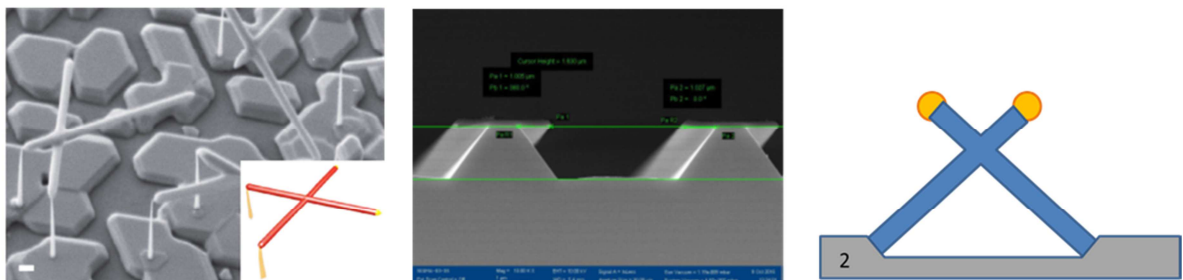
The new fabrication process results in perfectly flat gate dielectrics (<0.2 nm RMS, graph right) underneath the nanowires, which is critical for accurate field control inside the nanowire for Majorana zero state research. In 2014 the surface morphology was still significant (picture left).



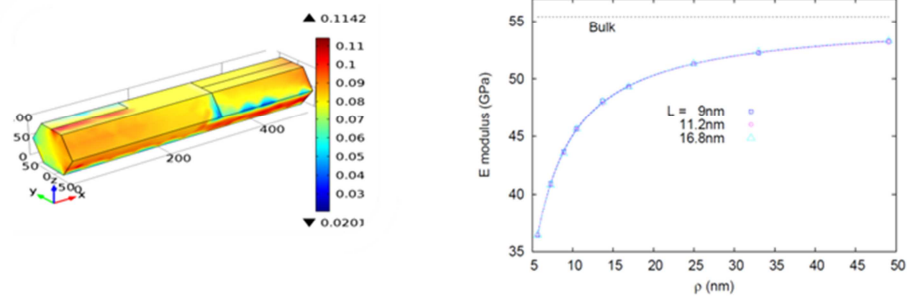
InSb nanowires were systematically characterized to optimize nanowire growth and fabrication procedures. High electron mobility in the nanowire are now achieved routinely.



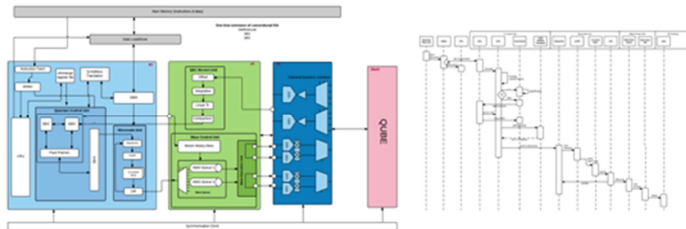
Growth of nanowire crosses is essential to braiding. So far crosses could only be grown by creative processes during growth inside the MBE system, with unacceptably low yields (picture left). In 2015 a 3D patterning process and gold dot deposition on InP substrates was developed (picture center). The geometry of the patterned surface will determine growth directions, which shall enable growth of nanowire crosses by more conventional MBE processes and much higher yields (graphic right). This growth process is currently under investigation (MBE system of Prof. E. Bakkers, TU/e).



Theoretical and simulation models have been developed further to predict the behaviour of Majorana devices due to operation loading. Results include a model in COMSOL (picture left), implementation of Vashista potentials for atomistic simulations of III-V compounds, theoretical results on size dependent Young's modulus (graph right) and gradients in InSb lattices (the so called skin-effect in nanowires).



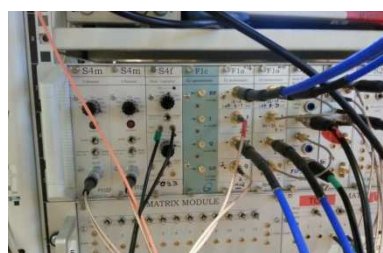
The first systems architecture models for fault-tolerant quantum computing have been developed. These models give the first indications on the milestones in scaling to large numbers of qubits; like the maximum number of qubits that can be controlled by brute force scaling of the number of cables, frequencies, and electronics. Multiple layers of software layers have been defined, with their respective interfaces and degree of dependency on specific physical qubit implementations.



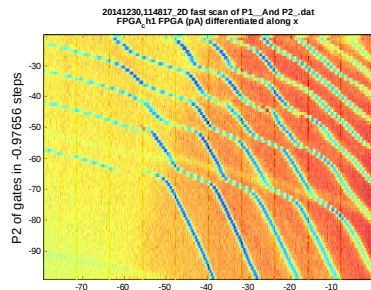
The QuTech Wave Generator (QWG, see picture), a specialized version of the commercial AWG, was designed and assembled. It will allow for flexible low-latency qubit control and measurements, in a scalable manner. Software and firmware developments are still ongoing.



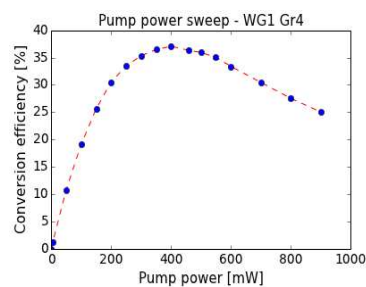
The Vector Switch Matrix for selective broadcasting of RF-signals to multiple qubits, developed in 2014, has been used in real qubit experiments (picture left). This work is published in a paper on arXiv, and is currently being reviewed for publication in Nature Quantum Information Processing. A dedicated upconverter (mixing 4-8 GHz RF signals with envelop signals from the AWG/QWG) was developed for qubit control (picture right).



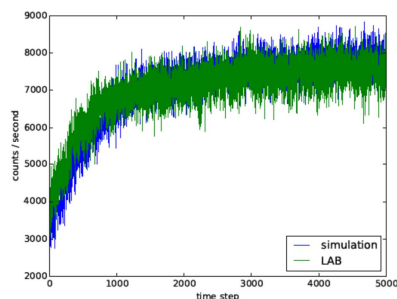
Automated tuning of spin quantum dots has been developed to initiate spin qubits fast. Initiation of a single spin qubits could still be done by hand (couple of hours). But double or triple qubit systems take hours to weeks of work. The algorithm, based on computer vision technologies, is already capable to tune a double spin qubit (see graph). In the coming years we envision further development of this technology to be able to initiate systems with larger numbers of qubits.



Light from N-V centers has to be converted to telecom wavelength in able to develop quantum communication over longer distances. We achieved over 35% conversion efficiency by means of difference frequency generation in PPLN crystals (graph below). This was achieved by better alignments of beams with the crystal, beam overlap, collimation, and temperature of the crystal.



A new algorithm was developed to enhance the collection efficiency on the emission from N-V centers by means of a deformable mirror. This algorithm is used to drive a mirror with 144 actuators and uses only the input from a photon-counting detector. (A wavefront sensor is thus not needed.) The photon collection is increased by a factor or more than two (graph below). Note that two of such setups have to be included in a single quantum communication experiment. This improvement shall thus lead to 2x2 times higher yields.



C. Sponsoring

Sponsoring of TUD-QuTech by Microsoft continues.

Sooner than expected has QuTech been able to set up a cooperation with Intel. The cooperation is intended to last for at least 10 years.

2.3 **Realized contribution to new knowledge and technology**

A. new knowledge and technology

See the achievements of this year. New knowledge and technology were developed in all disciplines. Especially interesting is the entanglement between all those 'classical' technologies with the quantum science. QuTech is one of the very few locations in the world where developments on this interface are actively being pursued.

B. contribution to the improvement of the technology position of TNO

As described above, this is mainly about the technology-quantum interface. But most technologies developed within QuTech are also of value to other domains. For example: optimizing algorithms for deformable mirrors, which are based on photon-counting feedback instead of wavefront measurements, are of interest to the astronomy domain. Being capable of doing multi-scale physics simulations, developed for understanding the properties of nanowires upon cooling, is of interest to the developments in device reliability- and semicon and automotive industries, too.

C. relevance of the results for the governmental departments or the companies/organisations involved

The ultimate goal is to develop quantum computing and quantum internet knowledge and prototypes that can be brought to the market by our commercial partners. This is the reason for Intel and other companies to work together with QuTech. In the end we aim for significant growth of employment and economic activities related to quantum technologies in the Netherlands.

D. contribution to the improvement of the market position of TNO

Additional projects like the Intel-TUD-TNO project and the IARPA-TUD-TNO proposal have generated additional turnover at TNO.

The abovementioned funding and projects generate stable or growing turnover for the next 10 years. The abovementioned funding and projects in turn attracted other companies to QuTech. It is very likely that more projects will be initiated in the next years.

Publications (reports, books, papers, presentations, websites etc.).:

1. W. Vlothuizen (TNO) et al, Flexible, low-latency architecture for qubit control and measurement in circuit QED, presentation at APS March Meeting 2015.
2. Bruno et al, Reducing intrinsic loss in superconducting resonators by surface treatment and deep etching of silicon substrates, arXiv:1502.04082v1, February 2015. (acknowledging V. de Rooij and E. van Velthoven of TNO)
3. S. Gielen (TNO) et al, "Thermo mechanical effects in Majorana type Quantum devices", EUROsimE paper, April 2015. Paper was selected for publication in Microelectronics Reliability. The paper was submitted and is waiting for review and publication
4. S. Asaad et al, Independent, extensible control of same-frequency superconducting qubits by selective broadcasting, arXiv:1508.06676v1, August 2015. (co-author D. Deurloo of TNO)

Further: patent descriptions, premier depots.

Patent: Microwave Switch Matrix for qubits

Patent to be applied for: automated tuning of qubits

3 ERP Complexity

3.1 *Management summary*

TNO has defined its Early Research Programs 2015-2018 to build a future knowledge base in close cooperation with external stakeholders. ERP Complexity has started in 2015 to build new knowledge and networks on the topic of complexity science. The performance of the ERP can be evaluated along 3 axes: science, partnering and stakeholder engagement.

Firstly, from a scientific perspective the activities in this ERP have led to several (applied) scientific breakthroughs. The formulation of efficient numerical tools for analysis of crack behavior in geological structures is a breakthrough for prediction of the effects of induced seismicity. These simulation tools can and will be of importance for other areas of research as well, e.g. fracture of building materials and food products. Similarly, efficient modelling tools for resilience of complicated gas networks are of importance for designing optimum use and maintenance strategies, but can and will be employed in logistical processes as well. These 2 and other examples illustrate that the development and use of modelling approaches is of prime importance in this ERP Complexity (as expected). Transfer between research domains in- and outside TNO not only will increase their application potential, but will also lead to benefits during further development. It is expected that the Netherlands Platform Complex Systems will play a stimulating role in this. In conclusion, the development of the scientific network for complexity is well on track and can be intensified in 2016 (e.g. towards high-tech systems).

Secondly, from a partnering perspective this ERP has led to a number of relevant industrial contacts that can be explored further, e.g. in the energy, health and mobility field. In 2016 these contacts must be intensified in the formulation of joint projects with academia, including a firm industrial commitment to support the development of ERP Complexity for the 2 chosen priority areas Logistics and AgroFood. This part of the ERP is considered less well developed, partly as a consequence of the delay in the formulation of the collaboration with NWO, and thus will be picked up with more emphasis in 2016.

Thirdly, from a TNO stakeholder perspective this ERP is well aligned with the 2 topsectors Logistics and AgroFood through the collaboration with NWO and the respective TKI offices. This provides direct alignment with topsector roadmaps and industrial and societal needs. It is expected that in 2016 the topsector HTSM will be included in the activities, while also initiatives will be taken to see if development of a European Complexity initiative is useful.

3.2 *Introduction*

Complexity is commonly briefly described as the science that deals with “the study of the phenomena which emerge from a collection of interacting objects”. The primary aspects investigated are fundamental dynamics of complex systems:

- the emergence of collective behaviour: how to create new properties transcending those of the constituent components
- the transition from one system state or phase to another: how to predict and influence the dynamics of change
- resilience to external shocks or disruptions: how to influence resilience to exert control

A small list of examples where complexity plays a role: traffic jams, epidemics, internet overload, criminal and terrorist organisations, quantum entanglement, animals or robots swarms, industrial value chains, stock markets, cell biology, oncology, cardiology, internal medicine, psychiatry etc.

For a number of TNO Themes the complexity tools and approaches are relevant and will be explored in this ERP. At the same time complexity is an emerging scientific area of interest and close cooperation with academia is thus considered of key importance for this ERP.

In the Netherlands NWO has formulated a multiannual Strategy 2015-2018 in which Complexity is addressed as one of the 6 significant societal and scientific challenges: “Een beter begrip van complexiteit kan ons leren voorbodes van omslagpunten in complexe systemen eerder te herkennen, en onvoorspelbare systemen op slimme manieren toch te beïnvloeden. En het zal ons in staat stellen complexe systemen te ontwerpen met uiterst nuttige toepassingen, zoals slimmere materialen of stabiele stroomnetwerken met duizenden kleine en wisselvallige producenten”. Consequently NWO will reinforce its efforts to stimulate research in this area, also in collaboration with industrial partners and TO2 institutes. TNO and NWO will strongly cooperate in a joint Complexity program for the period 2016-2020 (NWO-EW contacts Louis Vertegaal, Christiane Klöditz, Marieke van Duin) combining user inspired fundamental research at universities and TNO longer term research in this ERP on industrial relevant problems.

In 2015 the activities in this ETP focussed on

- research in TNO on selected use cases
- setting the scene for collaboration with NWO, universities and industry
- establishing the Netherlands Platform Complex Systems together with NWO and academia.

3.3 Program Execution and Results

In 2015 TNO started its activities in this ERP in a number of research projects³ as shown in Table 1 and defined in close collaboration with the various TNO themes. These projects include support for a part-time professorship and 2 PhD students (see also section 1.2). The research activities in TNO have largely centred around the development of modelling and simulation tools for the relevant use cases. It has proven very valuable to share these ideas and tools between the researchers active in different parts of TNO, to stimulate discussion for cross-fertilization.

In view of briefness 2 example projects are highlighted to show the research questions and to answer the question why complexity helps to solve those research questions. The total quantitative output of this ERP in 2015 is:

- presentations and lectures: approx. 35
- submitted journal papers: approx. 20
- submitted EC projects: 4

Research topic	Stakeholders		
	Industry, government	Academia, Applied Research	TNO Theme
Gas networks	Alliander, Liandon	TU Delft, Arizona State University	Energy
Induced seismicity	Open Seismic Sensorgrid Groningen (OSSG)	Research Program Induced Seismicity, in cooperation with Deltares, KNMI, universities and authorities (in development)	Energy
Energy transition	Alliander	TU Delft, ECN, Energy Academy Europe	Energy
Grip on health	Almery City, AH, Jumbo, de Vogellanden, Isala hospital, PON, Informens, NOC-NSF	Shanghai Institute of Systems Biology, UMC Utrecht, WUR, DLO, UL	Healthy Living
Smart industry		EUR, Holst	Industry

³ <https://www.tno.nl/nl/aandachtsgebieden/leefomgeving/mobility-logistics/logistiek/early-research-program-complexity-grip-op-complexiteit/>

<i>Cooperative driving</i>	<i>Volvo, Systemite, AVL, Ford</i>	<i>TU/e</i>	<i>Urbanisation</i>
<i>Safe installations</i>	<i>Exxon Mobile, Odjfell, Akzo Nobel, Huntsman, Hexion, Shin-Etsu</i>	<i>TU Delft</i>	<i>Urbanisation</i>
<i>Safe design of nanomaterials</i>		<i>Solliance</i>	<i>Urbanisation</i>
<i>Circular economy</i>	<i>Tamoil Nederland BV, Auto Recycling Nederland, Kargro Groep, VDL</i>	<i>UvA</i>	<i>Urbanisation</i>
<i>Smart cities</i>		<i>EUR</i>	<i>Urbanisation</i>
<i>Prof. H. van den Berg</i>	<i>Surfnet, KPN, Huawei, TomTom, Nedap</i>	<i>UT, UvA</i>	<i>Industry</i>
<i>PhD C. van Leeuwen</i>		<i>TU Delft</i>	<i>Industry</i>
<i>PhD E. van Harten</i>		<i>UU</i>	<i>Healthy Living</i>

Table 1 TNO research activities in ERP Complexity in 2015

Example project: Gas networks

The overall objective of the project is to help future operation of the future gas distribution network ensuring resilient and reliable delivery of energy to customers, taking into account the changes with respect to green gas suppliers, storage, interaction with the electricity and heat grids and the gas grid becoming smart. A shift is needed in gas network operations from the current reactive response to incidents towards “future network-wide automatic incident detection and model-assisted response and control”, while at the same time the complexity of energy distribution networks is growing and the dynamic behaviour is increasing. The project interacts with gas distribution network operators. The project distils academic research questions related to the resilience of smart gas grids. This activity is a close collaboration between the project and the Network Architectures & Services group at TU Delft.

To enable event detection and resilience evaluation algorithms a realistic network is used for testing and evaluation. The Texel network topology consisting of 56000 pipes, 8500 users and 220 pressure reduction stations was obtained from Alliander and used to generate a network model with all necessary attributes.

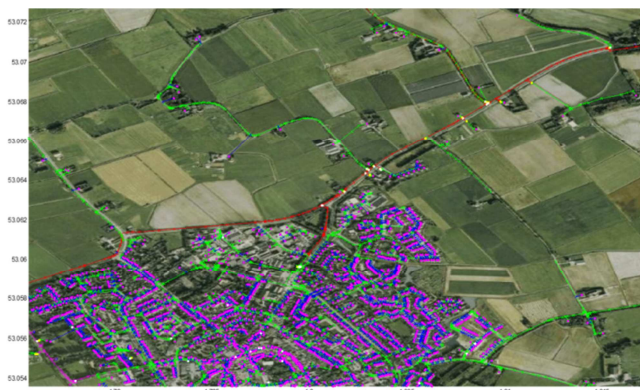


Figure 1 Gas networks

A method was developed for automatic detection of network inconsistencies using tree search methods in combination with heuristic network connectivity rules for detecting and repairing inconsistencies. This resulted in a method for screening complex networks and significantly reducing the number of inconsistencies that require human inspection. The network model in combination with

a consumption model of all users is simulated to generate time profiles of pressure and flow for all nodes in the network to serve as the main tool for event detection and resilience evaluation. Computationally fast graph theoretical metrics have been developed that can be used to identify the critical pipes in a gas distribution network, i.e., those pipes whose failure would result in the most gas demand not being served. Fast algorithms have been developed that can be used to compute the total reliability of gas distribution networks, based on failure probabilities of individual pipes.

The research project has been carried out in close cooperation with Alliander for clarification of input data and transfer of result of analyses, i.e. during the workshop on Robustness and Resilience of (Interdependent) Infrastructures on September 14 2015 at TNO with participants from Alliander, Arizona State University, TU Delft and TNO.

Example project: Grip on Health

The TNO Grip on Health research project aims to develop a health cost prediction model. It is based on combining non-linear biopsychosocial information from the individual (biology & psychology) and from the environment (social network, health behaviour, exposure) to simulate effects of interventions induced to motivate behaviour change towards health. Focus of the Grip on Health program is the healthy consumer, healthy youth, and healthy employer.

The first research question addressed is the fundamental issue of how to inform cost prediction models with non-linear biopsychosocial models. A first non-linear model developed is a stock-and-flow model related to type 2 diabetes. The cost prediction model is part of a cost-benefit analysis tool with an application to predict the long term return of benefits of the investment. The investors invest in achieving and maintaining a healthy society. The society's health model is a diabetes model. A set of investors can choose invest in interventions such as nutrition, exercise programs or changes in the environment, to modulate the population dynamics of the diabetes model. The model uses game theory to compute the investment options for which the return of investment among the various investors is maximized. The tool can be used for scenarios in which investors are cooperative or non-cooperative towards other investors. A dashboard is implemented to choose various investment options and visualize the predicted long term return benefits of investment.

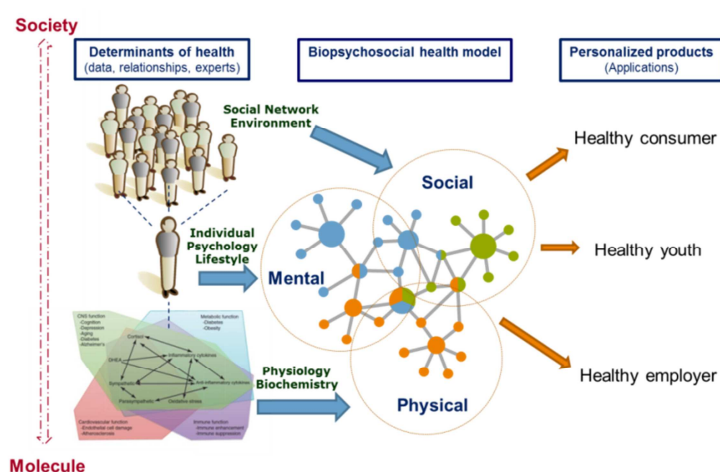


Figure 2 Grip on health

The second research area explored in 2015 deals with predicting state transitions (critical transitions) in health. The hypothesis is that sudden changes from health towards a chronic disease state can be predicted by observing the dynamics of the system just before the critical transition. The Shanghai Institute of Systems Biology has published proof-of-concept studies in this area. We started a collaboration with this institute as well as with the UMC Utrecht Rheumatology department to study

the prediction of treatment response in arthritis patients. The main research question is: which proteins predict the onset of critical transitions from a disease state towards a state of drug free remission in rheumatoid arthritis.

Datasets are currently being shared with the partner in Shanghai. The first results are expected in the first half of 2016. This method can then be explored in other health related areas.

The approach and results from this project for different target groups have been discussed intensively with a variety of stakeholders such as cities (Almere), industry (AH, Jumbo, PON), health organisations (Weight Watchers, Vogellanden, Isala Hospital), NOC-NSF, topsector AgroFood, topsector Health.

3.4 Output

Publications

Scientific Papers

1. J. van der Greef, H. van Wietmarschen, Y. Schroe'n, N. Babouraj and M. Troussellard, *Systematic Approaches to Evaluation and Integration of Eastern and Western Medical Practices*, Med Acu, 2015: 27(5).
2. B. Kremer, H. van Wietmarschen, B. van Ommen, *Getting a Grip on Complexity: Systems Nutrition*. 2015, vol 29(1).
3. R. de O. Schmidt, R. Sadre, A. Sperotto, H. van den Berg and A. Pras, *Impact of Packet Sampling on Link Dimensioning*, IEEE Transactions on Network and Service Management (TNSM), 12(3), 392-405, 2015.
4. W. Ellens, M. Mandjes, H. van den Berg, D. Worm and S. Blaszcuk, *Performance evaluation using periodic system-state measurements*. Performance Evaluation, Vol. 93 Issue C, November 2015, pp. 27-46.
5. W. Klein Wolterink, H. van den Berg, G. Heijenk and G. Karagiannis, *Modeling and evaluation of location-based forwarding in vehicular networks*. Book chapter in Chen et al. (eds.) Vehicular Communications and Networks: Architectures, Protocols, Operation and Deployment, Woodhead Publishing, April 2015.
6. W. Pino, D. Worm, R. van der Linden, R.E. Kooij, *The Reliability of a Gas Distribution Network: A Case Study*, submitted to IEEE Transactions on Reliability, October 2015.
7. X. Wang, Y. Koç, S. Derrible, S.N. Ahmad, W. Pino, R.E. Kooij, *Assessing the robustness of metro networks*, submitted to Transportmetrica B.
8. C.J. van Leeuwen, P. Pawelczak, *Cooperative Approximation of Distributed Constraint Optimization Problems*, IJCAI: International Joint Conference of Artificial Intelligence, submitted.
9. C.J. van Leeuwen, P. Pawelczak, *CoCoA: A Distributed Approach to Solving Discrete Optimization Problems in Communications*, INFOCOM: International Conference on Computer Communications, submitted.
10. C.J. van Leeuwen, *Architecture Optimization of Adaptive Networked Embedded System*, DATE: Design Automation and Testing Europe, submitted.

Conference papers

1. D. Worm, F. Fischer, W. Pino, R.E. Kooij, *Identifying Critical Components in complex gas distribution networks*, accepted for Net-works 2015, International Conference on Complex networks and their interdisciplinary applications, Granada (Spain), September 16 -18, 2015. Published in International Journal of Complex Systems in Science: http://www.ij-css.org/volume-05_01/ijcss05_01-001.pdf
2. W. Pino, T. Gomes, R.E. Kooij, *A comparison between Two All-Terminal Reliability Algorithms*, 2nd International conference on Networks and Information Security, October 23 – 25, 2015, Singapore

1. Gougliadis, D. Hutchison, P. Smith, P. Van Mieghem, R.E. Kooij, G. Ventre, *A Quantitative Resilience Framework for Interdependent Networks*, Proc. of 6th REA (Resilience Engineering Association) Symposium, June 22 – 25, 2015, Lisboa, Portugal
3. X. Wang, Y. Koç, S. Derrible, S.N. Ahmad, R.E. Kooij, *Quantifying the robustness of metro networks*, Proc. of 6th International Symposium on Transportation Network Reliability, August 2-3, 2015, Nara, Japan
4. S.M. Moghayer, H. Husby and H.J. Boonman, *Dynamic Behavioral Market Interactions in the Transition Towards a Circular Economy: a Heterogeneous Agent Approach*, Conference for Complex Systems (CCS'15), August 2015, Arizona (US).
5. S.M. Moghayer, H. Husby and H.J. Boonman, *Dynamic interaction of market and behavioural barriers in the transition towards a circular economy: a case of recycled tires*, World Resources Forum (WRF 2015), September 2015, Davos, Switzerland.
6. R. de O. Schmidt, H. van den Berg and A. Pras, *Measurement-Based Network Link Dimensioning*. In: Proceedings 14th IFIP/IEEE International Symposium on Integrated Network Management (IM 2015), May 11-15, 2015, Ottawa, Canada
7. J. Bosman, H. van den Berg and R. van der Mei, *Real-Time QoS Control for Service Orchestration*. In: Proceedings ITC 2015, September 8-10, 2015 Ghent, Belgium.
8. W. Ellens, P. Kovacs, H. van den Berg and S. Nunez Queija, *Routing policies for a partially observable two-server queueing system*. In: Proceedings VALUETOOLS 2015, December 14-16, 2015 Berlin.
9. M. Karimzadeh, Z. Zhao, L. Hendriks, R. de O. Schmidt, S. la Fleur, H. van den Berg, A. Pras, T. I. Braun and M. Corici, *Mobility and Bandwidth Prediction as a Service in Virtualized LTE Systems*. In: Proceedings IEEE CLOUDNET'15, October 5-7, 2015, Niagara Falls, Canada
10. Z. Zhao, M. Karimzadeh, T. I. Braun, A. Pras and H. van den Berg, *A Demonstration of Mobility Prediction as a Service in Cloudified LTE Networks*. In: Proceedings CLOUDNET'15, October 5-7, 2015, Niagara Falls, Canada

Journals

1. Nederlands Platform Complexe Systemen opgericht, Stator, vol 3, 2015, p 34.
2. H. van Wietmarschen, *Understanding the complexity of health and wellbeing*, <http://www.biosynergy.re.kr/newsletter/03/sub01.html>

Master Thesis Report

M. Thalen, *How interactions between chemical companies are related to process safety in chemical clusters*, Master thesis report, 2015, Delft University of Technology and University of Leiden.

Presentations (including workshops)

Key note presentations

1. R.E. Kooij, *Quantifying the Robustness of (Interdependent) Networks*, EINS Workshop on Emerging Trends in Critical Infrastructure Protection, 12-13 May 2015, AIT, Vienna, Austria
2. R.E. Kooij, *iTAPAS!*, *A variety of small presentations about the robustness of networks (and more)*, First Delft-Girona Workshop on Robustness of Networks, 17-18 June 2015, University of Girona, Spain

Invited speaker presentations

1. S.M. Moghayer, *Transition towards a circular economy: a heterogenous agent approach*, CeNDEF seminar series, March 30, 2015, University of Amsterdam
2. S.M. Moghayer, *Modeling resource efficiency in the POFLREE project using EXIOMOD POLRESS* workshop, February 27, 2015, Freie Universität Berlin, Berlin

Oral presentations

1. *Seismological Model Workshop, Schiphol, June 2, 2015 (attended e.g. by NAM, TNO AGE, Exxon Mobile, EBN)*
2. *Erik Langius - Philippe Steeghs, big data concepts of monitoring concept at VentureScan Event at Almere Big Data Value, September 24, 2015*
3. *H. van Wietmarschen, Inspiring Consumer Health, Oct 13, 2015, FoodValley, WUR, Wageningen*
4. *H. van Wietmarschen, BioSynergyEast is east and west is west, and never the twain shall meet? Aug 26, 2015, Shanghai*
5. *H. van Wietmarschen, Rural Development Administration personalized nutrition and health, Aug 31, 2015, Seoul*
6. *H. van Wietmarschen, East is east and west is west, and never the twain shall meet?, Aug 28, 2015, SuZhou University: Suzhou*
7. *H. van Wietmarschen, personalized nutrition and health, Sep 1, 2015, EHWA, University Seoul*
8. *H. van Wietmarschen, Systems Dynamics conference: Resilience based Systems Health Model for Determining Optimal Intervention Strategies for Type 2 Diabetes, January 29, 2015, Den Haag*
9. *H. van Wietmarschen, Obesity summit: A Biopsychosocial Model of Obesity for Determining Optimal Intervention Strategies, Apr 14, 2015, London*
10. *H. Wortelboer, Vogellanden, Systems Biology: integrating body, mind and spirit, March 27, 2015, Zwolle*
11. *Jakko van Kampen, 'Chemiebeurs', Sep 30, 2015.*
12. *B. Boonstra, A. Slob and W. Lofvers, special session AESOP (Association of European Schools of Planning) 'Complexity and Selforganisation', Planning Perspectives on Civic Initiatives, July 13, 2015, 11.00-12:30, Round Table M6 AESOP 2015, Prague*
13. *C. Bos and M. Groote Schaarsberg, Assessing the impact of policy measures in liberalized energy markets, BAEE Research Workshop, October 30, 2015, CORE, Louvain-La-Neuve.*
14. *C. Montalvo "Multinational facing the catching up with a response of Smart technologies and smart regulations, in international conference: Multinationals facing the challenges of new technologies and employment, October 2015, Mexico DF.*

See also at conference papers.

Poster presentations

1. *E. van Harten, Tuning the blue shift in InP/ZnS QDs by variations of shell precursors, DPG-summer school on physical properties of nanoparticles, 2015.*
2. *E. van Harten, Tuning the blue shift in InP/ZnS QDs by variations of shell precursors, FQDots15 conference. Prize for the best poster*
3. *E. van Harten, H. Schreutelkamp, E. Theodoropoulou, F. Kuper, E. Zondervan, A. Meijerink, and J. A. Post, Poster presentation: Safe design of quantum dot nanoparticles: The role of light and electron microscopy, FOM Biophysics 2015*
4. *E. van Harten, Poster presentation: Safe design of quantum dot nanoparticles: The role of light and electron microscopy, CHAINS 2015*

Other

Speech by Prof. Jos Keurentjes (TNO) on the importance of complexity research in the NWO and TNO strategy, Launch of the Netherlands Platform Complex Systems (NPCS), November 27, 2015, Utrecht.

Media attention

1. <https://www.tno.nl/nl/over-tno/nieuws/2015/10/innovatieprojecten-sensortechnologie-en-energie-ondersteund-door-groningen/>

2. <http://gemeente.groningen.nl/persberichten/gemeente-draagt-bij-aan-innovatieve-projecten> (page not available anymore, but also available via <http://www.target-holding.nl/nieuws/gemeente-groningen-draagt-bij-aan-innovatieve-projecten>)
 3. <https://www.technischweekblad.nl/nieuws/10.000-aardbevingssensoren-rond-groninger-gasveld/item8079>
 4. <http://www.rtvnoord.nl/nieuws/155847/Groningen-is-een-soort-proeftuin-voor-ons>
 5. https://www.nom.nl/open-seismisch-sensor-grid-groningen-krijgt-steeds-meer-vorm/?utm_content=buffer6697c&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer
 6. Crystal website: <http://crystal-artemis.eu/>
 7. <https://www.tno.nl/nl/samenwerken/expertise/early-research-programma/early-research-program-complexity-grip-op-complexiteit/>
 8. <http://www.npcs.nl/news/nederlands-platform-complexe-systemen-van-start>
- *Award Conference for Complex Systems 2015: ERP-Complexity contribution on circular economy selected as “especially worthwhile” paper*, October 28, 2015

3.5 Building the ecosystem

An important criterium for an ERP program is the degree to which an eco-system is built that will allow to more effectively gather and concentrate resources for faster development and realization of breakthroughs. This includes relations with academia, industry etc. Below the relations built in 2015 will be covered.

Co-research with NWO

The intended collaboration with NWO on Complexity has been shaped further following the approval of the NWO Strategic plan in April 2015 and the corresponding approval of NWO budget for the NWO Complexity program. The NWO budget will be allocated in the years to come and must be aligned with topsector needs. A first inventory resulted in two top sectors with clear interest in setting-up a joint Complexity initiative with NWO and TNO, Logistics and AgroFood. This will result in the submission of joint university-TNO-industry projects in the calls for Complexity & Logistics (4.5 MEUR NWO budget) and Complexity & AgroFood (1 MEUR NWO budget) in 2016. At this moment ideas for projects are being gathered and elaborated in close cooperation with the 2 top sectors mentioned and related industries/stakeholders, e.g. through the mechanism of the preparatory grant call Complexity & Logistics. In 2016 ideas for other top sectors will be developed, e.g. HTSM.

Co-research with TO2

TNO has contacted the (TO2) partners Deltares, DLO, ECN, NLR and RIVM to inform them on the developments in Complexity. They have the possibility to submit projects in the NWO calls together with TNO where useful and possible this will be done. They were also invited to participate in the Netherlands Platform Complex Systems.

Netherlands Platform Complex Systems

In May 2015 TNO and NWO took the initiative to come to the formation of the Netherlands Platform Complex Systems (NPCS)⁴. This initiative was quickly followed up by a number of researchers to come to an association of complexity scientists that will encourage national coordination in this multidisciplinary research area in the Netherlands. The platform will ensure that researchers working on more complex systems issues operate increasingly as a community. The platform will identify areas of complexity research where the Netherlands has particularly strong expertise and where social / industrial needs are great. Moreover, the platform will provide good access for (potential)

⁴ <http://www.npcs.nl/>

partners in industry and society to the research community of complexity scientists. Finally, the platform will position complex systems as a research field, and ensure better coordination both within the Netherlands and of the contribution of the Netherlands in European complexity research. NPCS was formally launched on November 27th 2015.

PhD researchers

In 2015 the following PhD researchers were active in this ERP:

- Coen van Leeuwen (TNO, TNO funded), active under supervision of prof. Langendoen (TUD) on self-organization of networked embedded systems
- Elleke van Harten (UU, TNO funded), active under supervision of prof. Meijerink (UU) on safe design of self-assembled quantum dots.
- Wendy Ellens (UvA), active under supervision of prof. van den Berg (TNO) and prof. Mandjes (UvA) on stochastic methods for network control" (finished 10 december 2015).
- Morteza Karimzadeh (UT), active under supervision of prof. van den Berg (TNO) and prof. Pras (UT) on mobile cloud networking.
- Frank Wetzels (AiO), active under supervision of prof. van den Berg (TNO) and prof. van der Mei (VU/CWI). on core network performance / new transport protocols.

Master students

- Hans Schreutelkamp (UU), active under supervision of Dr J.A. Post on the study of the toxicity of quantum dots in RAW 264.7 cells using microscopy. The project is directly related to the activities of PhD Elleke van Harten.
- Willem Pino (UU), active under supervision of R. Kooij on a comparison between two all-terminal reliability algorithms. The project is directly related to the ERP project on Gas Networks.
- Maayke Thalen. How interactions between chemical companies are related to process safety in chemical clusters. Master thesis report, 2015, Delft University of Technology and University of Leiden. The project is directly related to the ERP project on Safe Installations.

Co-development with stakeholders

The activities in the various projects within ERP Complexity in 2015 were performed in collaboration with many stakeholders (see Table 1). In addition, these activities have led to follow-up projects outside of this ERP. Examples include the project on monitoring of induced seismicity (OSSG or Open Seismic Sensorgrid Groningen) in Groningen⁵, projects on health, submitted and granted EC projects (Power2DM on health)⁶ etc. The alignment with NWO and topsectors has been elucidated in the sections above.

⁵ <http://www.target-holding.nl/nieuws/gemeente-groningen-draagt-bij-aan-innovatieve-projecten>

⁶ <https://www.tno.nl/nl/over-tno/nieuws/2015/11/onderzoek-gepersonaliseerd-diabetessysteem-kan-starten/>

4 ERP Personalized Food for Health

4.1 Management summary

The 20th century is characterized by a dramatic increase in life span and a reduced infectious pressure due to hygiene, antibiotics and optimized food logistics. However, at the same time a major increase in “lifestyle related” diseases is developing, such as cardiovascular diseases, cancer, obesity, type 2 diabetes, allergies, asthma/COPD, autism, dementia and so on. Typically, these diseases are treated from a medical and pharmacological perspective. We now realize that an unhealthy lifestyle and in particular unhealthy diet is a major cause of these diseases and thus may offer potential solutions. This needs new approaches in food design for “personalized health status”, motivational tools and personal empowerment in choosing the optimal diet.

The Early Research Program “Personalized Food for Health (ERP PFH) builds on two major societal and economical pillars:

- 1) The growing body of knowledge on human health over the entire life span, the diet and lifestyle related interventions to maintain and optimize this and to prevent “ageing disorders”.
- 2) The societal awareness of self-empowerment, personal ownership and personal control of many aspects in life, connected to the vast biological and ICT developments.

Together with the healthy-food focused technologies at TNO, they allow both the emergence of a personal food and health related service industry, and the facilitation of the citizen / consumer to choose exactly the right diet and lifestyle that fits personal goals, optimal performance and healthy ageing. This is valid over the whole lifespan, i.e. from birth to old age.

TNO has decided to build upon its strengths in combining a series of fundamental technologies to serve both industry and the citizen in these goals, focusing on two major areas as use cases, i.e. early life and healthy ageing.

In its first year, the ERP PFH has constructed the foundation of personalized foods by developing a number of technologies, constructing a knowledge base and providing some proof of principle personalized food applications, partly together with industry.

Healthy Aging

Health is characterized by the flexibility of all major processes and mechanisms, and ageing and disease relate to loss of this flexibility, causing onset of disease. Thus, shaping and maintenance of this flexibility by personalized diet and lifestyle in order to prevent loss of flexibility is the goal of the Healthy Aging program within the ERP Personalized Food for Health.

The basis for the Healthy Ageing program is an integrated knowledge base in which all relevant information on biological mechanisms, nutrients and their interactions are stored in such a manner that they can be exploited for a large number of applications. The applications developed in 2015 were:

- A Nutritional Systems Toolbox, called NuSyBox, connecting the knowledge base, the central repository of nutritional knowledge and data values, to different modules such as nutritional advice systems and visualisation tools
- The development of personalized dietary advice systems for blood pressure, cholesterol, metabolic health and weight management, and health effects related to nightshift work.

The combined tools have led to one major research collaboration with food industry and two major ecosystems with both academic and industrial partners.

Early Life

The early life phase strongly contributes to the health status during future life. It is characterized by development of all relevant parts of the human body, a development which is influenced by genetics, life style and nutrition.

Main driver for our work in this field is the development of a system to make a healthy development measurable and quantifiable. This system allows both for a diagnostic approach but also forms the basis for determining the efficacy of interventions. A first generation of such a system already exists in the form of the well-known growth-curve which is used for all Dutch infants. New developments which were started in 2015 include:

- Expanding the existing growth curve for children with both cognitive development and intestinal microbiome development as novel read-outs for healthy development.
- Develop *in vitro* and *in vivo* technology platforms for Early Life studies, such as a developmental curve in mouse models and microbiota screening platform using infant gut microbiota.

Furthermore it became clear that a reliable knowledge base on healthy development during early life, taking relationships between different health aspects into account, is currently lacking and will receive more focus in 2016. A scientific and stakeholder based network in the area of early life is under construction.

4.2 Program Execution and Results

Highlights

Healthy Aging

The basis for the Healthy Aging program is presented in the Figure 1, which shows the multi-layer systems approach connecting all major health goals to the molecular processes, their diagnosis and the dietary interventions. A structured capturing of all relevant knowledge of all areas in a proprietary knowledge base now allows for multiple applications in the area of personal health, service development, food products, health claim substantiation and healthcare focusing on curing lifestyle related diseases. The successfully developed Nutritional Systems Toolbox, NuSyBox, integrates a number of fundamental technologies present at TNO and thus optimized the TNO technology position in the area of personalized food for health. This is demonstrated by a number of emerging academic and commercial collaborations.

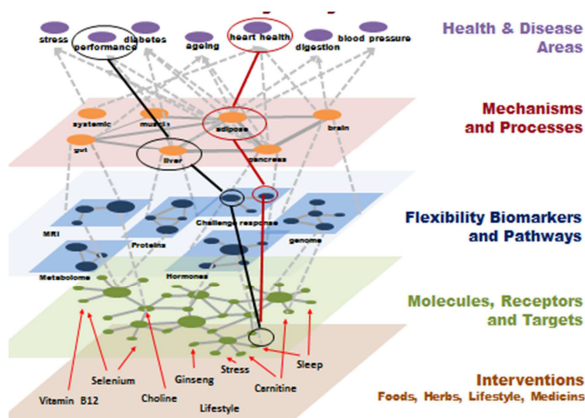


Figure 1. A multi-layer systems model is the basis of the Nutritional Systems Toolbox.

A specific example of this approach is the “biosynergy” tool, which exploits and unravels the health effects of herbs and phytochemical mixtures in a scientific manner (see Figure 2), thus providing a new basis for development of health applications in the area of supplements. The focus of 2015 was on providing scientific evidence for the effects of plant products on the health of people with metabolic syndrome or type 2 diabetes.

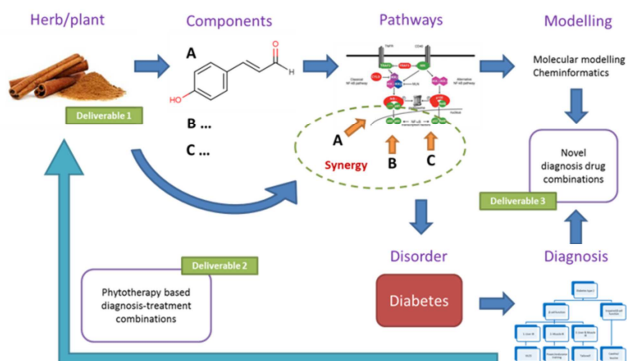


Figure 2. Schematic overview of the Biosynergy tool.

Highlight Early Life

The main driver for the Early Life program in 2015 was to develop novel concepts for analysing a healthy development during Early Life. Based on the growth curves for infants (a TNO development since the 1950s) which are based on measuring length and weight at defined ages novel health measurements targeting other health aspects have been explored. Two of these are shown in Figure 3 and 4.

The right graph in Figure 3 is an addition to the current growth curve (on the left) and represents the development of the intestinal microbiota (the bacteria present in the colon, which are implicated in many different diseases in adults). It is clearly shown that this composition changes over time (1-18 months period), but it is also clear that not all infants have the same composition. The different subgroups observed fit very well with the personalized aspect of this ERP. In this specific case it is currently not yet known whether different subgroups differ in their health, but this has already been shown in other cases (also by TNO).

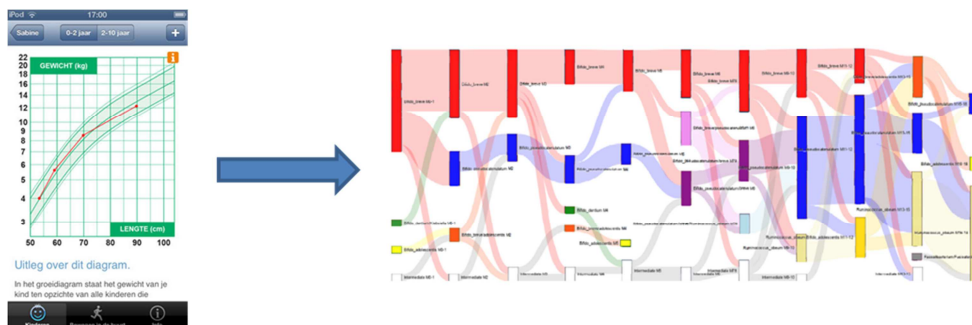


Figure 3. On the left the growth curve as measured for all infants born in The Netherlands is shown. The right graph shows the development of the intestinal microbiota of a group of healthy infants.

The right graph in Figure 4 shows an example of coupling the screening technologies of TNO to early life development in infants. The graph shows measurements of various developmental parameters in young mice. The d-score (short for developmental score) is targeting cognitive development for which the early life plays a very important role.

These novel tools allow for understanding healthy development and determining the current health status of an infant (is the infant in a healthy situation or not). It creates the opportunity to provide preventative advice on diet and lifestyle similar to the advice systems in Healthy Aging. At the same time, the screening technologies allow for measuring the effects of nutritional interventions. They will thereby support the development of novel food products and dietary advices. This way of thinking is not limited to early life but can be applied to all phases of life.

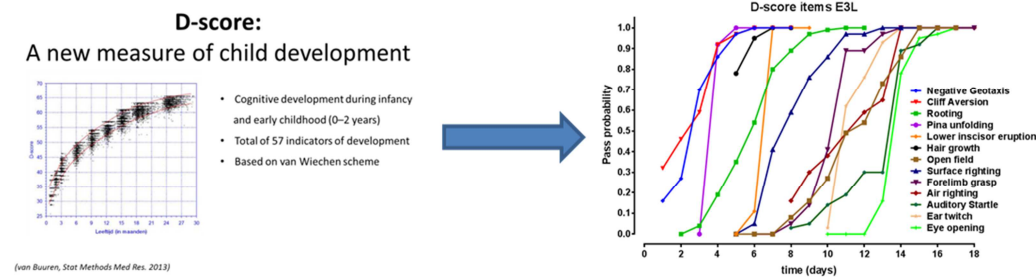


Figure 4. The left graph represents the D-score that is currently used for infants. The right graph shows the measurements of various parameters of the newly developed d-score in a mouse model.

Results vs Deliverables

Healthy Aging

The Healthy Aging program 2015 covered the entire range of combining knowledge and technologies to promoting self-empowerment, which also required the expertise of 5 different research groups within TNO. As already mentioned in the highlights, the development of the NuSyBox was successful in combining knowledge and technology and creating the first steps toward understanding the effects of diet interventions. In addition, developing mouse studies on cognitive decline and “leaky gut” has broadened the spectrum of technology that can be offered to food industry to analyze effects of diet interventions in more detail.

The last months of 2015 provided the opportunity to test the do-it-yourself diagnostics and to investigate the effects of self-empowerment in a working environment in a kind of field lab, called Health Café. Initial try-outs have been done at TNO internally and were a big success. The high-level of interest has motivated the choice to continue to develop this Health Café into a format that can be offered to any interested party. Setting up field labs in collaboration with industrial partners has proven to be a time-consuming process and negotiations are still ongoing. However, the preparatory steps for these field labs did result in a cholesterol module and advice systems for night-shift workers.

Early Life

One of the surprises when starting this ERP was the large number of activities in the area of Early Life within different research groups. At the same time it was also clear these activities had all been separate from each other. Bringing together all these activities, bringing all experts from 6 expertise groups into contact with each other and focusing all activities under one umbrella has been an important part of the 2015 activities and has been successfully accomplished, meaning that most goals of 2015 have been accomplished. This has already led to very interesting new developments as also shown in the Highlights.

One setback of 2015 was the inability to develop a zebrafish screening platform for cognitive development. These activities will not be continued in 2016. Another challenge remains in trying to promote the Dutch maternity care to other countries, due to differences in health care systems.

It has become clear that the Early Life field is very broad and a specific focus on selected health targets is essential. Furthermore it is also clear that the knowledge base for healthy development during Early Life is rather limited. Even in the field of metabolic health in which TNO has over 10 years of experience in adults, it is clear that translation of adult knowledge to early life knowledge is not straightforward and needs additional efforts (which are now part of the 2016 program).

4.3 Output

Journal papers

1. Hermanussen M, Stec K, Aßmann C, Meigen C, Van Buuren S (2015). Synthetic growth reference charts. *Am J Hum Biol.* Jun 30. doi: 10.1002/ajhb.22759.

2. Pease AS, Fleming PJ, Hauck FR, Moon RY, Horne SC, L'Hoir MP, Ponsonby A.L., Blair PS. Swaddling and the risk of Sudden Infant Death Syndrome: a systematic review and meta-analysis of individual level data. *Pediatrics*. Accepted
3. Buuren van S, Bezemer R, Reijneveld RA, L'Hoir MP. Curve matching met de TNO Groeivoorspeller: Predictie van groei vanaf jonge leeftijd. NTvG, 2015. Submitted
4. Gijzen S, Petter J, L'Hoir MP, Boere-Boonekamp MM, Need A. Current procedures in child deaths in the Netherlands: a comparison . *Child Death Review*. Submitted
5. Van den Broek T. Boessen R. De Weerd H. Dijk-Stroeve A. Bouwman J. Caspers M. Van Erk M. Van Ommen B. and Wopereis S. Knowledge and data-driven development of the next generation of biomarkers: health improvement after 12 weeks of caloric restriction by quantifying phenotypic flexibility. draft

Reports

1. Hoogh de I, Stafleu A, L'Hoir MP. Voeding en cognitie, een literatuuronderzoek, intern verslag, TNO, 2014
2. Otten W, Rovekamp T, Keer M, De Graaf M & Van Keulen H (2015). Mogelijkheden voor webbased ondersteuning bij zelfmanagement van Type 2 Diabetes Mellitus. TNO/LS 2015 R11352.

Book

L'Hoir MP, Sleuwen van BE. HET alles wat je moet weten van SLAAPBOEK. Uitgeverij Why's.

Invited lectures

1. Wielinga P.Y. and Kleemann R. Early Life interventions and later health outcomes in translational mouse model. ESPGHAN meeting, Amsterdam, May 2015
2. Levin E. (2015). Personalized microbial network inference via co-regularized spectral clustering . Clusters, Games and Axioms, Leiden June 2015

Oral presentations

1. Satellite symposium during ESPGHAN 2015 (May, Amsterdam) presenting TNO highlights in the Early Life domain by 5 experts
2. Sleuwen BE, L'Hoir MP. Poster: Ultrasonic identification of infant crying. Tech innovation conference, Singapore, 22-23 September 2015.
3. van de Brug FJ, Lucas Luijckx NB, Cnossen HJ, Houben GF Early Signal Detection for Emerging Risks in Scientific and Technical Literature; EFSA symposium, Milan, Italy, 14-16 October 2015
4. van Buuren S (2015). Methodological Developments in Growth Modeling. ASA Proceedings of the Joint Statistical Meeting 2015, Biometrics section, 338-346.
5. Buuren S. Methodological Developments in Growth Modeling. August 13, Joint Statistical Meeting 2015, Seattle.
6. Buuren S. Curve matching: A new approach to personalized medicine. 2nd Transatlantic Conference on Personalized Medicine. Rotterdam, 8 October 2015
7. Hoogh de I, Stafleu A, Wouwe van JP, L'Hoir MP. A Literature Search on Cognition and Nutrition. [translated in Italian for the Expo Milano, 31 October 2015: "Nutrire il Pianeta, Energia per la Vita"]
8. I.A.C. Arnoldussen, Maximilian Wiesmann, Charlotte E. Pelgrim, Eline M. Wielemaker, R. Kleemann, Arend Heerschap, P.Y. Wielinga, A.J. Kiliaan. Sensitive imaging techniques demonstrate short-chain fatty acid-induced improvement of functional connectivity, metabolic and cerebrovascular function in obesogenic LDLr^{-/-} mice. Submitted to Neurorepair, Leipzig, 19-22 april 2016

4.4 Building the Ecosystem

Co-research with knowledge partners

Two projects taken up by the VP Food and Nutrition have been very important in 2015.

First, the OptiMuM project is a proof of concept study together with the Spaarne Gasthuis and Verloskundigenpraktijk Haarlemmermeer and Bollenstreek to test the value of various do-it-yourself diagnostic measurements by pregnant women. In addition, the burden of these diagnostic tools experienced by these women will be evaluated. Insights from this study will be invaluable for further development of technological tools within the Early Life Program.

The second project is a proof of concept study together with Wageningen UR on testing the implementation of personalized dietary and lifestyle advice by means of feedback on individual health status measured by do-it-yourself diagnostics using an adult cohort with elderly. Insights in processes such as METC-approval, motivational tools to empower people to change their diet and lifestyle will directly be taken into account in the Healthy Aging program.

In 2016 both projects will be continued. In addition, a collaboration with the RIVM has been set up in 2015 and the project will start in 2016. The research is focused on analysis of gut-microbiota in young children and adult cohorts. Moreover, the large collaborative EU project POWER2DM, partially supported by the ERP PFH, will start in 2016 as well, of which the main objective is to develop and validate a personalized self-management support system for T1 and T2 diabetes patients.

The academic network of the ERP Personalized Food for Health is further strengthened by contributing to the activities of professors and PhD students at the Leiden University, UvA, VU and Wageningen UR of which some examples are mentioned below.

Prof. dr. Jan van der Greef is an expert in systems biology in particular related to personalized health. His expertise within the ERP is also valuable due to his connection with the phenotyping activity research program of the Sino-Dutch centre for Preventive and Personalized Medicine, a collaboration between TNO, the University of Leiden and the Chinese Academy of Sciences. Moreover he is active in establishing “use case” studies related to the ERP-program and introducing new concepts using his expertise.

The project carried out by a PhD student at Wageningen UR is focused on analysing gene expression data from a high-fat diet intervention. The results will give us more insight in the role of fat intake on metabolic health. To strengthen the relation with Wageningen UR is essential when considering the future move of food related research of TNO to Wageningen.

In all, the network of academic parties and other knowledge partners is building up rapidly and generating fruitful collaborations.

Co-development with stakeholders

Two major partnership programs have been formed over the last year:

- Together with Wageningen University and Research, a joint research program with many Dutch and European industries is being created that further develops and implements dietary advice systems.
- Together with Medical Delta, a consortium is being created to develop and implement personalized food and lifestyle practice in healthcare, in the first instance to cure type 2 diabetes.

Spin-off projects

The combined tools of the Healthy Aging program have led to a major (4M€) research collaboration with food industry in developing personalized dietary advice systems.

5 ERP Energy Storage and Conversion

5.1 Management summary

One of the grand challenges for Europe in the coming decades will be to guarantee a sustainable supply of energy, while at the same time to keep the system reliable and affordable. The renewable energy directive 2009/28/EC established a European framework for the promotion of renewable energy, setting mandatory national renewable energy targets for achieving a 20% share of renewable energy in the energy consumption and a 10% share of energy from renewable sources in transport by 2020. To realize this “2020 target”, the development of new breakthrough technologies is essential.

Energy storage and conversion solutions facilitate the increase in flexibility of the energy system. This flexibility is needed to cope with the uncontrolled variability (‘intermittency’) of renewable energy sources and the fact that renewable energy production often takes place on a smaller, local and more decentralized level.

Within this ERP our mission is to provide solutions for energy conversion and storage issues for both industrial and domestic users. We will primarily focus on the following concepts:

Conversion of electricity to chemicals - “Electrons to Chemicals”:

The first process being studied is electrochemistry in which electricity (from renewable sources) can be used for the production of organic molecules. Such processes are already known, but for large scale application, issues like catalyst efficiency and separation technologies need to be improved. Our plans have been communicated with external parties as part of the VoltaChem program (<http://www.voltachem.com>) and their opinion is taken into account for further investigations.

Direct conversion of solar energy to chemicals – “Photons to Chemicals”:

An interesting new technology is the direct use of sunlight for the production of chemicals or fuels. Due to the direct use of the solar energy, the process is potentially more efficient than other processes using renewable energy. It's is expected to become an important technology for future energy storage.

We consider the progress made on the two concepts above to be promising. It is feasible to build a technology position, together with academic partners, that will attract the interest and support of industrial stakeholders necessary to generate the momentum for cutting edge innovations.

Heat storage of solar energy – “Thermochemical storage”:

A large need exists for storage of heat generated with solar collectors for use in winter. This project is aiming at finding the most suitable materials for thermochemical heat storage and release through dehydration and hydration of salts. Industrial parties interested in commercialization of such technology are involved in the development in an advisory board.

The project adds research on new promising materials to a strong technology position on the equipment for heat storage, thus providing a more attractive integral proposition.

Smart grid system control – “PowerMatcher”:

A smart control system will be necessary to match the increasingly fluctuating demand for electricity and supply of renewable energy. In our system called ‘PowerMatcher’ we take into account existing market mechanisms (fluctuating prices), the actual demand/supply situation, storage capacity and short and long term weather forecasts through a scheduling extension of the PowerMatcher (<http://flexiblepower.github.io/>). Energy suppliers are highly interested in this development and are kept updated through discussions and meetings.

The research strengthens the necessary scientific foundation that will yield versatile reliable models.

5.2 Program Execution and Results

Electrons to Chemicals

Concept

Within this project the main focal point is to support system development using electrocatalysis, by developing tools and creating knowhow. This should lead to showcases, which can be in a separate project demonstrated at a relevant scale.

In 2015 we worked on two main research lines. The first line is on 3D electrodes (nanostructured electrocatalysts). The second line is on in-situ product recovery (e.g. integrated reaction/separation systems). By combining these two lines an efficient and effective electrochemical system for transformations can be created.

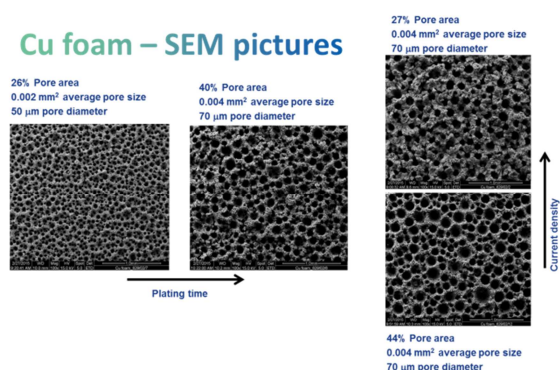


Figure 1: SEM pictures Cu Foam made within the ERP

Highlights

- Successful proof of principle of the increased efficiency of the conversion of butanol to butyric acid using nanostructured newly developed nickel foam.
- Design of special copper foams for CO₂ conversion towards ethylene.

Results

At first, the use case has been defined: the demonstrator process will be an oxidation reaction, with a commercially available bio-based chemical as starting material. Integration of a separation step of the product(s) must be feasible. As starting material 1-butanol has been selected based on both technical and scientific reasons. Moreover, the class of bio-alcohols represents an interesting domain for the further functionalisation of biomolecules.

One of the main improvements of the electrolysis process we are aiming for, is the development of nano-structured catalysts. From the performed experiments it can be concluded that the copper foams obtained in our work (Figure 1) resemble very well the structures reported on in literature, both regarding the morphology (although there are minor differences) as well as in the electrochemical behaviour as catalyst. These copper foams have been tested for the electrochemical reduction of CO₂ towards a.o. ethylene. The knowledge generated on the structuring of copper electrode has been used to make nickel foams. These foams have been used for the electrochemical oxidation of butanol.

Proof of principle has been achieved that these type of materials can lead to significant increased efficiency in the conversion of butanol to butyric acid.

Integrated continuous processing is a prerequisite for electrochemical conversions to become economically competitive for manufacturing of functional and specialty chemicals compared to conventional processing in batch operated stirred tanks. A workflow for design, development and evaluation of integrated processes for electrochemical conversions has been set-up.

In 2016, the tools for the economic assessment will be used to identify the critical parameters needed to achieve economic perspectives for the electrochemical transformation of functionalized molecules.

Output

- Dissemination events: Meetings related to the VoltaChem Program, Advisory board meeting June 5, 2015
- Press attention: Presentation of the VoltaChem Program (<http://www.voltachem.com>)
- IP protection: A patents search has been performed with promising results. Protection will continue in 2016.

Photons to Chemicals

Highlights

- Plasmon catalysis identified as very promising technology.
- Multiple plasmon catalysts identified and tested.
- Hybrid Au-Pd nanoparticles selected as most promising catalyst for Suzuki C-C coupling.
- Technology established for real-time monitoring of conversion and yield using RAMAN spectroscopy.
- Active collaboration on plasmon catalysis with Utrecht and Twente University within the NWO project "Unravelling the mystery of solar steam nanobubbles".

Results

Unlike conventional photocatalysis for conversion and storage of sunlight in molecular bonds, we decided not to focus on semiconductor catalysts for water splitting, carbon dioxide reduction or co-splitting of water and carbon dioxide, due to the limited energy conversion efficiency of these processes. Based on the fact that the semi-conductor catalysts only use UV, and in specific cases blue light, only a limited part of the solar spectrum is used, which typically leads to energy conversion efficiencies of less than 5%.

Within the photons to chemicals project, we decided to focus on metal-containing nanoparticles as catalysts for photochemical conversions. Based on the localized plasmon resonance of such particles, a mixture of metal containing particles of different size, shape and architecture is capable of harvesting the entire solar spectrum. Furthermore, such particles can be catalytically active themselves, or can be decorated with other metal particles or metal complexes for catalysis. To proof the concept of "plasmon catalysis" for chemical energy storage, we decided to focus on the Pd-catalyzed Suzuki-coupling as test reaction. Ultimately, we aim at further developing this system for the generation of platform chemicals and/or fuels. To demonstrate the concept using the Suzuki reaction, nanoparticles consisting of gold nanorods decorated with small palladium particles have been selected as catalyst of choice. We have tested the particles as catalysts in the Suzuki reaction in a laser reactor developed at TNO. For selected batches, we achieved high product yields. In 2016, we will study the reaction kinetics of the thermal and photocatalytic Suzuki reaction and elucidate their rate laws using the catalysts and real-time monitoring set-up developed in 2015. We will also focus on quantifying energy conversion efficiencies using this set-up.

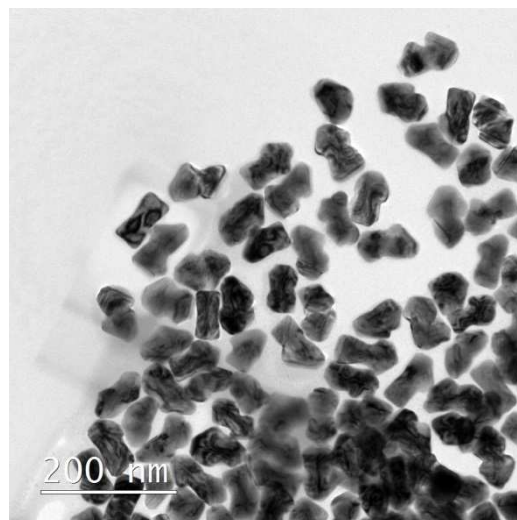


Photo: TEM image of Pd-decorated Au nanoparticles prepared in our laboratory at TNO.

Output

- (Invited) Lectures: Pascal Buskens, Nanostructured Optical Materials, invited lecture at NanoCity 2015.
- Daniel Mann, Pascal Buskens, c.s., Design, Synthesis and Characterization of Polystyrene-Gold and Polystyrene-Silver Core-Shell Particles with Tunable Plasmon Resonance Frequency and Absorption-to-Scattering Ratio, MRS Fall Meeting, oral presentation, December 2015.
- Dissemination events: Advisory board meeting June 5, 2015
- Other: Pascal Buskens, Nanostructured Optical Materials, habilitation thesis RWTH Aachen University, submitted October 2015.

ThermoChemical Storage

Concept

This project is aiming to create a breakthrough in compact thermal storage using hydration and dehydration of salts, by identifying alternative types of salts and new methods for the stabilization of these salts. Heat is stored through release of moisture (drying) from the salt; heat release is achieved by absorption of water. Such stabilisation is required for a long life time of the heat storage system.

The use case is a *heat battery* in an existing building, consisting of a compact thermal storage module that is connected to either a heat pump driven by renewable electricity or a solar thermal panel.

The ultimate goal for this project is to identify engineering principles for creating competitive heat storage materials based on the solid-solid transitions involving hydration and dehydration of salts. The knowledge gained will lay the foundation to select and outline optimal combinations of material performance, reactor concepts and production processes.

Highlights & disappointments

- New types of salt have been identified as potentially interesting.
- Several stabilization methods have been demonstrated successfully.
- However, optimized characterization methods were not available in time, so cyclic tests have only been performed on non-stabilized salt.

Results

Key Performance Indicators (KPIs) have been defined for the two selected use cases:

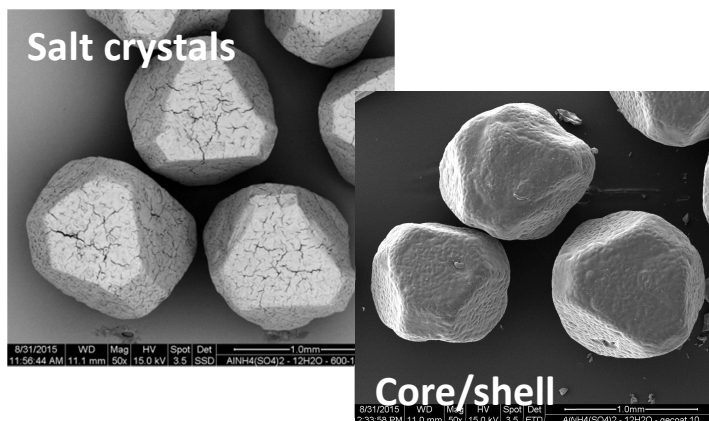
1. Decentralized storage of solar thermal energy.
2. Distributed grid-connected storage – utilizing heat pumps.

The selected KPI's were translated to critical material property requirements. A long list of possible ThermoChemical Materials (TCM) was established and traded-off against these materials requirements. From this list the four most promising candidates were selected for further investigation.

As these salts may 'melt' during moisture uptake, they have to be stabilized to keep their shape. The selected promising candidate materials were stabilized using three different techniques: 1. Grains of salt mixed with stabilization material, 2. Core-shell particles of salt inside a polymer shell (see figure). 3. Impregnation of salt in hollow fibres, 4. Impregnation of salt in metal foam. Various composite materials have been prepared for further characterization.

Specific testing equipment has been acquired to accurately measure the heat storage and release efficiency from the (stabilized) salts.

Design rules for crystallite, grain and bed size of a composite TCM were set-up based on vapour and heat transport equations. These have to be further elaborated.



Output

- IP protection: Possible patent applications are being investigated on two topics
- Dissemination events: Advisory board meeting on December 7, 2015

Smart grid system control

Concept

The goal of this project is to develop methods for a cost-optimized matching of demand and supply of electricity, like tools for planning and the effective use of buffering (stored electricity) for the purpose of deferred energy. The already developed “PowerMatcher” system is extended with new tools. The envisaged smart energy control is acting on changing circumstances, is aware of demand/supply planning and deviations to this planning. It determines autonomously if and what actions must be taken to adapt to the new situation, and optimizes the control and re-planning with respect to cost, stability, flexibility and other demand-related/supply related requirements of the network. This offers the possibility to decouple demand and supply timing by buffering of energy for later use.

We foresee interesting future potential for the knowledge and algorithms developed in SOSENS, to be used in a (to be developed, commercial) simulation tool for the analysis of the stability of smart grids, such analysis to be performed for a set of operational test scenarios, incorporating a given configuration / composition of the electricity network and demand and supply profiles including sun/wind forecasts. Such tool could also assist in the *dimensioning* of the smart grid.

Further, due to the planning and cost optimization possibilities offered by the SOSENS methodology, we also foresee potential for the use of the methodology for studying the effect of changing price policies on the (attractiveness of) generation and on use of sustainable energy resources (sun / wind, ..). This is possible by running simulations for reference scenarios (e.g. combinations of different types of users, demand/supply profiles, storage, traditional and sustainable energy sources, electric vehicles, heat pumps, etc.). Ideally this could result in a decision support tool helping policy makers to make better informed decisions for choosing / adapting price policies and/or make decisions on the type of (future) energy supply.

Highlights

- We have proven by simulations that the use of planning in combination with storage has advantages regarding cost, efficiency and stability for prosumers and for the network.
- The participants of our Transactive Energy (TE) Tutorial valued the half-day program a 9.0 out of 10. The lowest scoring question was: “The length of the course was about right”. The participants thought the tutorial should have been longer.

Results

Regarding the research topic on True value based bidding in TE systems:

1. A dynamic market environment model has been developed to be used by device agents to adaptively determine high and low bidding prices for their own circumstances (e.g. storage capacity) in a TE dynamic market context.
2. A set of design criteria/guidelines for transactive energy clusters (in terms of cluster composition and agent strategies) to implement true-value-based energy coordination.

Regarding the research topic of the use of planning and re-planning of demand and supply in smart grids:

Two types of planning algorithms have been developed: two time scales that takes a more global expectation of future demand and supply into account and N-time slot that uses a specific expectation of future supply and demand.

We have a good understanding of the performance of these algorithms in an island scenario (2015) and developed knowledge of how we can (dynamically and adaptively) select the best planning algorithm based on utility of those algorithms under given constraints in communication and computation.

Regarding the research topic of Self-organization / reconfiguration decisions in the micro-grid:

Through the research done in 2015 we better understand current and future problems with stability of the grid. With the preliminary analysis done in 2015 we understand how smart control algorithms for demand side flexibility can help to stabilize the grid in cases of for example intermittent sources (e.g. sun, wind) and aggregated high demand (e.g. electric vehicles, heat pumps, etc.). Especially the combination of planning with energy storage facilities in the network will offer important stabilizing effects. The controlled use of storage has the potential of reducing the need of having spare (balancing) supply capacity in the grid, thereby reducing operational costs.

Regarding the DTU Fellowship

In 2015 we made a start with gathering formal description of the models we use for simulation. Objective is to publish benchmark study cases based on this. It is expected that publishing such benchmarks fills a gap in the smart grids research community and will further strengthen TNO's position.

Output

Publications:

1. Pia Kempker, Hans van den Berg (TNO), Werner Scheinhardt, Nico van Dijk, Johann Hurink (TU-Twente); Optimization of Charging Strategies for Electric Vehicles in PowerMatcher-Driven Smart Energy Grids, conference paper and presentation for 9th EAI International Conference on Performance Evaluation Methodologies and Tools, Berlin, 14-16 December 2015
2. Paper in progress: Pamela MacDougall "Risk assessment of aggregated flexibility usage for multi-market trade" ". Submitted to the CIRED Conference.
3. Paper in progress: Junjie Hu, Guangya Yang, Koen Kok, Yusheng Xue, Henrik W. Bindner, "Transactive Control: A Framework for Operating Power Systems Characterized by a High Penetration of Distributed Energy Resources". Submitted to the Journal for. Modern Power Systems and Clean Energy, early January 2016.

Dissemination events:

Koen Kok, Steve Widergren and Leigh Tesfatsion, "Intelligent Systems Support for Transactive Energy Systems: The Fundamentals", Tutorial at the IEEE PES General Meeting 2015, Denver, Colorado, 25 July 2015.

5.3 *Building the ecosystem*

Electrons to Chemicals

Together with the project Photons to Chemicals an Advisory board has been established with the following members: Eric Appelman (Perstorp), Peter Berben (BASF), Petra de Jongh (Universiteit Utrecht), Jurgen Klankermayer (RWTH Aachen), Marc Koper (Universiteit Leiden), Jan Kees vd Waal (Avantium), Edwin Berends (Albemarle). On June 5 2015 we had our first meeting and the second will be on 22 January 2016.

Moreover, the visibility of TNO within academia and industry has been substantially improved via the VOLTACHEM program. The current VoltaChem community consists of companies Nuon, Cofely, Technip, Magneto Special Anodes, Proton Ventures and Coval Energy. They are directly involved in discussions on high-level aspects of system integration, energy conversion & storage and electrification of the chemical industry. Also we have presented the program at several events, including Deltalinqs workshop (NL), Topsector Chemie Dag (NL), Werkconferentie Topsector Energie (NL), ISPT System integration workshop (NL), DIFFER solar fuels workshop (NL), EemsDeltaVisie industrial congress (NL), NWO CHAINS congress (NL), EERA JP Energy efficiency (EU), EERA JP Energy Storage (EU) and discussed with relevant stakeholders at AICHEMA World Forum for the Process Industries (D), 5th Carbon Dioxide Utilization Summit (D) and Brussels Sustainable Development Summit (B).

Through this interaction with relevant stakeholders from chemicals, energy and equipment we further adapted the roadmap related to the impact vision, technology focus, business focus and work plan. Furthermore, we have already had multiple bilateral project based on past expertise in this field and requests for PPS projects, both short-term and long-term.

By aligning the ERP work with the EZ transition activities on electrochemistry together with ECN (who have focus on power-2-heat and power-2-hydrogen developments), a broad coherent electrochemistry program has been created at TNO.

Photons to Chemicals

Together with the ERP project Electrons-to-Chemicals we organized an Advisory Board on Catalysis. On June 5 2015 we had our first meeting and the second will be on 22 January 2016.

We participated in the Interreg proposal EnOp, which aims at joining forces between leading universities, research and technology institutes and companies in the South-East of the Netherlands and Flanders. If granted, part of the resources for the P2C project in 2016 will be allocated to this project, in which TNO focuses on plasmon catalysed hydrogenation reactions, ultimately working towards the hydrogenation of carbon dioxide. NanoHouse is the coordinator of this proposal.

We cooperated with DWI-Leibniz Institute for Interactive Materials e.V./RWTH Aachen University (DWI) and Delft University of Technology on the synthesis and optics of polystyrene-Ag and polystyrene-Au CSPs. This cooperation resulted in one accepted publication in RSC Advances (RSC Adv. 2014, 4, 62878-62881), one manuscript in preparation entitled Tuning the Plasmon Resonance of Polystyrene-Au and Polystyrene-Ag Core-Shell Particles: What Is Theoretically Possible, and What Is Realized in Practice?, and one oral presentation at MRS Fall Meeting 2015. Furthermore, this work is part of the habilitation thesis of Pascal Buskens entitled "Nanostructured Optical Materials".

We cooperated with Twente University and Utrecht University in the framework of the NWO project "Unravelling the mystery of solar steam nanobubbles". One of three Ph.D. students in this project, Thijs Verkaaik, started in May 2015 and is located at TNO Eindhoven. TNO, BASF and Albemarle co-finance this project.

We are currently evaluating cooperation with DIFFER in the field of plasmon-mediated reactions (Dr. A. Baldi).

ThermoChemical Storage

Through close cooperation in national and European funded research programmes, an eco-system is being built that comprises the relevant material suppliers, system suppliers, construction companies, energy companies and end users.

An Advisory Board for TCS has been established with a strong foothold in the academic and industrial field.

The H2020 project CREATE has been awarded and started. Partners are amongst others, DOW, Vaillant and EDF.

In a joint effort between the ERP Orchestrating Innovation and the ERP ECS, a detailed analysis of the market and the driving forces has been made, resulting in an identification of the relevant/dominant players and their respective interest. Based on the “value-web” that has been built up, a specific marketing strategy is under development (to be completed Q2-2016).

As input for the marketing strategy, discussions with several National, European and worldwide industrial players (a.o. DOW, VAILLANT, ALLIANDER, EDF, ...) have been held. These discussion strongly support the market potential of a TCS based Heat Battery.

Within the TKI IDEEGO project “Meerjarenplan Compacte Conversie en Opslag” a Dutch Roadmap is under development. As an outcome of this roadmap, a follow-on project on TCS will be defined (deadline September 2016) in which first results of the ERP work can be included as TNO background.

For 2017 a H2020 call is under preparation for which TNO has positioned itself as a very good candidate for follow-on funding.

Smart grid system control

PowerMatcher is one of the two leading implementations of a Transactive Energy System in the world. Especially in Europe, where functions of energy delivery are separated from those of network operation, future smart grid coordination must be able to handle multiple energy suppliers operating in a single network area. In particular network operators on a regional (Alliander, Stedin, Enexis) and national scale (Gasunie, Tennet) are interested in the development of these grids, since investments in infrastructure are performed for the next 30 years.

We cooperated with research laboratory PNNL (USA), Iowa State University (USA) and with the Technical University Denmark (DTU). Further, there are two PhD projects closely related to the project: “Time-critical Demand Response Functions for Secure Power System Operation” at the University of Strathclyde (partly financed through the ERP) and “Availability and longevity forecasting of demand response flexibility in the smart grid” at the Catholic University of Leuven. The latter is performed by TNO-er Pamela MacDougall and is partly carried out within the project.

An innovation proposal (project name: Energie 6.0) has been submitted to the RVO program “Demonstratie Energie Innovatie” (DEI) together with NL market parties Priogen, iReal and Chematronics and launching customer Van Agt. The proposal uses and builds forth on SOSENS knowledge.

A project proposal with DTU has been submitted to Danish ForskEL Programme. The proposal ended in the sub-top and was not selected for funding unfortunately. Both parties have the intention to use the proposal for a new opportunity.

It is expected that the anticipated future extension of PowerMatcher with planning functionality including energy storage modelling will further boost the interest of network operators for smart grid control.

6 ERP 3D Nanomanufacturing

6.1 Management summary

The market growth of semiconductor, solar energy, energy conversion, electronics and photonics has significant impact on Dutch and European economy. Using strategic innovation, the Netherlands has been able to keep a competitive advantage in the development of equipment for nanometer feature sized manufacturing/patterning and metrology. Examples include UV-light assisted patterning (ASML), electron beam imaging (FEI) and Atomic Layer Deposition (ASM).

To further develop the competitive edge of these industries, yield enhancement, cost reduction and reduction of time-to-market are essential with the simultaneous technological challenge to develop next generation reliable (nano-)manufacturing and metrology solutions along 2 main routes. First, in the next decade the device dimensions will shrink to the level that technologies currently used for production and quality control approach physical boundaries and will no longer be technologically or economically feasible. Second, 3 dimensional structuring will be introduced to achieve new functionalities and to make optimum use of the available space. As a result of both routes breakthroughs in manufacturing and metrology methods for (3D) nanoarchitectures are required. This is precisely the goal of early research program 3d nanomanufacturing.

The progress of this ERP is characterized from three perspectives.

Science perspective (Hamed Sadeghian – Principal Scientist): “I see in this program scientifically well underpinned proof-of-concept development of equipment and instrumentation for “3D nano-manufacturing” and “3D nanometrology” to enable future nano devices.

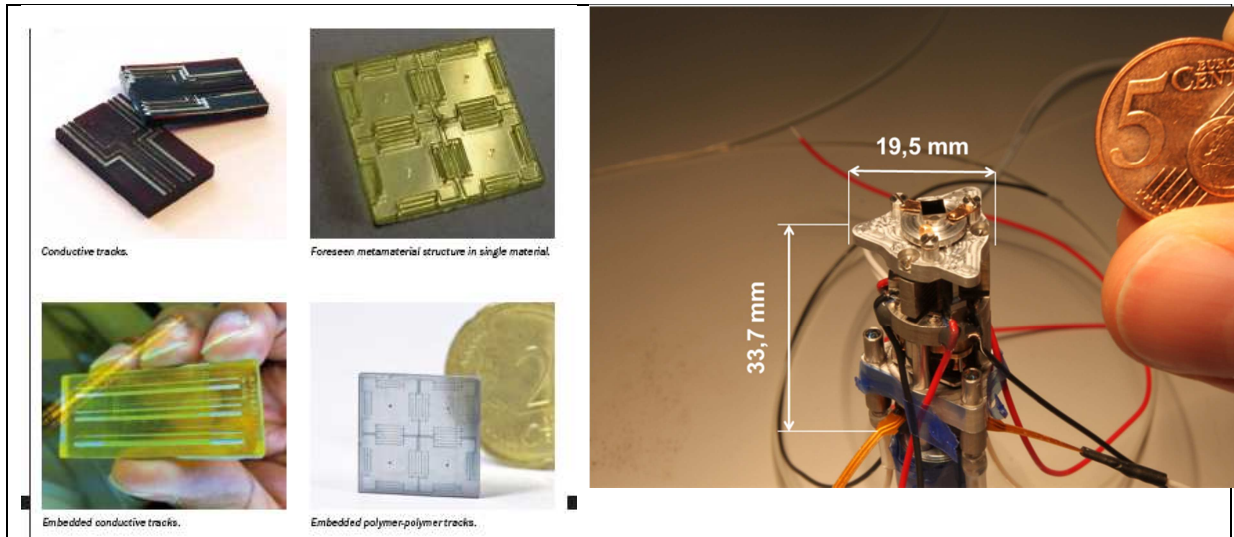
More attention must be given to industrially relevant key drivers such as high yield and throughput and lower cost. Collaborations with external partners started and are growing. I would like to see the program to become much more geared to collaboration with outside partners in 2016 and onwards.”

Partnering perspective (Machteld de Kroon - Director of Research): “Due to the knowledge that has been built by the ERP 3D Nanomanufacturing our relationships and collaborations with universities, FOM Institutes (AMOLF) and renowned research departments of industry (Applied Materials, IBM and ASML) received a major boost and are intensified. Interest in and acknowledgement of developed technology by Chief Technology Officers from Industry and by professors of universities implicitly shows the quality and the relevance of the work done by the Early Research Program ERP 3D nanomanufacturing.”

Stakeholder perspective (Roland van Vliet – Director of Roadmap – Semicon): “ERP 3D Nano Manufacturing enables the development of breakthrough technology that in an innovative way adds to the roadmaps of our industrial partners. We have seen that this can happen very quickly. Technology developed in the ERP last year is already being implemented in applications of our valued customers ASML and Applied Materials. The ERP also provides a solid knowledge base that contributes to our reputation worldwide. Furthermore, the Program 3D Nanomanufacturing now contributes directly to new business in the Netherlands with a soon-to-be-launched spin-off company. This ERP is thus fully aligned with the mission of TNO: “to boost the competitive strength of industry and well-being of society (www.tno.nl)”

Finally, Paul de Krom (CEO TNO) reflecting on our interview in NRC.next of 21 October: ... Congratulations, it really is a wonderful example of what TNO is all about! ... the added value of TNO for science, private companies and society at large.

6.2 Program Execution and Results



Technologies for 3D Nanomanufacturing and Metrology have been accessed in 2015.

Nano metrology and Nano manufacturing

For low cost, high yield manufacturing of nano-transistors it is very important that the details of nanostructures in terms of dimension (in order of tens of atoms) and their material properties be well characterized and inspected.

In 2015 focus was on developing technologies based on optical inspection, quantitative phase imaging, acoustic imaging

Nano manufacturing

The use of nearfield interactions for nanomanufacturing:

This technology has shown to be capable of nanometrology with sub-nanometer resolution as well as capabilities for nanomanufacturing and nanopatterning. Moreover, this family of instruments are already used in semiconductor industry at the research and ramp-up laboratories. However, the speed and thus the throughput of the measurement is very low to be used in in-line applications. TNO has developed several technologies in order to enhance the throughput to the level of acceptance by industry. The current SPMs are not yet capable of real 3D measurement (2.5 D). Further development is needed to develop SPM for real 3D measurement for negative-slope features (undercut) and high aspect ratio measurement. Due to finite size of the tip, very small trenches (< 14 nm) cannot be measured currently. TNO has started the developments on special tip manufacturing process for sub-20 nm teach measurement.

Cross over use cases

To achieve focus, a single primary use case has been selected that will guide the decisions during the research. However, the technologies developed for this primary application (3D nano-manufacturing for future 3Dnanoelectronics architectures) are also very relevant for the application domains below:

– 3D nano-manufacturing and nanometrology of printed large-area electronics and of photonics and photovoltaics devices. This is an important cross-over use case, as nanostructures are expected to strongly enhance light incoupling in solar cells and light outcoupling in lighting devices such as OLEDs. Manufacturing of novel batteries with enhanced performance thanks to 3D structuring at nanoscale.

– Microwave frequency devices for Defense and Space applications to improve the performances of complex antenna systems. The fabrication and the performance of metamaterials, as an enabling technology for radar applications, is also to a large extent related to the technologies which will be developed in this ERP. Free-form 3D manufacturing of metamaterials and inspecting the shape and performance in 3D is the key challenge for this cross-over application.

– Instruments for bio-medical and health-care.

6.3 Output

List of publications:

Journal Papers

1. Herfst, R.W., Klop, W.A., Eschen, M., van den Dool, T.C., Koster, N.B., Sadeghian, H. (2014), 'Systematic characterization of optical beam deflection measurement system for micro and nanomechanical systems', *Measurement*, Vol. 56, 2014, P 104–116.
2. Bijster, R.J.F., de Vreugd, J., Sadeghian, H., 'Phase lag deduced information in photo-thermal actuation for nano-mechanical systems characterization' *Applied Physics Letters* 105 (7), 073109.
3. Herfst, R.W., Dekker, B., Witvoet, G., Crowcombe, W., de Lange, D., Sadeghian, H., 'A miniaturized, high frequency mechanical scanner for high speed AFM using suspension on dynamically determined points', *Review of Scientific Instruments*, November 2015.
4. Sadeghian, H., Herfst, R.W., Klop, Winters, J., Crowcombe, W., Kramer, G., van den Dool, T.C., Van Es, M., 'Development of a Detachable Miniature Scanning Probe Microscope for Large Area substrates Inspection', *Review of Scientific Instruments*, November 2015.
5. D. J. Maas¹, T. Fliervoet, R. Herfst¹, E. van Veldhoven, J. Meessen, V. Vaenkatesan and H. Sadeghian, 'Sub-50 nm metrology on extreme ultra violet chemically amplified resist—A systematic assessment', *Review of Scientific Instruments* 86, 103702 (2015)

Conference papers

1. Pisano, E., Silvestri, F., Gerini, G., Lancellotti, V. & Galdi, V. (2015). 'All-dielectric metasurface for optical focusing'. Conference Paper : Proceedings of the 9th European Conference on Antennas and Propagation (EUCAP 2015), 12-17 April 2015, Lisbon, Portugal, Piscataway: IEEE Service Center, accepted or in press.
2. Silvestri, F., Pisano, E., Gerini, G., Lancellotti, V. & Galdi, V. (2015). 'Nanoresonator based dielectric surfaces for light manipulation'. Conference Paper : European Microwave Week, The 45th European Microwave Conference, 06-11 September 2015, Paris, France.
3. A Keyvani, H Sadeghian, H Goosen, F van Keulen, 'Transient tip-sample interactions in high-speed AFM imaging of 3D nanostructures', *SPIE Advanced Lithography*, 9424-100, 2015.
4. H Sadeghian, TC van den Dool, Y Uziel, RB Or, 'High-speed AFM for 1x node metrology and inspection: Does it damage the features?' *SPIE Advanced Lithography*, 9424-26
5. H Sadeghian, B Dekker, R Herfst, J Winters, A Eigenraam, R Rijnbeek, 'Demonstration of parallel scanning probe microscope for high throughput metrology and inspection', *SPIE Advanced Lithography*, 94240O-94240O-14., 2015

6. M. H. van Es, J. D. human, H. Sadeghian, 'EUV blank defect and particle inspection with High throughput Immersion AFM with 1 nm 3d resolution', SPIE Advanced Lithography 24 feb 2016, San Jose, California United States Paper 9778-109.
7. H Sadeghian, TC van den Dool, WE Crowcombe, RW Herfst, J Winters, 'Parallel, miniaturized scanning probe microscope for defect inspection and review', SPIE Advanced Lithography, 90501B-90501B-7.
8. H Sadeghian, RW Herfst, TC van den Dool, WE Crowcombe, J Winters, GFIJ Kramer, 'High throughput parallel SPM for metrology, defect and mask inspection', Awarded 2nd best paper "European Mask & Lithography Conference 2014".
9. H. Sadeghian, M. van Es, Parallel, high throughput atomic force metrology and inspection for EUV masks and wafers, SPIE Advanced Lithography 24 feb 2016, San Jose, California United States Paper 9778-46.
10. M. van Es, H. Sadeghian, 'High Throughput Atomic Force Microscope for Self-Assembled Monolayers Metrology and defect inspection', SPIE Advanced Lithography 24 feb 2016, San Jose, California United States Paper 9778-76.
11. S. Keyvani, H. Sadeghian, 'Simultaneous AFM Nano-Machining and imaging for Photomask Repair', SPIE Advanced Lithography 2016, Paper 9778-42
12. M. Tamer, H. Sadeghian, 'Quantitative, time varying nanomechanical force in AFM measurement', SPIE Advanced Lithography 23 feb 2016, San Jose, California United States Paper.

Invited Lectures and conference presentations without publications

1. Invited: Stefan Bäumer, Maarten van Es, Giampiero Gerini, Hamed Sadeghian, Fabrizio Silvestri: 'Meta-Instrument for Super-resolution imaging', High tech system event March 2015 den Bosch.
2. Maarten H. van Es, Hamed Sadeghian, 'High speed imaging with the use of immersion AFM. Quantification of the relation between cantilever response speed and damping' LINZ conference 2015.
3. Fabrizio Silvestri, Giampiero Gerini, Netherlands Organization for Applied Scientific Research, TNO - Eindhoven University of Technology, TU/e, Netherlands; Elvira Pisano, Vincenzo Galdi, University of Sannio, Italy: 'High numerical aperture all-dielectric metasurface micro-lenses', 2015 IEEE AP-S Symposium on Antennas and Propagation and URSI CNC/USNC Joint Meeting - Vancouver 2015.
4. A. Keyvani, H. Sadeghian, H. Goosen, F. van Keulen, 'Low Force Tapping Mode AFM Imaging of Biological Samples with Tapered Cantilevers' LINZ conference 2015.
5. D. Maas, H. Sadeghian, 'Sub-50 nm metrology on EUV chemically amplified resist – A systematic assessment, International Symposium on Extreme Ultraviolet Lithography 2015', taking place in Maastricht, The Netherlands on October 5-7, 2015.
6. Invited: H. Sadeghian, 'Nanomechanical Sensors with Industrial Applications', SEIA' 2015
7. Invited: H. Sadeghian, Scanning Probe Microscopy for industrial application, Thermal probe workshop 2016, IBM and Swiss Litho, Switzerland.

Conference Posters

Y. Tang^{1*}, M. Xu^{1,2}, A. J. L. Adam¹, H.P. Urbach¹ ; 1Optics Group, Imaging Physics, Faculty of Applied Sciences, TU Delft; 2 TNO Optics department

List of Patents:

Several patent applications were filed in 2015 and now they are in the patent pending status:

1. A high throughput metrology and inspection device
2. A microscope based on nearfield thermal heat exchange
3. tapping Tip-sample interaction force measurement method for tapping AFM during imaging
4. Design of miniature clean 2D positioning unit for parallel metrology, inspection and lithography

5. Method of operating Atomic Force Microscope with wide band probes. Direct Force Controlled Mode
6. A device for sub-nanometer, substrate independent level sensing
7. A method for overlay measurements with subsurface AFM
8. A method for GHz Hyperdyne force microscopy
9. Automatic tuning of subsurface parameters

Dissemination event

In December 2015 we organized a dissemination and networking conference at TNO Delft Stieltjesweg to disseminate our knowledge and network with our relevant partners of our ecosystem. Industrial partners and Universities were invited and met. Apart from internal Principal Scientists, invited lectures were given by

- Invited speaker: Joost Frenken - Director of ARC/NL: ARC/NL: the Advanced Research Center for Nanolithography and Scanning Probe Microscopy of 'Real' Processes
- Invited speaker: Jos Benschop- Senior vice president technology at ASML: ASML innovation ecosystem
- Invited speaker: Ron Naftali - CTO Applied Materials: Metrology & Inspection Challenges

As result of this dissemination and networking event follow up meetings were planned to further investigate collaboration on one of the presented topics by presentation or one of the 16 scientific posters of the Event. Posters were presented by colleagues of TNO and industrial company Swiss Litho. The external invited speakers also selected the best poster of the event and the award was given to Mr. Fabrizio Silvestri, PhD student at TU/e, for his work on metasurfaces.

The 21th of October 2015, NRC.next published a two-page article about the Early Research Program of TNO. In this article two ERP's of TNO were addressed ERP 3D Nanomanufacturing and ERP Structural Integrity.

We started the development of an Early Research Program website on which we can disseminate our knowledge, notify partners which conference we will join and be present, to be easy findable and approachable for Academic and Industrial Partners. In 2016 we hope to launch the final website.



Visitors of the dissemination event on 10 December 2015.

6.4 Building the ecosystem

Relation with Topsector

For ERP 3D Nanomanufacturing, the most important Roadmap is the HTSM roadmap, especially

- Nanotechnology and
- Nanostructures

Our Contact person of the HTSM roadmap is Frank de Jong, responsible for HTSM Nanotechnology.

Last year Frank de Jong was informed about in the roadmap ERP 3D Nanomanufacturing and the projects involved such as high throughput scanning probe technologies, metamaterials for beyond conventional optics. The coming years we will further align our roadmap activities with the roadmap HTSM nanotechnology. A meeting will be held with Frank de Jong coming February to align the roadmaps of HTSM and ERP 3D Nanomanufacturing together. The annual plan 2015 of ERP 2015-2018 Proposal Program has been sent to Frank de Jong as input for the discussion. Obviously he was also invited for the dissemination event at TNO. As part of this ERP program we proposed the development of 3D metrology based on force microscopy and electrical characterization of nanostructures in an EU project, in which Frank de Jong is coordinator. This project is granted which is in the program of 3D nanomanufacturing and one important step in the roadmap.

We will also participate together in the EU-project 3DAM, 3D atomic Force Microscopy which is part of the ERP 3D nanomanufacturing, Frank de Jong is coordinator of this project.

Frank de Jong is member of the board of Nanonext.nl. In 2015 Principal Scientist of ERP 3D Nanomanufacturing Hamed Sadeghain and Director of Research Machteld de Kroon of TNO wrote a Nanonext.nl follow up proposed program, which was one of the four topics (among all proposed) selected for the follow up. An important criteria for selection of the proposal was the alignment of the proposal with the roadmap of Top-Sectors.

Besides the HTSM-roadmap, we aligned with the EU-roadmaps. In 2014 and 2015 we were work package leader of "Nano and Micro Printing for Industrial Manufacturing" in the FP7 EU-project Value4Nano. In this project roadmaps for four pilot lines were defined, we aligned our roadmap for ERP 3D Nanomanufacturing with the EU roadmap for Nano and Microprinting for Industrial Manufacturing.

We will invite the Topsectors to our dissemination session in November/December 2016 as we did in 2015.

Relation with Key knowledge partners:

Several collaborations with TU Delft, TU Eindhoven, AMOLF, Leiden University, University of Twente, University of Alberta and Technical University of Ilmenau have been started, resulted in total 14 PhD's projects and proposals and 7 MSc students.

A collaboration between ECN, NLR and this ERP on the topic of multi-material printing has started in 2015.

Relation with Key module technology partners:

A collaborations with Smart Tip (Spin off company from Twente university) has started on developing smart tips (electrostatic) for nanometrology. With LPM (Spin off company of Leiden University) a collaboration on fiber based AFM and further on miniaturized SPM is planned. With VSL, several collaborations on the topic of 3D AFM probe, meta-instruments and advanced electrostatic/nano-photonics NEMS has been started.

Relation with end users (Key requirements):

It is the end user of the developed technologies who will determine what are the problems, what are the requirements and how the solution should look like. To make sure the right application and

technology is being developed in this ERP, several collaborations with end users have started. This includes

Intel: Next generation 3D Nanomanufacturing based on selective deposition. They already provided TNO with samples for further testing and characterization.

MP Mask/Micro: also provided expensive EUV masks that at ERP 3D nanomanufacturing the developed technologies can be tested.

Relation with Key OEM:

Several collaborations with ASML (next gen overlay and metrology), AMAT (next gen metrology), Bruker (next gen metrology), Swiss Litho (Massive parallel 3D nanomanufacturing), Estec (Metasurface based Computer Generated Holograms (CGHs) for highly efficient optical contactless metrology) have started.

A strategic collaboration with IBM is under preparation. It is expected that in the first quarter of 2016, IBM prepares a proposal for collaboration with TNO on this topic and to be reviewed by TNO.

7 ERP Structural Integrity

7.1 *Management summary*

Goal

Condition-Based Maintenance (CBM) of macro-structures is the most effective way to safeguard their structural integrity while reducing maintenance costs, maximizing the “up-time” of the structures and allowing utilisation in a different way than a structure was originally designed for. Making the maintenance condition based requires new technology for inspecting, monitoring and forecasting the integrity of structures. ERP Structural Integrity aims at breakthroughs with respect to this grand challenge which enable: “detection and monitoring of (precursors of) degradation inside macro-structures” and use this information for “diagnosis of their structural health and forecast the service life for various intervention options”.

The program’s results will have wide application for maintenance of macro-structures, in particular in the transportation infrastructure and energy production infrastructure. In addition, it will be the basis for improved design of macro-structures.

The technology developed in this program is directed at the following four use cases 1- Offshore wind support structure integrity; 2- Concrete (rail)road supporting structure (steel reinforced bridge) integrity; 3- Well integrity for safe abandonment; 4- Composite vehicle protection and integrity.

General approach

ERP Structural Integrity combines a demand-driven approach (what exactly do the stakeholders need) with a technology-driven approach (what scientific solution can TNO, together with knowledge partners, offer). Iteration between these two positions (demand-driven and technology driven) led to an increasingly well-articulated description of the building blocks to be developed. The system design of the overall toolbox for offshore wind is sketched in the next section, as an example of the toolbox system designs elaborated for all four use cases.

An important element in the system design process was the analysis of business cases from the perspective of the stakeholders. In order to translate the qualitative description of the stakeholders’ needs to quantitative requirements with respect to the performance of tools being developed, each use case will further focus on a specific field site for development and demonstration together with stakeholders and partners. While stakeholders have been consulted in the iterative process described above, they are now approached for joining in the next steps focusing on the test and demonstration (field) sites.

After starting the ERP with existing partners, we are now specifically investing in strengthening the relations with a few research institutes with the perspective of joint research programmes.

7.2 *Program execution and results*

Value of Information

The Value-of-Information (VoI) approach assists in prioritizing activities by deriving the added stakeholders’ value of additional or improved information. A (probabilistic) framework for the Value of Information approach was developed, implemented and illustrated for a specific case. This framework has components dealing with monitoring data, physical models, data assimilation, utility functions and optimization routines, all of them treated probabilistically so that uncertainties can be incorporated. Substantial effort will still be needed in order to arrive at a tool of which the ‘logic’ is sufficiently understandable by stakeholders and that is easy to apply.

1. T. Attema et al., Value of Information; Framework for value of information in structural integrity. TNO 2015, R11625.

2. T. Attema et al., Structural Health Monitoring in end-of-life prediction for steel bridges subjected to fatigue cracking. In: Proceedings of the first Workshop on Quantifying the Value of Structural Health Monitoring. DTU Denmark 2015, DTU Civil Engineering Report: R-336.

Offshore wind

Fig. 1 illustrates the system design of the offshore wind toolbox that is being developed. The left part concerns the system components for designing an optimal monitoring system that gives insight in the (critical) stresses in the structure. The middle part concerns the assessment of defects developing over time and the point at which they are critical with respect to the safety of the structure. The right part concerns the output required by the stakeholders. Not shown is the part that concerns the transition from a single wind turbine structure to a wind turbine park.

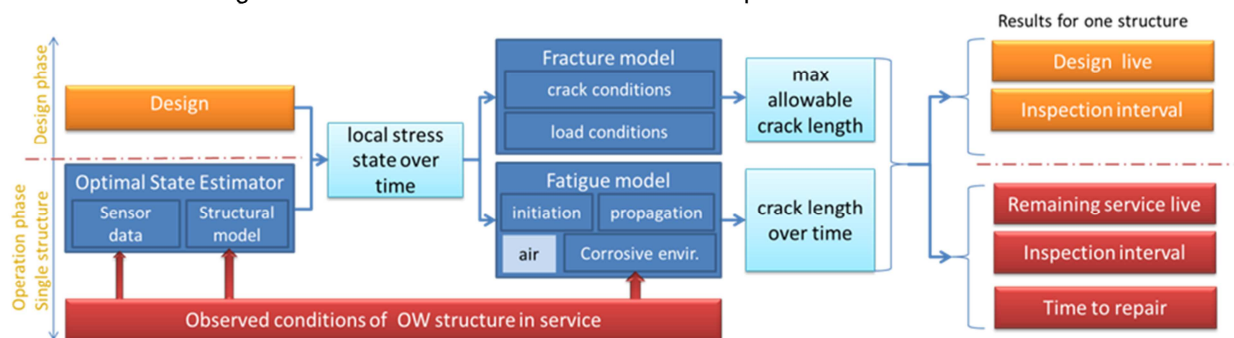


Fig. 1 System design of the overall toolbox for offshore wind.

The following results were obtained with respect to system components. A method was developed for the simulation of sensor readings for offshore wind turbines under realistic loading conditions. By combining the sensor readings, dynamic equations of motion and numerical model of the structure, the accuracy of a monitoring system will be improved. To enable the processing of the large data sets generated, techniques have been developed for data reduction and compression, event detection, and for performance of calculations by using 'big data'-developments.

A software/framework was developed for finding the change in the temperature at which fracture changes from ductile to brittle, depending on the strain rate. The software can take in standard fracture toughness test data and return the critical crack length in a realistic structure. This improves industrial practice which assumes that the laboratory measurement is identical to what is to be expected from a real structure. The theory that was developed for fracture has also opened up the possibility to replace traditional fracture mechanics tests by revolutionary new tests that use specimens so small that acquiring them is minimally destructive.

A literature evaluation on corrosion fatigue initiation resulted in the identification of the main parameters for fatigue initiation at positions with localised corrosion. A simplified model, predominantly based on the work of Jakubowski, makes it possible to identify corrosion fatigue crack growth rates as a function of stress intensity range and frequency. The corrosion rate interacts with the (mechanical) fatigue crack growth rate. Therefore the structural models are combined with electro-chemical and thermo-dynamical models describing the chemical process, dissolution and hydrogen transport in the material.

1. NN An approach to using Weibull stress analysis in design. Conference ISOPE (draft).
2. Schot, J., Dijk, T. van, *Feasibility study for the computation of stress histories of the support structure of Offshore Wind Turbines with the tool FAST*. TNO 2015, R10590a
Dijk, T. van, *Study to a simplified version of an Optimum State Estimator*. TNO 2015, R11628

Concrete bridge

The following results were obtained with respect to development and integration of fit-to-purpose sensors and sensor systems, and high-accuracy models and computational instruments. A system for measuring corrosion of steel reinforcement bars was set up. The goal is to reliably derive the corrosion probability and growth rate by fusing and interpreting data from conventional sensors. In cooperation with a specialized SME it will be demonstrated on naturally corroded specimens at TNO. New acoustic sensor techniques are explored for detecting the present corrosion state of reinforcement bars (see Fig. 2), for detecting crack growth inside the concrete and for making tomographic diagnostic images of the concrete structure. A selection out of these promising directions need to be made to create further focus. Fibre optic sensors were investigated (see: well integrity) for monitoring the corrosive environmental load.

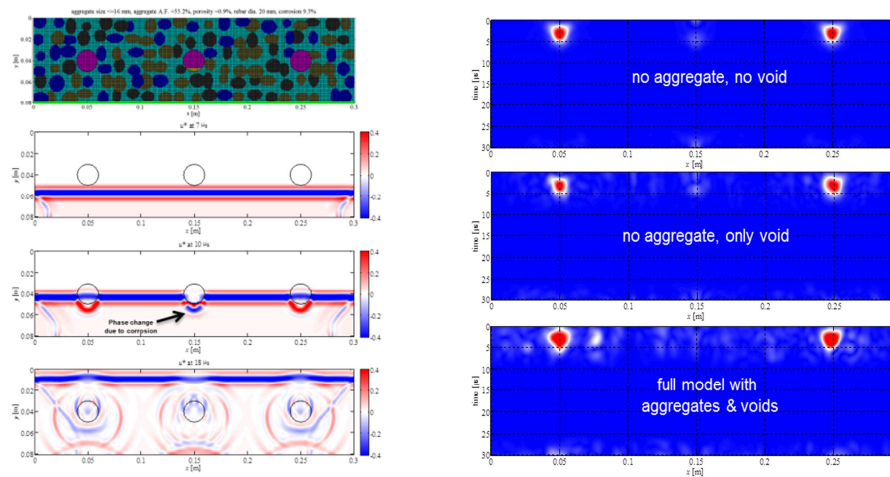


Fig 2. Modelling the acoustic wave propagation with middle bar corroded: (left) snapshots of wave propagation; (right) cross-correlation of 1st echo (from top) and 2nd (from bottom) from the rebars which distinguishes the corroded bar (little correlation) from the uncorded bars (red = high correlation).

In addition to the sensor development, high-accuracy models of the corrosion process and resulting de-bonding at the interface between steel and concrete were set up. A 2D and 3D electrochemical model for (pitting) corrosion propagation relates progressive corrosion of reinforcement to reduction of the steel cross-section and damage in the surrounding concrete. A 2D and 3D fracture-mechanics-based finite element (FE) model relates rebar de-bonding from concrete to reinforcement corrosion. Results were validated against experimental data from Chalmers University and University of Rome. For incorporating the corrosion damage in the assessment of the integrity of an entire bridge, a framework was established based on generalized stochastic mapping of corrosion fields (see Fig. 3) in the FE models for assessing the structural integrity. A stochastic FE modelling approach was designed for the assessment of structural safety level and the service life prediction, accounting for the spatial distribution of corrosion. Essential input for service life prediction is the present condition of the structure. Parameters were identified which appear suitable for monitoring (and stopping) tests with increasing loads performed to assess the present strength of a structure in-situ.

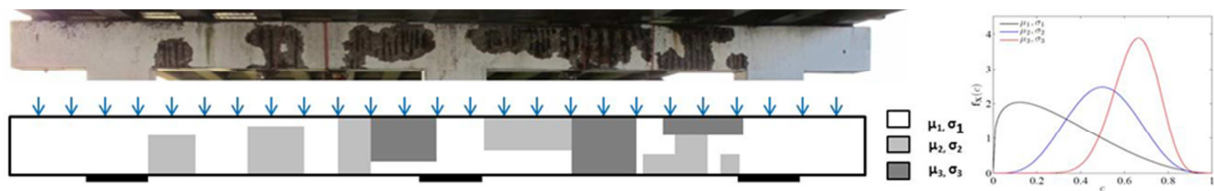


Fig 3. Principle of random corrosion damage fields

1. J. Pacheco, R.B. Polder, *Reinforcement corrosion propagation models – SotA*. TNO 2015, R11164
2. J. Pacheco, R.B. Polder, *FEM modelling of chloride induced pitting corrosion*. TNO 2015, R11555
3. J.H.M. Visser, *Properties of corrosion products in reinforced concrete*. TNO 2015, R11066
4. D. L. Allaix, A.J. Bigaj-van Vliet, *Finite element modelling of short pull-out tests of specimens with corroded reinforcement bars*. TNO 2015, R11556
5. W.H.A. Peelen, *Heterogeneous multi sensor data fusion system for reinforcement corrosion*. TNO 2015, M0100291644
6. R.B. Polder et al., *Propagation models for pitting corrosion of steel in concrete: conceptual models*, 6th Int. Conference on Concrete Repair, Thessaloniki, June 2016
7. G.G.A. Dieteren et al., *Need for code provisions for assessment, intervention and management of existing concrete structures*. Workshop outcomes, fib Workshop “Advancing Model Code for Concrete Structures”, The Hague, 2015
8. Sangers, A. et al., *Data analysis for in situ testing*. TNO 2015, R11525
9. Slobbe, A.T., Burggraaf, H.G., *Stochastic structural analysis of corroded RC structures*, TNO 2015, R11549
10. Allaix, D.L., *Literature review on advanced stochastic analysis methods*, TNO 2015, R11550
11. A PLT number has been registered to patent the interferometer technology for ultrasound wave detection.

Well integrity

New acoustic sensors techniques are being developed for improving the information that can be obtained with logging tools used to detect defects in a well barrier. The modifications in the Full Waveform Imaging method developed at TU Delft (Delphi Model) required to make the method suitable for imaging well structures, have been identified. Signal processing algorithms are being developed using inversion techniques so that the resolution that can be obtained with existing hardware for inspecting the first well barrier layer will be improved. In addition we now can explore the use of lower frequencies needed to penetrate beyond the first layer of the well barrier and detect defects in places for which present signals do not give any information.

For the prediction of possible defects in the well structure, chemical parameters need to be measured inside the well. A chloride sensor, being developed primarily for the use case concrete bridge, is used as a starting point. Further development to measure chemical parameters which are important for the use case well integrity is planned. To develop a fibre optic sensor that can measure chlorides, a sensitive coating has been formulated that swells or shrinks due to changes in chloride concentration. In parallel different packaging concepts have been studied and verified in an experimental set-up to validate mechanical protection of the sensitive coating and chemical interaction with the environment. Coatings investigated so far have failed for different reasons. Alternative routes will be discussed with the stakeholders.

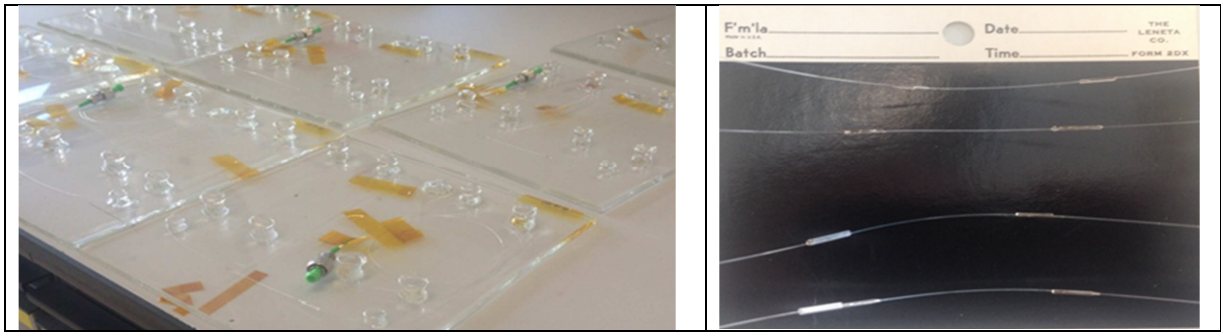


Fig 4. (left) Two coating formulations were applied on the fibre, submersed in boiling water for 24 hours, after being exposed to chloride and nitrate; (right) the responsive coatings are tapered and glued to make sure that they remain properly attached to the fibre.

Generic geochemical models of the near-well area were developed with the aim to assess degradation of bulk cement sheath and study the effects of reactive flow through debonded casing-cement interfaces. In addition, generic geo-mechanical models were developed to study the effects of loads on well integrity in the different phases of well construction and exploitation. A review of the literature was conducted in order to identify and investigate the processes that lead to well failure and the potential ways to modelling the risks connected to these failure modes. The outcome of this review was used to create a first Bayesian Belief Network to assess the risk of well failure in abandoned wells related to geochemical and geomechanical loads.

1. M. Koenen et al., *Reactive transport modelling of cement-caprock interface* (draft).
2. B. Orlic, et al. *Numerical estimation of structural integrity of salt cavern wells* (submitted to the ARMA 50th US Rock Mechanics/Geomechanics Symposium, Houston, Texas)
3. Sijacic et al., *Monitorability of present and future structural integrity for abandoned wells*, TNO (in preparation).

Composite vehicle

A toolbox (models and small scale tests with new sensors for measuring the damage evolution during a blast) has been developed for investigating Fibre-Reinforced Plastics (FRP) panels for a revolutionary new type of military vehicle made of composites. In the next years, the toolbox will be utilized for optimizing materials and geometries of composite parts of military vehicles.

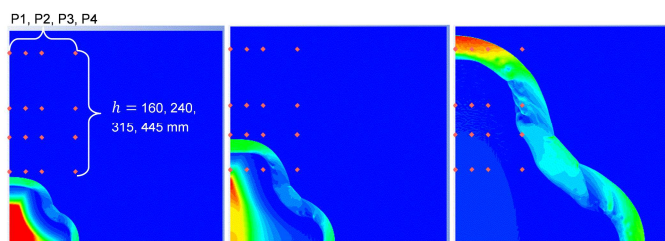


Fig. 5 Snap shots from numerical simulation of detonation and generated blast profiles.

A numerical model was made to predict the blast loading on an arbitrary geometry at short distance of the explosive. This model was successfully validated with a series of explosion tests. The capability to model the structural response of a monolithic plate was evaluated by modelling the blast reference test on aluminium plates. High speed stress measurements were done with fibre optic sensors mounted on a plate. The first two batches failed but the third one was successful. Blast panel tests on the FRP composite panels were simulated, starting with modelling only a limited number of layers (i.e. 8). By adding micro-mechanical materials model to the "Computational Material

Sciences toolbox” giving as output suitable parameters for the structural models, different scales were successfully connected.

Material testing was performed using a “Split Hopkinson Bar” device at the TU Delft in a modified setup. Real time recording of the response as well as the shear damage development at high strain rates was a challenge. The potential of optic fibers for high frequency loading and response have been evaluated. Tests were carried out on reference aluminum panels, FRP-panels (based on glass and carbon fibers) and hybrid composite panels combining glass fibers and aluminum layers. The response and failure behavior of these panels could be reconstructed using the 3D high speed video recordings. Deformation capacity, time of delamination and failure mechanism could be estimated. The main conclusion was that control on the delamination process in composites is essential to obtain material behavior that can compete with existing armor solutions. This control is believed to be obtainable by the use of dedicated foils on a range of interfaces in the composite material. The specific material design will be manufactured and tested on blast loading.

Further analyses are planned, but the first results indicate that the blast load model and the material models proved to be suitable for predicting the blast dynamic structural response as well as the delamination process. Furthermore, it appears that we developed the capability to design better FRP panels for military vehicles.

1. D. Turkenburg et al., *Mode I and II Fracture Toughness Testing of Interleaves for Ballistic Impact*, Paper EMMC 2016 conference
2. J. Verreault et al., *Blast loading experiments and modelling to simulate mine blast loading*, TNO report, 2015
3. E.J. Kroon, *TNO comparative blast testing of metal and composite plates versus NATO AEP-55 procedures for evaluating the protection level of armoured vehicles*. TNO 2015, memo 15EM/3051
4. X.Frugone, *Blast related out of plane loading of composite materials; high Strain rate Inter-laminar failure*, 2015 TNO report
5. G.H.J.J. Roebroeks, *Development of instrumented blast panel tests*. TNO report (draft)
6. L.Tang. *Composite material models in LS-DYNA* , TNO memo December 2015
7. L.Tang and F.J.M. van Eeden, *Validation blast tests aluminium*, TNO memo, 2015
8. F.M. van Eeden, *Validation blast tests composites*, TNO-memo, 2015

7.3 Building the ecosystem

Offshore wind

Cooperation with TU Delft (prof. Sluys) and SINTEF has been continued, while contacts have been established with worldwide leading experts on corrosion fatigue (Prof. Melchers, University of Newcastle; The Welding Institute, Cambridge, dr Jakobowski, University of Gdansk). The corrosion fatigue toolbox takes advantage of Endures corrosion models (dr Xiaolong Zhang). There is a mutual strengthening of ERP work and the TKI Offshore Wind project FeLosoFi (e.g. corrosion fatigue, test procedures and big –monitoring– data processing).

The proposal on microbiological corrosion (MIC) submitted by TNO to the TKI Offshore Wind, builds on the corrosion fatigue initiation knowledge developed in the ERP. The fracture portion of the ERP project has potential spin-off technology in non-destructive fracture testing. Potential industrial partners for a Joint Industry Project (JIP) are being contacted to solicit potential interest. This JIP is expected to draw interest from new customers within the offshore and maritime industry and important other parties (owners of large steel structures in general). The work done also supported the proposed JIP MONITOR that was granted by TKI Offshore Wind.

Concrete bridge

The Public-Public Partnership InfraQuest (TU Delft, TNO, RWS) was also directed at the objectives of this ERP programme and early 2016 a workshop will be held to explore a common ERP-STW

programme on the integrity of concrete structures. Collaboration was initiated with ETH Zurich (dr U. Angst) on conceptual pitting corrosion modelling and with University of Rome (dr Z. Rinaldi) on modelling of de-bonding for corroding reinforcement. An International Federation for Structural Concrete (fib)- workshop on advancing code provisions for existing concrete structures was organised in The Hague on June 30, 2015. Cooperation was initiated with BAM (Bundesanstalt für Materialforschung und -prüfung): a joint seminar has been held in Berlin on November 11, 2015. On four topics cooperation is planned to start at a follow up workshop early 2016 in Delft: fibre optic sensors, acoustic sensing, multiscale modelling and experiments on each other's field test sites. As an important stakeholder, RWS is now involved in the activities for setting up a field test and demonstration site.

Well Integrity

The ERP work provided TNO with the input for the EU LIFE Climate Action programme. Actions for commercialization of multi-physics models for well barrier degradation were initiated. The proposal "Downhole field lab – Wellbore sealing by rock salt" was approved by the TKI Gas. The EU LIFE proposal "Methwell", using the developed models in the domain of leakage of abandoned gas wells was submitted in September 2015. A connection has been made with the Industry Technology Facilitator (ITF) company by submitting two expressions of interest. A joint industry consortium on well integrity is expected to start early 2016.

Composite vehicle

There is a close cooperation with the TU Delft, both with respect to the experimental facilities and with respect to model development. Material solution ideas will be IP protected. Testing and numerical analysis techniques will be applied in the L-AMPV project financed by the European Defence Agency (EDA), in which we intend to realize a demonstrator.

8 ERP Human Enhancement

8.1 Management summary

We are currently facing an increasing level of automation of systems in e.g. the industrial (maritime and offshore) sector but also in the mobility sector (automated driving). It is broadly accepted that the behavior and interaction of users with these systems is the key to successful innovation and that the system behaviors should be well-adapted to these users. The challenge is to establish, effective and resilient, joint human-automation behavior patterns. That is, we need further breakthroughs in our knowledge to be able to develop the next generation of adaptive systems for safe and efficient operation. New validated and transparent (human-in-the-loop) automation modules are required.

The *first research ambition* of this Early Research Program (ERP) Human Enhancement is to develop a *transparent* (human-in-the-loop) adaptive automation platform that substantially improves safety for maneuvering and control tasks⁷, based on a computational human model to assess current and predicted human state (i.e., situation awareness and task load). This will be the focus of the use case Adaptive Automation for the automotive and maritime domain. The following main research questions will be addressed:

- How can a human state estimator be extended with real-time human state prediction (for near and future predictions in time) and how can its concepts be formalized in a reusable and extendable ontology?
- Which layered set of algorithms can (1) map unobtrusive measurements and human input into a model of the problem space and (2) support the required resultant model-based decision-making processes with high level of accuracy?
- What are the specifications for a modular, layered and extendable architecture that uses multiple data sources to estimate and predict the required level of automation and transition of the supervisory control task, and that automatically handles multiple situations in order to be able to function on multiple use cases and scenarios?

The *second* research ambition will be the development of a multidimensional prospective model for human resilience and related monitoring instruments and organizational interventions. At present, almost half of all work disability is related to psychosocial factors, which is a rise from 30% since 1998⁸. Front runner companies realize that an increase of human resilience and intrapreneurship are prerequisites for improvements in human health and organizational performance. However, adequate resilience tools and interventions are lacking, resulting in large personnel and organizational costs⁹. This means that measures to improve resilience are not only important for maintaining health and operational performance, but will also result in potential large financial savings. Although the importance of supporting employee's resilience is widely accepted, an integrated theory is still lacking, mainly due to the large amount of factors determining human resilience. In order to develop an integrated model of human resilience the research will be structured around the three activities:

- For the modeling platform, a multi-factor and multi-level human resilience risk profile will be developed, integrating psychosocial and physiological factors that drive resilience development, and a tool to calibrate and validate the model will be developed for specific (team, and organizational) contexts or use cases.

⁷ Janssen, W.H., Aim, H., Michon, J.A., & Smiley, A. (1993). Driver support. In: J.A. Michon (Ed.) Generic Intelligent Driver Support. London: Taylor & Francis, 54-66.

⁸ Minister Sociale Zaken en Werkgelegenheid. Kamerbrief hoofdlijnen aanpak psychosociale arbeidsbelasting. 2014.

⁹ RTO-MP-SAS-095. Cost-Benefit Analysis of Resilience Training. How to reduce post-deployment psychosocial strain, psychopathology, and associated costs. V.L. Kallen & J.E. Korteling

- For the sensing and monitoring platform, the identified factors in the model and the key environmental moderators will be operationalized so that it can be used to conduct semi-continuous automated data-collection that is minimally intrusive for the individual.
- For the data modelling and feedback (=coaching) platform, a research infrastructure will be developed consisting of a data management and modelling environment that can produce contextualized and personalized output about the status of resilience development. In addition, the data management and modelling platform will include a user-friendly context sensitive feedback system that can provide individuals with personalized feedback.

In the starting year 2015, the ERP Human Enhancement focused on building the internal and external research eco-system, defining the long term research agenda and needed expertise and partners. For the automotive use case we were able to start experimenting with the developed human driver model in simulator and road tests as the testbed was already available. The results indicate that human readiness predictions are promising but that the a-priori predictions of automation preferences of an individual driver is not accurate with the current driver model. This model should be extended and modified in 2016 for better performance. For the maritime use case we developed a testbed and a first theoretical operator model and ontology which resulted in two industrial partners to participate in further research activities.

The developed generic integrative human resilience model was successfully translated in a software (app) prototype for individual users. Pilot experiments indicated that the theoretical approach is promising to be successful in the next step of experimentation which resulted in the interests of two end-users who will participate in the next research phases.

8.2 Program Execution and Results

The main focus of the Adaptive Automation research line is on supervisory control functions, from highly time critical functions (e.g., operating a road vehicle in traffic) to less time critical but highly safety critical functions (e.g., maritime tasks such as dynamic positioning for diving support vessels, remote operated vehicles or pipe layers). This requires the development of an intelligent layered automation system consisting of the following capabilities:

- Sensing: Detection and processing of data that describe driver state by means of diverse elements (the “observables”) into a persistent human state recording with a common time frame.
- Modelling: derivation and/or deducing of the concerning human state models (an abstraction of the “observables”). This might include human-in-the-loop machine learning and recognition of behavioral patterns and cognitive state.
- Reasoning: assessing current model states and possible actions, and initiating changes in human (task) state.

This layered approach is chosen to establish persistent, trustworthy reliable and valid sensing, modelling and reasoning modules. Elements that need to be included in the layered framework are elements related to the human operator state, such as behavioral parameters, task performance, the environment, platform state and automation etiquette (e.g. capabilities, limitations, value tensions, ethical dilemma). An ontology will be also developed and maintained, which formalizes these concepts and their relationships (as a foundation for the adaptive automation). After this first conceptual description and formalization, the scenario definition will be made, one for road traffic (e.g. driving in free-flow motorway traffic) and one for the maritime context (e.g. operating high-speed craft in an operationally demanding context) for experimental testing. Underpinned by the first version of the ontology (the ontology will be refined during the project), algorithms need to be developed and will need to be fed with human and task data. These data will be gathered by means of simulator studies, field operational tests, naturalistic data, and expert field tests. These data will be used to fit the parameters and will enable model learning.

In 2015 a theoretical model has been developed to implement the approach of adaptive automation as an intelligent operator support layer on available automation software systems in the maritime domain. This Intelligent Operator Support System (IOSS) will have to act as an intelligent control layer, primarily focused on providing assistance to the operator (DPO) based on extracting of system data (DPS), see figure 1. The level of user support will range from gathering relevant system information and presenting it in a comprehensive way, to a more advanced advisory systems that can take over control when the operator experiences a cognitive lock-up.

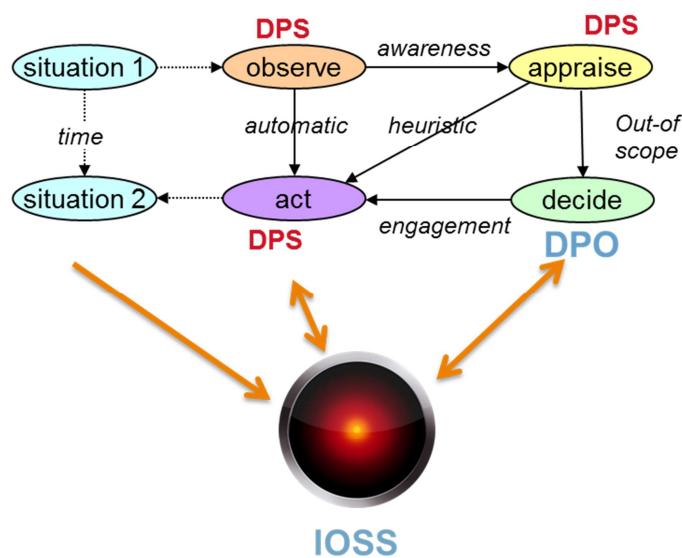


Figure 1. IOSS third control layer

Furthermore, an architecture and an ontology model was developed as the next step for the IOSS advice system. Based on previous IMCA fault reports, several scenarios that describe the sequences of operator actions and decisions that led to out-of-position incidents were documented. Finally, a testbed for human-in-the-loop experimentation with the prototype of the IOSS was developed, based on a generic maritime simulator. A demo of a first concept of the intelligent operator support system was demonstrated during the ERP customer meeting on 5 November, during the Europoort 2015 Maritime Exhibition at Ahoy Rotterdam.

In 2015 we extended the current TNO car automation platform with a new driver state module that could accommodate transition of control issues and adjust to different driver types. The available drivability model of Bekiaris, Amditis and Panou (2003) was therefore modified in order to accommodate the adaptivity feature of the automation platform. We first focused on the measurement of Situational Awareness and Vigilance of the driver, as crucial indicators for the transition of control (see developed drivability model in fig. 2).

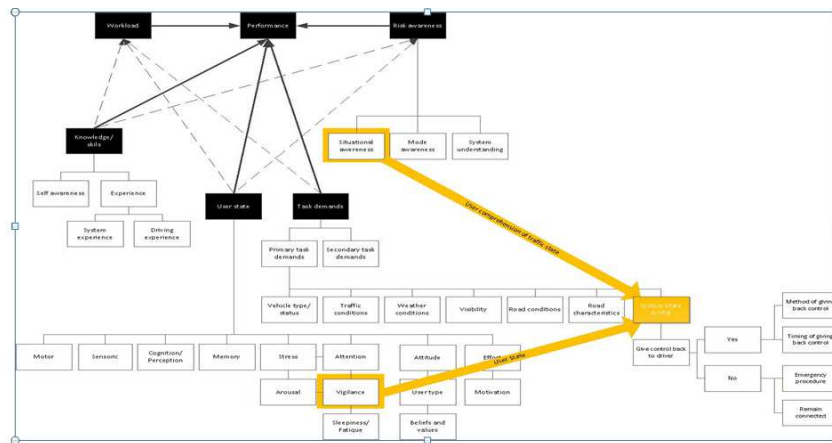


Figure 2. Adaptive Drivability Model: human aspects investigated in the use case

The developed prototype of the driver preference module was tested in two pilots on the road for predicting the driver preference on the automation level of the car automation system. For this we used time-based measurements of vehicle data and applied machine learning algorithms in combination with driver preferences. The experimental results indicate that driver preference for the level of automation was not linked to the subjective or actual driving behaviour but that other (not measured) factors were more important. This means that for the years to come, we will include more extreme and diverse driver categories and will focus on an extension of test scenarios. This will feed into the driver readiness model, in which we can predict how long it will take for a driver to get back in control. Further experimental data was gathered on driver readiness in simulator studies during eleven typical automation levels. Driver readiness was defined as the transition time needed to take over full control over a previously automated vehicle. This data will be used to predict when it is safe or unsafe to handle over control in further tests.

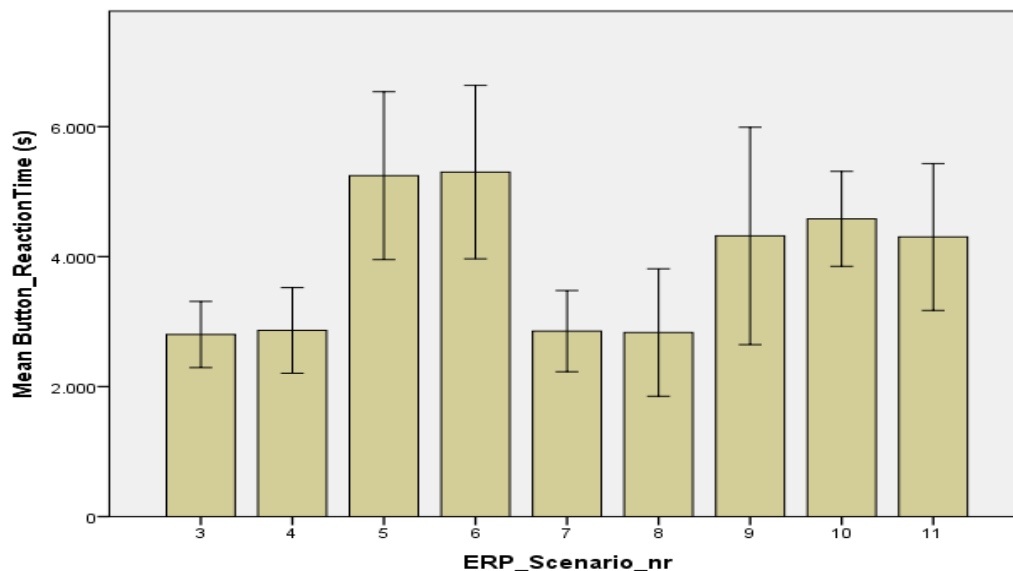


Figure 3. Mean reaction times for taking over control in different scenarios

In 2015 the first prototype of a human resilience model was developed combining expertise from different disciplines (organizational psychology, social psychology, cognitive psychology, stress physiology, movement sciences). Furthermore, this was translated in a process model in order to design and test feedback algorithms in a prototype app. First pilot experiments have been conducted into ways to formalize the models (i.e., ontology development, hierarchical linear modelling, Marvel). The prototype contains four technical components: a data platform, a dashboard, a smartphone application and a Microsoft Band. These components and their relationships are displayed in fig. 4. The prototype thus combines wearable (off the shelf) sensors and short questionnaires delivered via a smartphone app to measure the factors that have been identified as relevant demands, resources and outcomes for the end user.

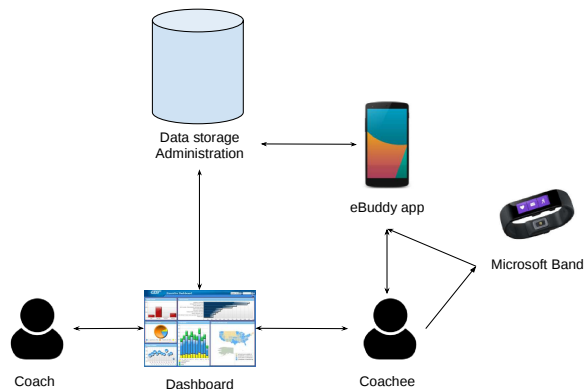


Figure 4: Components of the prototype of a mobile resilience application for knowledge workers

A personal data dashboard was developed to give feedback on the resilience status of the end user. This prototype will be further developed to generate consolidated information on resilience of groups of employees to coaches or staff services in organizations (see Figure 5).

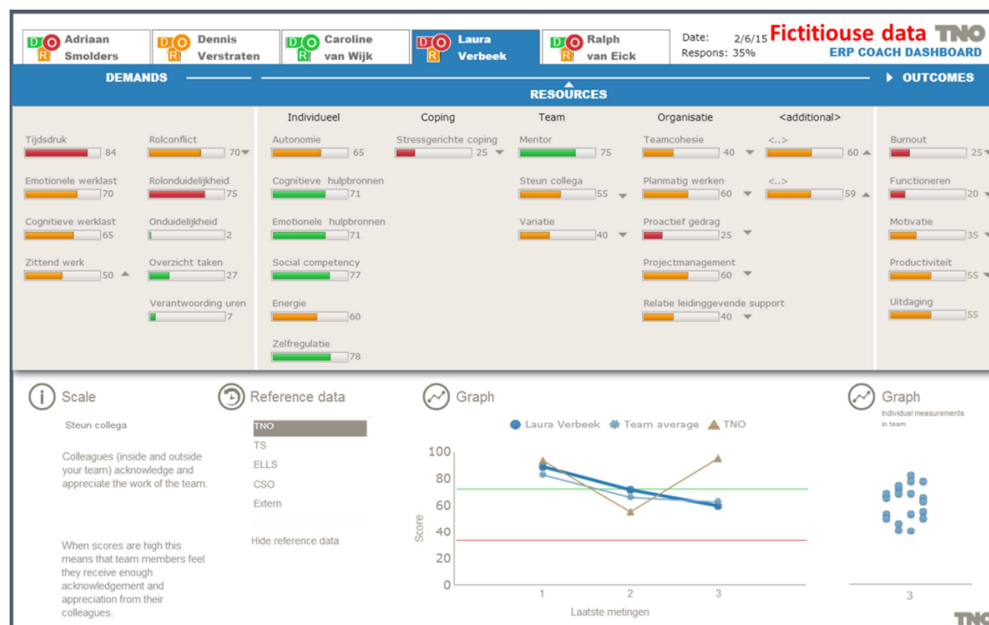


Figure 5: Screenshot of the Buddy app dashboard

8.3 Output

A Publications 2015.

1. Barth, S., Schraagen, J.M.C., & Schmettow, M. (2015). Network measures for characterizing team adaptation processes. *Ergonomics*, 58(8), 1287-1302.
2. Binsch, O., Wabeke, T., Koot, G., Venrooij, W., & Valk, P. (2015). Enhancing resilience: Monitoring, sensing, and feedback (TNO 2015 R11632). TNO: Soesterberg.
3. Brouwer, A.-M., Dijksterhuis, C. & Van Erp, J.B.F. (2015). Physiological correlates of mental effort as manipulated through lane width during simulated driving. *acii* 2015.
4. Brouwer, A.-M., Hogervorst, M. Reuderink, B., Van der Werf, Y. & Van Erp, J.B.F. (2015). Physiological signals distinguish between reading emotional and non-emotional sections in a novel. *Brain-Computer Interfaces*, XX, xxx-xxx. Doi: 10.1080/2326263X.2015.1100037.
5. Brouwer, A.-M., Zander, T. O., van Erp, J. B. F., eds. (2015). Using Neurophysiological Signals that Reflect Cognitive or Affective State. Lausanne: Frontiers Media. doi: 10.3389/978-2-88919-613-5.
6. Brouwer, A.-M., Zander, T.O., Van Erp, J.B.F., Korteling, J.E., Bronkhorst, A.W. (2015). Using neurophysiological signals that reflect cognitive or affective state: Six recommendations to avoid common pitfalls. *Frontiers in Neuroscience*, 9:00136. doi: 10.3389/fnins.2015.00136.
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8. Erk, S.M., Toet, A., Van Erp, J.B.F. (2015) Effects of mediated social touch on affective experiences and trust. *PeerJ* 3:e1297 <https://dx.doi.org/10.7717/peerj.1297>.
9. Goemans, C., Kerstholt, J., Berlo, M. van & Lindt, M. van de (2015). Living with water: Shifting Dutch approaches to community resilience. In: R. Bach (ed.). *Strategies for supporting community resilience*. Stockholm: Crismart
10. Graafland, M., Schraagen, J.M.C., Boormeester, M.A., Bemelman, W.A., & Schijven, M.P. (2015). Training situational awareness to reduce surgical errors in the operating room. *British Journal of Surgery*, 102(1), 16-23. Accepted
11. Graafland, M., Ten Cate, O., Van Seventer, J.P., Schraagen, J.M.C., & Schijven, M.P. (2015). Mapping the demand for Serious Games in Postgraduate Medical Education using the Entrustable Professional Activities framework. *Games for Health Journal*, 4(5), 381-386.
12. Gutteling, J.M., Terpstra, T. & Kerstholt, J. (2015). Meten risicobewustzijn en zelfredzaamheid. Een project voor Rijkswaterstaat. Enschede: Universiteit Twente.
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14. Kerstholt, J. (2015). Meer veiligheid door gedragsbeïnvloeding: Bewerking van Jan de Kroeslezing NVVK congres 2015. *Tijdschrift voor toegepaste Arbowedenschap* nr. 4, december 2015.
15. Kerstholt, J., Ven, J. van de, Rijk, R. & Hijlkema, S. (2015). Helpende burgers: wegsturen of niet? *Magazine Nationale Veiligheid en Crisisbeheersing*, nr. 4, 34-35.
16. Kerstholt, J.H., Vries, A. de & Mente, R. (submitted). Politie en burgers: van informatie delen naar volwaardige samenwerking. *Tijdschrift voor Veiligheid*.
17. Kleij, R., van der, Broek, H., van den, Brake, G., te, Rypkema, J. & Schilder, C. (2015). ERP Human Enhancement Progress Report: Use Case and Computational Model for Adaptive Maritime Automation. TNO Report 2015 R11581.
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19. Kolen, B., Vermeulen, C., Terpstra, T. & Kerstholt, J. (2015). Randvoorwaarden verticale evacuatie bij overstromingen. Rapport HKV. Delft: HKV Lijn in Water.
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22. Paradies, G., Wabeke, T., De Korte, E.M. (2015). Empowering employees and organizations with self-tracking technologies: the state of the art and future opportunities. Manuscript submitted for publication.
23. Preenen, P. T. Y., Liebrechts, W., & Dhondt, S. (2015). Intrapreneurship stimuleren? Tijdschrift Voor Ontwikkeling in Organisaties, 5(3), 51-58.
24. Richters, F., Schraagen, J.M.C., & Heerkens, H. (2015). Assessing the structure of non-routine decision processes in airline operations control. *Ergonomics*, DOI:10.1080/00140139.2015.1076059
25. Schnittker, R., Schmettow, M., Verhoeven, F., & Schraagen, J.M.C. (accepted). Comparing an ergonomically designed to a classic infusion pump interface: results from a multi-measures approach. *Applied Ergonomics*.
26. Schraagen, J.M.C. (2015). Human factors in de zeescheepvaart. *Journaal Zeevaart*, 14(4), 46.
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29. Stubbé, H.E., Emmerik M.L. van & Kerstholt, J.H. (2015): Helping behavior in a virtual crisis situation: effects of safety awareness and crisis communication, *Journal of Risk Research*, DOI: 10.1080/13669877.2015.1071865
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31. Tak, S., Toet, A. & Van Erp, J.B.F. (2015). Public understanding of visual representations of uncertainty in temperature forecasts. *Journal of Cognitive Engineering and Decision Making*, 9 (3), 241-262.
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B 2015 Congres presentations / invited lectures / workshops

1. Bos, J. (2015) ERP AMA presented at the FPSO-Forum. Delft.
2. Broek, H., van den (2015) ERP AMA presented at Dynamic Positioning conference. Houston.
3. Brouwer, A., Dijksterhuis, C. & van Erp, J.B.F. (2015). Physiological correlates of mental effort as manipulated through lane width during simulated driving. *Proceedings International Conference on Affective Computing and Intelligent Interaction (ACII)*
4. Delahaij, R. (2015). Human resilience; a multifactorial approach. Invited presentation at Vrije Universiteit, Department of Social Psychology, Amsterdam, Netherlands
5. Delahaij, R., Kamphuis, W., Valk, P. & Hoogh, I. (2015). Human Resilience in sports. Invited presentation at NOC NSF, May 7, Papendal, Netherlands
6. Jong, A. (2015) ERP AMA presented at Offshore Construction, Heavy Lifting and Pipe laying conference. Amsterdam.
7. Kerstholt, J.: 'Jan de Kroes' lezing op het NVVK congres (31 maart, Arnhem)
8. Kerstholt, J.: Helping citizens: effects of risk and crisiscommunication. Presentation SPUDM (Marije Bakker), Budapest, augustus 2015.
9. Kerstholt, J.: Inleider op Ontwikkelplein rondom het thema 'Hoe sluiten wij aan op burgerinitiatieven' georganiseerd door Politie Oost Nederland (9 april, Voorthuizen)
10. Kerstholt, J.: Modereren sessie 'Burgers, technologie en zelfredzaamheid' op de 'Dag van de Veiligheidsregio's (19 maart 2015, Twente Safety Campus).
11. Kerstholt, J.: Presentatie/ discussie over samenredzaamheid voor Masterclass Innovatie voor Ministerie van Infrastructuur en Milieu (15 oktober 2015)
12. Korte, E., de (2015). Presentation ERP Human Resilience. Presentation for PEROSH network, NRCWE, Copenhagen, Denmark.
13. Martens Marieke: Invited panel discussion Human Factors in First Automated Truck conference Stuttgart (22nd of October 2015) Special Interest Session ITS Bordeaux: Human Factors in automated
14. Neerincx, M.A. Presentation "Human-Robot Collaboration". Human-Robot Interaction (HRI) Symposium at Stanford University, USA, 20 October 2015. Neerincx, M.A. Invitation for workshop "Trust in Automation", sponsored by Air Force Office of Scientific Research (AFOSR) to define research agenda, at USC Institute for Creative Technologies USC-ICT, USA, August 19-21, 2015.
15. Neerincx, M.A. Invited presentation for workshop "Virtual Immersive Environments for Complex Human-Machines" at the University of the Bundeswehr Munich, Germany, June 10-11, 2015. Paradies, G (2015). Lost in translation: A multidisciplinary approach for developing usable, effective, and reproducible persuasive technology for health promotion. Presentation at 9th International Conference on Pervasive Computing Technologies for Healthcare, Istanbul, Turkey

16. Richters, F., Schraagen, J.M., & Heerkens, H. (2015). Balancing goal trade-offs when developing resilient solutions: A case study of re-planning in airline operations control. In: 6th REA symposium, 22-06-2015 - 25-06-2015, Lisbon.
17. Schraagen, J.M.C. (2015). Resilience and networks. In: 6th REA symposium, 22-06-2015 - 25-06-2015, Lisbon.
18. Schraagen, J.M.C. (2015). Resilience om veilig en productief te kunnen blijven werken. Lezing voor het Nationaal Netwerk Risicomanagement, Den Haag, 2 juni.
19. Schraagen, J.M.C., Ruizeveld de Winter, B., & Van Hattem, N. (2015). Drivers for a sustainable personnel structure. Undersea Defence Technology, Rotterdam, 3 juni.
20. Siegel, A.W., & Schraagen, J.M.C. (2015). Can team reflection of rail operators make resilience-related knowledge explicit? - An observational study design. In: 6th REA symposium, 22-06-2015 - 25-06-2015, Lisbon.
21. Willemsen, D., Stuiver, A. & Hogema, J. (2015). Automated Driving Functions Giving Control Back to the Driver: A simulator Study on Driver State Dependent Strategies. Proceedings of the Enhanced Safety of Vehicles conference. Paper 15-0109-0.
22. Wilschut, E. (2015) Presentation TOC RWS study. At the Round Table Human Behaviour (Connecting Mobility, Beter Benutten en DITCM meetings)

C Events & Media exposure 2015

1. Broek, H., van den (2015) TNO Adaptive Automation. Prezi presentation. Costumer day, Ahoy <https://www.tno.nl/en/collaboration/expertise/earth-life-and-social-sciences/human-behaviour-and-organisational-innovation/early-research-program-human-enhancement/>
2. Broek, H., van den. EPR AMA pitched at TNO Maritime & Offshore customer day (17th of September 2015) Rotterdam.
3. Brouwer, Anne-Marie Pitched to a delegation of Army Research Lab: 'Collaboration proposal: Detecting unexpected ACC behavior' (23th of June 2015) TNO Soesterberg.
4. Jong, A. & Broek, H., van den (2015) JIP DPO-Next. TNO ERP product Flyer.
5. Kerstholt, J.: Beter omhoog dan vertrekken. Als het water toch komt (Dorine van Kesteren). Interview in H2O (48), 28 mei 2015.
6. Kerstholt, J.: De doe-democratie komt eraan! (Door van der Wielen). Interview in Secondant, september 2015.
7. Kerstholt, J.: Hoe evacueer je een olifant? (Walter Baardemans). Interview in Vakblad Arbo nr 3 2015, Vakmedianet.
8. Kerstholt, J.: Mensen gewoontedieren. Interview in Sprank (Peter Boorsma). Sprank, 29 januari 2015, http://www.divosa.nl/sites/default/files/sprank_201501_mensen_gewoontedieren.pdf
9. Kerstholt, J.: We denken te simpel over zelfredzaamheid (Piet-Hein Peeters) Interview in Zorg+Welzijn, september 2015.
10. Martens, M. NPO radio 1 about role of human in vehicle automation (24th of May 2015)
11. Martens, M. Presentation and moderator about Human Factors in automated driving (session Connekt and RWS knowledge agenda Automated Vehicles April 2015).
12. Martens, M. Special Interest Session ITS Bordeaux: Human Factors in automated driving (6th of October 2015).
13. Martens, M.: Presentation RWS driving sim experiment about driver response to unexpected but critical Transitions of Control (Connekt and RWS knowledge agenda Automated Vehicles (24th of September 2015).
14. TNO ERP Human Enhancement, adaptive maritime automation custom day. TNO workshop on Adaptive Automation for Dynamic Positioning at the Europort Exhibition for Maritime Technology (5th of November 2015).
15. Two demonstration videos ready for the P-ACC use case and the A-VTB use case. <https://www.tno.nl/en/collaboration/expertise/earth-life-and-social-sciences/human-behaviour->

and-organisational-innovation/early-research-program-human-enhancement/
<https://youtu.be/DzVS7x-Ge4k>

AND

16. ERP movie on TNO website: [Use case description](#)

8.4 Building the ecosystem

The following academic and industrial partner relationships were accomplished in 2015. Also a list of submitted research proposals is given to extend on the research in the ERP Human Enhancement.

Academic partners

- Collaboration set up with Rotterdam Scheepvaart en Transport College (STC): Maarten van Hoogtrop, Monique van der Drift, Jacco Griffioen;
- Collaboration set up with Hogeschool Rotterdam, Kenniscentrum Duurzame Havenstad, Liek Voorbij
- Collaboration has been sought with University of Leuven, Department of Organizational Psychology (prof. Euwema and prof. Schaufeli) and the possibilities for a joined AiO are being investigated.
- Hanze University of Applied Sciences Groningen, Profesorship Labour Participation (dr. Oldenhuis) and a proposal is being written for a joined AiO.
- the Vrije Universiteit (Amsterdam), department of Social Psychology (dr. Nale Lehman) surrounding the topic of emergence of resilience in groups or teams. An exploration of this topic will be part of the project in 2016.
- Via the International 'Network of Excellence on Psychological Resilience for Military' collaboration is sought with the American organisation RTI International (Robert Bray, Becky Lane, and others). Different topics of mutual interest have been formulated and currently efforts are made to turn two topics into pre-proposals for US DoD grants (e.g. MOMRP - Military Operational Medicine Research Program).
- A co-development was started with NOC-NSF and the police. A proposal for collaboration has been written in with the KNKV, and prototype development and data collection will start in Q1 of 2016. For the use case of the police, a number of meetings was held with stakeholders of the VGW (Veilig en Gezond Werken) department of the Police, resulting in an initial agreement to collaborate in the context of the ERP. A draft proposal has been written to start with the development and data collection in Q3 of 2016.
- Collaboration has been set up with COMMIT (public-private research community) for the project SWELL (Smart Reasoning Systems for Well-Being at Work and at Home). In SWELL, the prototype that has been developed for the ERP Human Resilience has been used for a large data collection effort. In return, the data gathered can be used for the ERP project.

PhD students

- Marije Bakker. 'Mechanisms underlying active citizenship' (Universiteit Twente),
- Wendy Schreurs. 'Community Policing' (Universiteit Twente).
- Jori Kalkman. 'Collaboration Dynamics of Civil-Military Emergency Response Networks (CDCERN)' (Vrije Universiteit Amsterdam)
- F. Richters Impliciete denkhandelingen in afwegingsprocessen, (Universiteit Twente),
- W. Siegel. HMI-R enabling resilience to improve the capability to cope with calamities and disruptions, (Universiteit Twente),
- E. van Wijk. Real time telemonitoring of biosignals and cognitive craving to reduce relapse rates in alcohol addiction, (Universiteit Twente),
- Y. Mun. Serious gaming in complex decision making, (Universiteit Twente),

Master Students

- Iris Boers. 'The protection motivation and protective behaviour of people towards the risk of burglaries; the influence of perspective taking and knowledge of neighbour help' (april 2015).
- Liselotte Kraanen. 'The influence of mood on tunnel vision in crime investigation' (augustus 2015).
- Frank Gruijters. has worked exclusively on the Seahorse project and has contributed greatly to the development of the multi-level resilience assessment tool.
- Serena Dorrestijn. has contributed directly to the EU TRADR project (Department PCS). Currently,
- Isabel Moning conducts her master thesis work within HOI on the Innovation of Traffic Management,
- Rob van Broekhoven assists Willy Siegel in analyzing workload assessment data.

Private partner participation within the ERP program

- Bluewater: in kind 0,2fte
- Imtech Marine: in kind 0,01fte
- RWS: additional project for the experimental condition in truck platooning study

Joint Proposals submitted

- proposal INSPIRE-2 (Improving Military Selection: Screening of Psychological Resilience) has been granted. This project is performed under CapTech ESM4 (Human Factors and CBRN) of the European Defence Agency (EDA)
- the proposal 'Logics to Logistics' has been granted in the NWO accelerator call for Logistics (topsector Logistics, together with EVO and TLN Kamer van Koophandel and FNV).
- the interreg proposal SHINE has been submitted by the TNO theme Healthy Living. The purpose of SHINE is to allow healthcare institutions to gain more control over the value creation in all aspects of their services.
- STW Perspectief proposal i-Cave (granted 13th of November 2015) about automated vehicles. Project inside this programme dealing with Human Factors, for three PhDs and 0.4 post-doc (70% STW funding, 25K cofounding ERP per year)
- Two US proposals with US Army Research Lab
 - Fixation-locked EEG processing
 - Detecting unexpected ACC behavior on the basis of EEG measurements

9 ERP Sense Making of Big Data

9.1 *Management summary*

Big Data and Data Science are topics of intense R&D activities world-wide. The TNO ambition is to develop big data sense making technology in collaboration with strategic partners in order to develop data driven innovations, that transform application domains with a multi-stakeholder setting and are characterized by distributed, dynamic data. The domains of (personalized) health and logistics were taken as a starting point for selecting challenging research topics since these domains have a multi stakeholder setting and data collection and storage is distributed. Main research lines are: creating value, extracting meaning, distributed data infrastructures, human machine interface aspects of sense making and Big Data architectures for data driven innovations.

Progress on science

In 2015, some program lines already demonstrated world-class results. TNO achieved best results for recognizing complex events in low level video analytics in the worldwide technology challenge TRECVID in a collaboration with City University Hong Kong (VIREO). Other promising research lines are the application of deep learning in combination with Multiview clustering of health data and the strategic partnership with KPN on Information Centric Networking. It proved quite difficult to acquire data sets from external partners, inspiring the development of new approaches for bringing algorithms to the data in cooperation with partners collaborating in the Dutch Techcentre for Lifesciences (DTL).

Progress on partnering

The program objectives and results are aligned with the roadmaps of the different departments as described in their Knowledge Position Audits. One of the goals of the program is to stimulate multi-disciplinary research, and use cross over of technology developed for one application area for new solutions in another areas. The program has greatly advanced the common understanding of the involved departments of their respective contributions. This has created the expected new insights and opportunities. An example of this is the research on multi-view clustering, developed for nasal microbiome analysis (nose bacteria) which has been adapted and applied to other areas such as defense challenges.

Progress on stakeholder involvement

In 2015 TNO strengthened its role in the main national and international ecosystems on the topic of big data. On national level TNO was co-writer of the KIA ICT (Knowledge and Innovation Agenda part of the “topsectoren” approach) and the related program COMMIT2DATA. With the election of TNO’s Program Director on ICT Henk-Jan Vink as one of the board members for the Big Data Value Association, TNO also has created a good starting position to participate in Horizon 2020 Data Research. TNO is involved in the Big Data Value center in Almere, where extensive networks of public and private organizations both from the solution (supply) and the demand side participate. Next to that, collaboration with partners such as the CBS and the city of Almere have been formalized. Two main projects with industry are a TKI project with KPN on the topic of ICN, where shared research is done on potential new forms of internet, and a large project with Google on mobility data. The program and the activities associated with the program has strengthen the TNO position on Big Data significantly in the national and international ecosystem, exceeding expectations. We hope to see in the following years that this position will spark even more PPS projects with industry partners.

9.2 Program Execution and Results

Highlights

The ERP program has highlights on several different aspects. A scientific highlight is the Best Paper Award for the paper *Applying Semantic Reasoning in Image Retrieval* from Maaïke de Boer et.al. Also the large number of journal papers and the frequent requests for panel meetings can be seen as highlights.



On the ecosystem building axis the election of Henk Jan Vink as board member of the BVDA is a highlight. Combined with the large contribution to the workgroups of the BVDA this shows the good connection to the European Ecosystem.

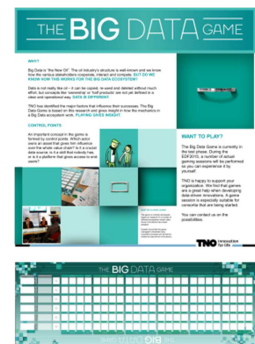
In 2015 the ERP co-financed a project for Knowledge Discovery in Medical Forums (GIST). This project is used as an example of a Big Data project in the advisory report that has been published by the AWTI (Adviesraad voor Wetenschap, Technologie en Innovatie¹⁰).

Results vs Deliverables

An overview of the deliverables planned in the program proposal and the results are given in the text below. It can be seen that most deliverables are realized. The inspiration of research challenges by the use cases was less than desired as the formulation of the challenges for the use cases started in 2015 and acquiring the data proved more difficult than expected. The interaction between the disciplines was high, especially within the work packages.

D1.1 Preliminary value model that shows what aspects determine the value of a big data application and how these are related

An analysis framework for the human aspects of Data-driven innovation has been created, both theoretical and practical. For the theoretical part, the existing DAMIAN method (created by TNO) to analyze innovative ecosystems is extended for data-driven innovations. This explicitly enables the analysis of control points, and thus the balance of power in an ecosystem. The method is supported with protocols and data-gathering and visualization tools. Additionally, a serious game has been developed which provides insight and enables people to become acquainted with the concepts that are relevant in Big Data ecosystems. The game is a low-barrier entry point for dissemination and project development.



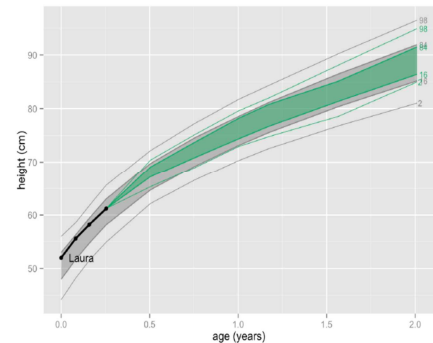
D1.2 Validation experiment of data value in logistic chains: operational testing of data value aspects in practical situations

This validation experiment is done for two use cases: Port Base use case and mobility for logistics use case. It was found that especially ownership of data and the large amount of stakeholders are bottlenecks for data-driven innovations in this area. A huge amount of practical considerations that have to be taken into account for data-driven innovations has been collected. These have been described in a deliverable (in the form of a handbook) that outlines the 'conditionality' of data-driven innovations.

¹⁰ <http://www.awti.nl/documenten/adviezen/2015/9/21/klaar-voor-de-toekomst>.

D1.3 Validation experiment of data value in health: operational testing of data value aspects in practical situations

This validation experiment is done for three use cases: Vitality at work, Zorgkubus Almere and child growth. For the first two experiments the main control points and solutions for data-driven innovation were identified. For the child growth use case new visualization concepts are developed for the presentation of uncertain predictions, and a way to select individual curves from a larger set of data.



D2.1 Tools for real-time data analytics in distributed data sources

In 2015 we focused on three different techniques: multi-view learning techniques, deep learning and data description. The goal of multi-view clustering is to construct models that can take advantage of multiple data representations simultaneously, given various heterogeneous data sources. Several new methods were developed and applied to real datasets. The goal for deep learning is to apply deep learning technology to a selection of challenging datasets. One of the challenges is to train a network with few examples, using examples from similar cases. This is found to work best if the amount of examples is very different. The third method we used was data description, where we focused on uncertainty in the data. A hybrid approach of statistics and statistic-based methods may give an optimal solution. In this approach, data and models would be seen as part of the same process, i.e. whenever data are acquired they should be used in models leading to verified knowledge that can be used.

D2.2 Predictive and prescriptive data analytics applied to logistics

In 2015 it was not yet possible to use real data from the Use Case Logistics. We applied descriptive and predictive analytics to other datasets, and set up requirements to the datasets in relation to Predictive and Prescriptive Analytics.

D2.3 Model to move from average causal effect in health situations to individual causal effect

A visualization tool has been developed for depicting individual predictions and the uncertainties in growth curves. In 2016 the tool will be made interactive: the effects of the type of intervention together with the time of intervention will be displayed in the growth curves..

D3.1 Prototype for plug and play in heterogeneous data environments, using data management and semantic interoperability

An Adaptive Data Transformation (ADT) analysis tool has been developed. This technology is a core technology for connecting and sharing any data set across the distributed data infrastructure.

D3.2 Scalable anonymization techniques for heterogeneous data environments

A Qualitative assessment of existing data anonymization and encryption techniques for sense making from Big Data has been developed. We also validated enhanced and developed new techniques for data anonymization and encryption in the context of the use cases.

D3.3 (Standardized) protocols, models and tools for optimal architectural design of Information Centric Networks

ICN is a technology that has the potential to radically change the internet, since data are the primary objects instead of servers. Implementing ICN poses several challenges:

For the architecture part we focused on three parts

- 1) implementing a cloud broker function: Actual experimental validation of developed cloud broker function for rapid and 'tailored' deployment of storage and processing architectures

- 2) fundamental research on the topic of ICN, where also a testbed environment has been set up for validation of the developed ICN-based networking architectures in 2016
- 3) and more applied research on how to use parts of the ICN framework for current developments using software defined networking (SDN). The basic elements of the underlying SDN architecture have been implemented and demonstrated in a more generic setting Demonstrator.

9.3 Output

An overview of the output is presented in the table below.

Journal papers	8
Conference papers	15
Presentations	9
Patents	0
Miscellaneous	9



The paper *Applying Semantic Reasoning in Image Retrieval* from Maaïke de Boer et.al. received the best paper award at ALLDATA 2015: the First International Conference on Big Data, Small Data, Linked Data and Open Data. Patent applications are foreseen in 2016, e.g. on the topic of Information Centric Networking.

Dissemination events

Dissemination of the results has been done at various scientific conferences and at meetings with stakeholders and customers such as the CBS, within the BDVC and with Philips. We organized the Small Big Data congress at the Big Data Value Centre in Almere. 30 TNO researchers pitched their big data project for an external jury with persons involved in the Top Sector HTSM and the KIA-ICT.



Journal publications

1. Tak, S., Toet, A. & Van Erp, J.B.F. (2015). Public understanding of visual representations of uncertainty in temperature forecasts. *Journal of Cognitive Engineering and Decision Making*, 9 (3), 241-262.
2. Maaïke de Boer, Klammer Schutte, Wessel Kraaij, Knowledge based query expansion in complex multimedia event detection. *Multimedia Tools and Applications*, 2015
3. Maaïke de Boer, Paul Brandt, Maya Sappelli, Laura Daniele, Klammer Schutte, Wessel Kraaij, **Query Interpretation - an Application of Semiotics in Image Retrieval**. *Advances in Software International Journal On Advances in Software*, vol. 8, number 3 and 4, 2015. pp 435 - 449.
4. Suzan Verberne, Maya Sappelli, Kalervo Järvelin, and Wessel Kraaij. **User Simulations for Interactive Search: Evaluating Personalized Query Suggestion**. In Allan Hanbury, Gabriella Kazai, Andreas Rauber, and Norbert Fuhr, editors, *Advances in Information Retrieval*, volume 9022 of *Lecture Notes in Computer Science*, pages 678-690. Springer International Publishing, 2015.
5. Marina Ruiter en Peter Desain en Jop van Heesch en Joanneke van Hengel en Wessel Kraaij en Monique Lindhout en Mia Verschaeve. **Afasie Gespreksboek, van papier naar app..** *Stem-, Spraak- en Taalpathologie*, 20(0), 2015.
6. Thijs Veugen, Robbert de Haan, Ronald Cramer, and Frank Muller, *A Framework for Secure Computations With Two Non-Colluding Servers and Multiple Clients, Applied to*

Recommendations. IEEE Transactions on Information Forensics and Security, Vol. 10, No. 3, March 2015.

7. Marc Makkes, Reggie Cushing, Adam Belloum, Silvia Olabarriaga, Mikołaj Baranowski, Cees de Laat, Robert Meijer, *Data Intrinsic Networked Computing*. Submitted to: IEEE Internet Computing, October 2015.
8. D.Worm, F. Fischer, W. Pino, R.E. Kooij, *Identifying Critical Components in complex gas distribution networks, proc. of Net-works 2015*, Int. J. Complex Systems in Science Vol. 5(1), 2015.

Conference papers

1. Henri Bouma, Pieter T. Eendebak, Klamer Schutte, George Azzopardi, Gertjan J. Burghouts, Incremental concept learning with few training examples and hierarchical classification" *Proc. SPIE*, vol. 9652, 2015.
2. Hao Zhang, Yi-Jie Lu, Maaïke de Boer, Frank ter Haar, Zhaofan Qiu, Klamer Schutte, Wessel Kraaij, Chong-Wah Ngo, **VIREO-TNO@TRECVID 2015: Multimedia Event Detection**, Proc. TRECVID 2015, 2015
3. John Schavemaker, Martijn Spitters, Gijs Koot, Maaïke de Boer, **Fast re-ranking of visual search results by example selection**. *Proc. 16th International Conference on Computer Analysis and Patterns (CAIP 2015)*, held in Valletta, Malta, September 2 - 4, 2015.
4. Klamer Schutte, Henri Bouma, John Schavemaker, Laura Daniele, Maya Sappelli, Gijs Koot, Pieter Eendebak, George Azzopardi, Martijn Spitters, Maaïke de Boer, Maarten Kruithof, Paul Brandt, **Interactive detection of incrementally learned concepts in images with ranking and semantic query interpretation**. *Proc. Content-Based Multimedia Indexing Workshop (CBMI 2015)*, held in Prague, Czech Republic, June 10 - 12, 2015.
5. Maaïke de Boer, Laura Daniele, Paul Brandt and Maya Sappelli, **Applying Semantic Reasoning in Image Retrieval**. *Proc. ALLDATA 2015: The First International Conference on Big Data, Small Data, Linked Data and Open Data*, ISBN:978-1-61208-445-9, pp. 69 - 74, IARIA, held in Barcelona, Spain, April 19 - 24, 2015. (best paper award)
6. S. Koldijk, J. Bernard, T. Ruppert, J. Kohlhammer, M.A. Neerincx, and W. Kraaij. **Visual Analytics of Work Behavior Data - Insights on Individual Differences**. In *Proceedings of EuroVis 2015*, 2015
7. Bram van der Waaij, Jan Sipke van der Veen, *Uniform Application Deployment on Multiple Clouds*. Submitted to: IEEE Big Data Service 2016, Oxford, 29 March – 1 April 2016.
8. Piotr Zuraniewski, *Development of an SDN-based Virtual Private Network Service*. Presentation at 1st COST ACROSS open Workshop co-located at Summer School "NFV meets Big Data" in Wurzburg - 15 April 2015.
9. Jan Sipke van der Veen, Robert Meijer et al., *Dynamically Scaling Apache Storm for the Analysis of Streaming Data*. In: *Proceedings IEEE BigDataService 2015*, San Francisco, 30 March - 2 April 2015.
10. Attema, Thomas, Peter-Paul van Maanen, and Erik Meeuwissen. "Development and Evaluation of Multi-Agent Models Predicting Twitter Trends in Multiple Domains." *Proceedings of the 2015 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining 2015*. ACM, 2015.
11. Wout Hofman, *Data collection architecture for Big Data*. Paper and presentation at Workshop "Big Data Interoperability", co-located with IWEI 2015, Nimes, 27 May 2015.
12. Thijs Veugen et al., *Content Based Recommendations with Approximate Integer Division*. In: *Proceedings 40th IEEE International Conference on Acoustics, Speech and Signal Processing (Session on Multimedia Encryption, Forensics, Indexing and Biometrics)*, Brisbane, 19-24 April.
13. Robert Meijer, Reginald Cushing, Cees de Laat, Perry Jackson, Sander Klous, Ralph Koning, Marc Makkes, Arthur Meerwijk, *Car2x with software defined networks, network functions virtualization and supercomputers technical and scientific preparations for the Amsterdam Arena*

- telecoms fieldlab*. In: Proceedings IEEE International Conference on High Performance Computing & Simulation (HPCS), pp. 656-657, 2015.
14. Marc Makkes, Ana Varbanescu, Cees de Laat, Robert Meijer, *Fast packet forwarding engine based on software circuits*. In: Proceedings of the 12th ACM International Conference on Computing Frontiers, Ischia, Italy, 18-21 May 2015.
 15. W. Pino, T. Gomes, R.E. Kooij, *A comparison between Two All-Terminal Reliability Algorithms*, Proc. of 2nd International conference on Networks and Information Security, 23-25 October 2015, Singapore.

Presentations

1. Wessel Kraaij, ***The shared value of personal and population data: Trusted architectures, self management, patient driven hypotheses***, 2ND Transatlantic Conference on Personalized Medicine (TCPM), Rotterdam, The Netherlands, 8-9 October 2015.
2. Stef van Buuren, ***Personalized prediction of growth and development by curve matching***, 2ND Transatlantic Conference on Personalized Medicine (TCPM), Rotterdam, the Netherlands, 8-9 October 2015.
3. Pepijn van Empelen, ***MHEALTH: Identify change mechanisms and promoting behavioral changes***, 2ND Transatlantic Conference on Personalized Medicine (TCPM), Rotterdam, the Netherlands, 8-9 October 2015.
4. Piotr Zuraniewski, *Anomaly Detection*, Invited Presentation at SDC PIRE 2015 Workshop, Amsterdam - 8-12 June 2015.
5. Thijs Veugen, *participation in tutorial session "Signal Processing Tools for Big Data Analytics"*, IEEE International Conference on Acoustics, Speech and Signal Processing (Session on Multimedia Encryption, Forensics, Indexing and Biometrics), Brisbane, 19-24 April 2015.
6. Paul Brandt, *Presentation on PhD research*, EIRICT (Eindhoven Institute for Research on ICT), 2 June 2015, "Semantic interoperability - an application of semiotics in computer communication"
7. Piotr Zuraniewski, Michal Golinski, Borgert van der Kluit, Bart Gijzen, Otto Baijer, Ronald van der Pol, *CoCo: easy multidomain VPN service. On-demand, SDN based connectivity to support BigData applications*. Demonstration at 27th International Conference for High Performance Computing, Networking, Storage and Analysis (SC15), Austin, Texas, 15-20 November 2015.
8. Data-gedreven innovatie als strategie – Jop Esmeijer – 30 September 2015, Utrecht
9. Wessel Kraaij "Quantified self voor gepersonaliseerde gezondheid " , bijeenkomst Data gedreven wetenschap, AWTI 5 juni 2015

Miscellaneous

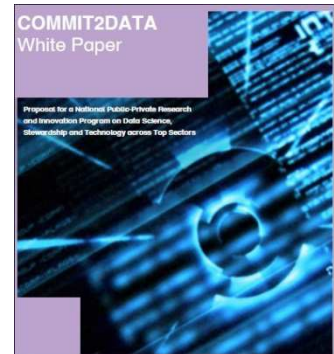
1. Hans van den Berg, Co-organizer of COST ACROSS Summer School "NFV meets Big Data", University of Würzburg, 8-15 April 2015.
2. Hans van den Berg, TPC member / Steering Committee member of ITC-27 Conference on "Traffic, Performance and Big Data", Ghent, Belgium, 8-10 September 2015.
3. Wout Hofman, TPC member Workshop "Big Data Interoperability", co-located with IWEI 2015, Nimes, 27 May 2015.
4. Big Data Value Position Paper – TNO (Tom Bakker, Jop Esmeijer)
5. Meerjarenplan Almere-TNO (Jan Wester, Alwin Sixma, Yolanda Musson)
6. Webpage: <https://www.tno.nl/en/focus-area/urbanisation/smart-cities/tno-partner-in-advanced-metropolitan-solutions/> Small Big Data Congress – 3 March 2015, Almere
7. Monthly presentations at the 'MKB Café' at BDVC Almere.
8. Wessel Kraaij, panelist at panel discussion 'De Maakbare Mens', Eureka! Festival nationale wetenschapsagenda, November 2015
9. Wessel Kraaij, "Visie van" opinion article I/O magazine December 2015, on personal health data

9.4 Building the ecosystem

Ecosystems, TopSectors and Themes / Stakeholders

The Big Data Value Association (BDVA, <http://www.bdva.eu/>) is a non-profit, industry-led Public Private Partnership whose members include lead companies, research institutes and universities from within Europe. The Big Data cPPP (contractual Public-Private Partnership) is a partnership between the European Commission and the BDVA. The goal of this cPPP is to tackle the main research challenges and needs for advancing Big Data Value in Europe in the next 5 to 10 years. The cPPP is domain neutral, however, there are a number of focus domains mentioned, including Health, Transport and logistics.

The *Knowledge and Innovation Agenda ICT 2016 – 2019* recognizes Big Data as one of the leading ICT Research and Innovation Themes, which is addressed in its Action Line 4: Data: Big Data. The COMMIT2DATA proposal, based on the KIA-ICT, aims to maintain and strengthen the Dutch top-5 knowledge position in Big Data. The proposal describes the role of Big Data in four innovative economic sectors: Life, Energy Transition, Smart Industry and Security, and maps the different Big Data scientific challenges on these innovative sectors. TNO is one of the founding partners of COMMIT2DATA and contributes matching, other prospective matching partners include NWO, industry associated to the relevant top sectors and the EU.



TNO plays an important role in these national and international ecosystems on the topic of big data, with Henk-Jan Vink elected as one of the board members for the BDVA, and TNO contributions to the programs. The main connections of the ERP with the NL Top Sectors are through the KIA ICT and COMMIT2DATA. TNO has an active involvement in the agenda setting for these initiatives, and contributed to the texts of their roadmaps and proposals in 2015. Participation of TNO in these bodies enables TNO to influence both the national and the international research agenda.

Another interesting ecosystem is the High Tech to Feed the World initiative¹¹, which focuses on applying ICT solutions from the top sector HTSM for challenges from the top sector Agri&Food. TNO also contributed to this roadmap.

Collaboration agreements

In 2015 TNO signed strategic partnerships on Big Data with Statistics Netherlands (CBS) and the city of Almere. TNO works with a number of partners in the Amsterdam Institute for Advanced Metropolitan Solutions (AMS), in order to apply and valorize the ERP research results. On the topic of Personalized Health there are contacts with Almere and Amsterdam for collaborative research and implementation projects. Connected to the program are many TKI projects in different phases, from idea to already executed on subjects varying from more fundamental Big Data research to Big Data applied to several application domains such as logistics or farming.

Instrumental in setting up joint projects with industry is the involvement of the Big Value Data Center (BDVC). The BDVC has organized an extensive network of public and private organizations both from the solution (supply) and the demand side.

Research with knowledge partners

Research with knowledge partners is mainly done by TNO part-time professors, assistant professors and PhD students connected to the program. An overview of these researchers is presented below. It can be seen that the universities and topics are very diverse. Through their academic projects and

¹¹ www.dutchfoodsystems.com/wp-content/uploads/2015/05/High-Tech-to-Feed-the-World-v3.1-Bijlage-v1.1.pdf

PhD's and post-docs, the professors and assistant professor immediately enhance the academic eco-system of the ERP.

Who	Where	Topic
Prof.dr.ir. W. Kraaij	Radboud University Nijmegen	Information Filtering and Aggregation
Prof.dr. J.L. van den Berg	University of Twente	Design and Analysis of Communication Systems
Prof.dr.ir. R.E. Kooij	Delft University of Technology	Robustness of Complex Networks
Prof.dr. R.J. Meijer	University of Amsterdam	Applied Sensor Networks
Prof.dr. J.B.F. van Erp	University of Twente	Tangible User Interaction
Prof.dr. S. van Buuren	University of Utrecht	Missing Data
Prof.dr.ir. L.A. Tavasszy	Technical University of Delft	Freight Transport and Logistics
Dr.ir. W.J. Hofman	Technical University of Delft	Semantic interoperability and linked data
Ir. P. Brandt	Technical University of Eindhoven	Data Management and Interoperability
M.H.T. de Boer, Msc	Radboud University Nijmegen	Complex event search in video data

Spin-off & co-finance projects

The topic Making Sense of Big Data can be applied to different use cases, providing various opportunities to participate in Horizon 2020 programs and projects. One of these opportunities is in the Big Data Value cPPP. The knowledge developed in the ERP allows TNO to be able to participate in a large field of proposals in logistics, ICT, health, security, etc. In 2015 a number of proposals on Big Data were submitted or prepared, on a number of different topics. The proposals include PANEL (BIS-LOG), Marco Polo, ACCESS, StepForward and CrowsNest.

Within the Netherlands, we work with partners within TKI projects. In 2015 a TKI proposal on the topic of ICN was granted, a proposal in the core of Sense Making of Big Data. Next to that there are TKI projects for logistics, smart dairy farming, applying sensor technology and big data analysis to monitor underground duct stability and combining both public market data and value chain data in the flower and agriculture sector to better predict future demand. We also work with partners on the topic of big Data and health within the FES project COMMIT/ SWELL and on big data and logistics in the H2020 project ACCUS.

10 Seed ERP Organ function on a chip

10.1 Management summary

A serious issue in the development of new drugs (and concomitant high costs for medicines) is the high attrition rate. Too many compounds fail in the late development stage (highly expensive clinical trials) due to the limited predictive power of simple in vitro and in vivo preclinical models. Better predictive preclinical models that represent the human situation will lead to better selection of success or failure of compounds in the clinical development phase. Organ function on-a-chip models (in vitro models consisting of human cells growing on microfluidic chips, which can be used to better mimic the physiological environment of the cells) provide a promising approach to solve this issue. TNO has unique knowledge and technologies in house to significantly improve and speed up the model development and application of “organ-on-a-chip” technology. By combining these technologies we will unlock the full potential of the somewhat scattered expertise present at TNO, combine this with knowledge and technology provided by our collaborators and generate a potential new growth area.

Ambition of the TNO ERP Organ-function-on-a-chip is to improve the efficiency of drug and food development by developing better predictive personalized in vitro screening models. We aim to achieve this by generating, optimizing and validating sophisticated generations of human in vitro “on-a-chip” models in a step-by-step approach (as described in “technology lines”), according to the market demand.

As use cases, organ-function models were selected, gut, liver and lung. Each of these models has applications in at least two application fields, making each organ model interesting for several roadmaps within TNO.

Reflection on progress:

ERP Organ function on a chip made the right steps in evolving from a seed ERP (2015) into a full ERP (in 2016). Our network was extended by making contacts with different industrial partners and also academic collaborators. With several of the collaborators, specific plans for collaboration were set-up, with the CALM consortium as a very successful example. This is a consortium of three partners, TNO, InvitroCue (providing scaffolds for culturing experiments) and Takara (providing stem cells and specific culturing protocols) and will work on setting up a liver-function on a chip model.

In addition to a more detailed technical plan on the steps to be taken, partners were identified for collaboration both in academia (different academic groups with the most intensive contact being with University of Twente) and in industry, InvitroCue, Mattek, Takara, TissUse and Mimetas. These partners can contribute with state of the art technology to the developments of our models, in addition to other (inter)national initiatives such as hDMT (TNO is in negotiation), funded projects (RAAK project) and initiatives enabled by topsectors, such as Nanonext.

In addition to external collaborations, internal collaborations and discussions took place between different research groups. Main contributors were from Metabolic health research, Microbiology and systems biology, Applied environmental chemistry. On state of the art technology in 3D printing Equipment for additive manufacturing contributed to the program. In 2016, further collaborations are planned with the optics group in the area of readout technology. To facilitate the internal collaboration, a workshop was organized for all internal stakeholders, with presentations and discussions of the plans for 2016.

The scientists involved in the ERP collaborated closely with business developers of several roadmaps, Food and Nutrition, Predictive Health Technologies, Urbanization and Defence, safety and security in order to develop sound business cases for the most important markets. Based on the business cases, the technical work was focused on the expected most successful product-market combinations.

A presentation about the ERP was prepared that can be shown to visiting potential stakeholders. More presentations for pharma, food and chemical industry are planned for 2016.

So far, the program succeeded in achieving the goals set for 2015: taking first steps in technical developments of advanced in-vitro models, the ecosystem was extended and the program led to successful new internal collaborations.

10.2 Results

Technology line 1: Gut function-on-a-chip

Within the “gut-function-on-a-chip” program we will combine expertise’s and develop a predictive humanized *in vitro* model of the intestine to study the impact of drugs, nutrition and environment on gut health. This model should preferably mimic gut characteristics, such as structure, microbiota and absorptive and secretory functions. This gut-on-chip model will therefore have its application in the pharmaceutical and nutritional industry by providing a predictive human *in vitro* model to study intestinal absorption, digestion, and metabolism of their compounds, and to study the effect on microbiota/microflora composition, mucus interaction and immune response/allergy. Moreover, in order to generate a “GI-tract-on-chip”, for different phases of life (babies, children, adults, and elderly), different conditions will be optimized. In the future, the gut-on-a-chip can be combined with liver-on-a-chip models in order to more accurately predict human oral bioavailability of compounds.

Progress in 2015:

Collaboration has been set-up with technology providers MatTek, TissUse and Mimetas, and contacts have been intensified with academic partners like HUB foundation and AMC regarding the culture of human intestinal organoids.

A microinjection facility was set-up in order to screen for host-microbe interactions (e.g. pathogen response) upon microinjection of organoids with specific microbes/pathogens. We have successfully set-up the use of human intestinal tissue ex vivo in an InTESTine system, in order to study intestinal transport of compounds and to study host-microbe interactions. The development of the first prototype of a 3D printed microfluidic plate to be used for the culture of intestinal stem cells (on permeable scaffold membranes) is presented below.

Highlight: 3D printed scaffolds used for cell cultures

For the gut-on a chip, a surface mimicking the villi of the gut can help to improve the cell differentiation. By using additive manufacturing at TNO EfAM in Eindhoven, a project has started to fabricate these villi-like structures. First a material has been developed suitable for cell adhesion and growth which was successfully tested with Caco2-cells. With this material, micron size features up to ~150µm can be made which is in the order of the villi-size (see pictures). The actual scaffolds were designed and tested in culturing with cells. The next step is to make there structures permeable in order to mimic the adsorption processes in the intestine.

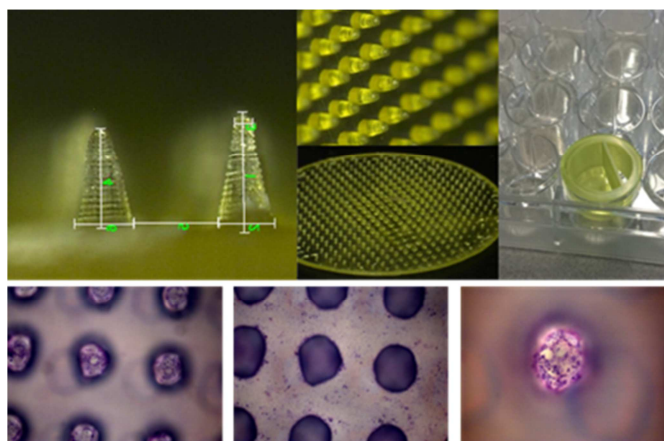


Fig. 1 3D printed scaffolds mimicking the villi structure of the gut, with cultures of Caco2-cells.

Technology line 2: Liver function-on-a-chip

The “liver-disease-on-a-chip” will be a predictive *in vitro* disease mimicking (i.e. non-alcoholic steatohepatitis; NASH) model using co-culture of human pluripotent stem cell-derived hepatocytes and stellate cells (or other liver cells) on an *in vitro* 3D cell culture platform that will have its application in testing the effect of compounds on the disease development, prevention and or treatment. Besides for the pharmaceutical industry, this will also be relevant for applications in the nutrition industry. The combination of disease, materials, stem cells system biology and read-outs is challenging and will give opportunities for broader applications towards a personalized health approach and stratification (“population on a chip”).

Progress in 2015:

In 2015 we tested induction of hepatocytes by fatty acids, induction of collagen / fibrosis by stellate cells using cell lines (easily available) and defined conditions for cell culture and read outs. For stellate cells we also used primary human cells, which could be activated to become fibrotic. Using the hanging drop system we grew hepatoblasts and primary cells in 3D culture. Primary hepatocytes only formed 3D microtissue in the presence of stellate cells.

With a Singapore-based biotech company and a Sweden based biotech company a consortium was formed, in which we'll use human hepatocytes differentiated from human stem cells in a 3D scaffold able to harbor >100 spheroids. To this consortium other partners (Erasmus MC and the Dutch Maag-Lever-darm stichting) were added, with whom we together applied for a ZONMW Meer Kennis met Minder dieren grant on “application of innovations”.

Highlight: Induction of steatosis in a 3D cultured cell model

To generate a physiological relevant and sophisticated disease mimicking model several hallmarks of the disease should be implemented within the model. Steatosis (fatty liver cells) in cell lines (HuH7), iPSc derived hepatocytes (HepaRG) and primary hepatocytes was induced by the exposure to fatty acids (oleate) at different concentrations to determine the optimal induction conditions. The fatty acids showed accumulation in the cell membrane of cell lines (Fig. 2) and primary cells cultured in a 3D hanging drop approach (Fig. 3).

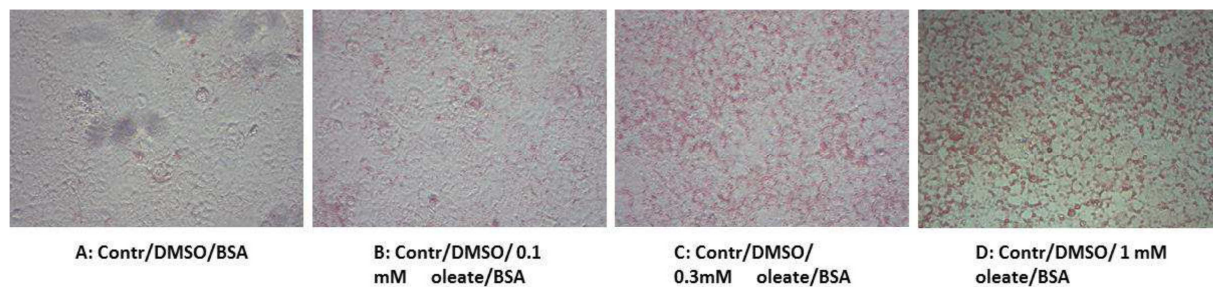


Fig. 2 Induction of steatosis in the human hepatocyte HuH7 cell line

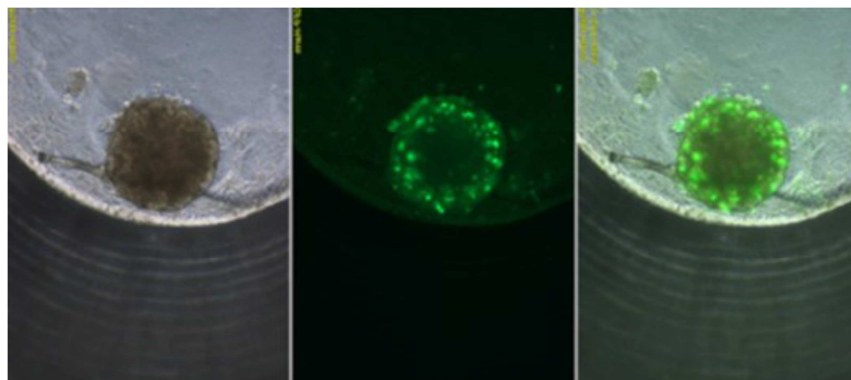


Fig 3. Primary hepatocyte maturation in a 3D hanging drop cell culture

Technology line 3: Lung function-on-a-chip

We aim to develop a novel (human) *in vitro* inhalation model combining fully differentiated lung cells and a relevant exposure route, that can be used to study:

- (personalized) lung health
- Effect of drugs, nutrition and environment
- Host-microbe interactions
- Permeability and drug or nutrient absorption.

This model has been established to measure the toxicity of chemicals and will be further applied for a variety of research questions from the nutrition industry and the pharmaceutical industry.

In vitro assessment of exposure to aerosolized pollutants and pharmaceuticals is becoming increasingly important in terms of determining health effects in humans. The use of animal models for studying human airway toxicity/efficacy is increasingly recognized as non-predictive in certain circumstances. Currently, *in vitro* methods for inhalation models include the use of primary human cell models, air-liquid interface exposure modules and aerosol generation technologies. Development of these technologies is important for both increasing scientific knowledge and societal benefits such as improving health and reducing use of animals in research.

Progress in 2015:

The *in vitro* inhalation model has been used in a collaboration project with the LUMC (Longfonds project) in which the biological effects of diesel exhausts were measured under controlled lab conditions. The state-of-the-art automotive facility of TNO Helmond has been used for this. In this comprehensive experiment we have been able to test different fuels and different cell models (advanced 3D cell model of the LUMC and a co-culture of cell lines). Operational this has been a major exercise since Helmond facilities had to be customized for biological labwork and different disciplines had to be connected.

In 2015 a collaboration has been set up with the group of Prof. Harren at Nijmegen University to measure CO at cell systems. CO is produced by the enzyme Heme oxygenase and this enzyme is induced in a first (oxidative) stress response of the cell after exposure to xenobiotics. In first experiments we have determined CO production using a lung cell line (A549).

The business case for lung function-on-a-chip in pharma applications was extensively discussed with several stakeholders.

Furthermore, based on our model and the available knowledge, potential of developing a biosensor for the measurements of effect of exposure in different settings will be explored in 2016.

Highlight: Monitoring of oxidative stress as a generic read-out

In the early stages of the oxidative stress process, carbon monoxide (CO) is produced by the enzyme HO-1 and released into the cell culture medium and into the air phase. Measuring the quantity of CO over time can be an indirect but sensitive way of assessing the activity of HO-1 and therefore of the induction of oxidative stress, for example in an *in-vitro* lung model. Several possibilities have been explored including photo-acoustics spectroscopy, turn-on fluorescent probes and reaction with hemoglobin followed by spectrophotometric analysis. This parameter of oxidative stress has been highlighted and a demonstrator study has been performed in collaboration with Radboud University Nijmegen.

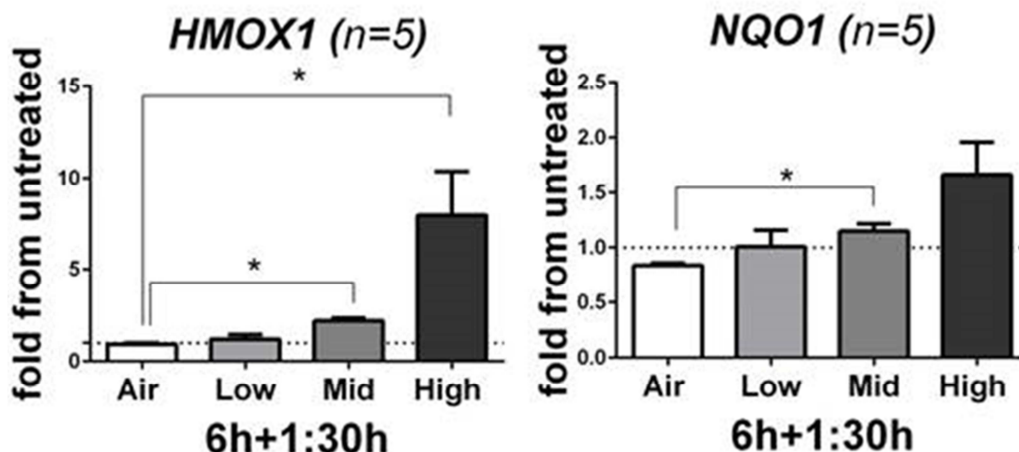


Fig 4. Measurement of CO over time: Heme oxygenase and control

10.3 Output

Presentations at conferences:

IVTIP meeting Copenhagen 29 May 2015

I. Kooter, Preliminary validation studies of a 3D in vitro inhalation model, using cytokine and gene expression responses to metal-oxide particles

EUSAAT congress Uni of Linz 20-23 September 2015, Austria

I. Kooter, Preliminary validation studies of a 3D in vitro inhalation model, using cytokine and gene expression responses to metal-oxide particles

Poster SOT 2015

- Preliminary validation study of a 3D in vitro inhalation model, using cytokine and gene expression responses of copper oxide nanoparticles; Ingeborg M. Kooter, Mariska Grollers-Mulderij, Evert Duistermaat, Yvonne Staal, Frieke Kuper, Eugene van Someren, Eric Schoen,
- Manuscript submitted to Am J Physiol: Cellular response of mucociliary differentiated primary bronchial epithelial cells to diesel exhaust Maria Concetta Zarcone, MSc; Evert Duistermaat; Annemarie van Schadewijk, MSc; Aleksandra Jedynska, MSc; Pieter S. Hiemstra, PhD; Ingeborg M. Kooter, PhD

Dissemination events and activities:

In October a workshop was organized with internal and external participants from University of Twente. The goal was to involve more TNO research groups in the definition of the plans for 2016 and to strengthen contacts between TNO and University of Twente.

The topic of this ERP fits into the strategic research agendas of several Topsectors such as Agri&Food, High Tech Systems and Materials (HTSM) and Life Sciences and Health (LSH). In the Topsector LSH around 10 roadmaps are defined of which the roadmap Enabling Technologies, Regenerative Medicines and Pharmacotherapy fits well. Overall the 3R policy is considered as the story line throughout the whole LSH program. Via the Roadmap director of Predictive health technologies, LSH was informed about the research performed within this ERP. A broader dissemination event will be planned in 2016.

10.4 Building the ecosystem

In order to have an effective innovation strategy, to create focus in the research lines within the ERP, and to define the most relevant partners, decisions have to be made regarding the potential innovation model for TNO. This has been done by brainstorm meetings with BD and scientists of TNO, and business canvases for the applications gut-on-a-chip and liver function-on-a-chip and lung-function on a chip were generated. The innovation models were discussed with several stakeholders, both within TNO as well as outside TNO (pharma, biotech, academia, potential partners and clients). This has resulted in the formulation of an innovation case with both a market and technology roadmaps for all three use-cases, and a broad network in which the expertise of TNO is acknowledged. Our activities are complementary to the already existing consortia. Besides technology, the added value of TNO is the focus on the biological application, knowledge of diseases and the approaches regarding implementation and (regulatory) acceptance of new technologies.

Besides the collaborations TNO is currently establishing in this area, also funding opportunities already are actively being pursued. For example, TNO, together with a consortium consisting of Dutch academia (Hogeschool Utrecht, Utrecht University and WUR) and several technology providers and food industry, have been awarded a grant for a RAAK-PRO project, regarding the development of better *in vitro* intestinal models to assess health effects of food ingredients.



Fig 5. Ecosystems overview. Green: academia / research institutes, purple: pharma, orange: bio tech or technology provider

Co-research:

Especially the technical universities (Delft, Twente, Eindhoven) are actively working on organ-on-a-chip technologies, all with specific technology expertise (e.g. biomedical microfluidics, electrical engineering, mechanical engineering) and different application areas (in national and international

collaborations). These groups focus primarily on technology development, and put less efforts in optimizing the biology, translation to in vivo and validation of the models. We have intensive contact with the University of Twente and are exploring possibilities for postdocs in 2016.

Two master students from LUMC are currently interns at TNO working on the liver *in-vitro* models. This further strengthens the collaboration between TNO and LUMC.

Co-development:

In 2015, extensive negotiations took place between TNO and Invitrocue and Takara BioEurope AB.

Invitrocue is a Singapore based company that provides innovative products and services in the fields of *in vitro* DMPK, *in-vitro* toxicology and digital pathology utilizing cell-based models and image analytics.

Within this project, InvitroCue will provide knowledge and expertise on cell culture and scaffolds (the Cellusponge technology platform), focused on co-cultures of human liver cells

The focus of Takara Bio Europe AB is on the application of human stem cells (Enhanced hiPS-HEP); a highly homogeneous population of hepatocytes derived from human induced pluripotent stem (hiPS) cells. Takara Bio Europe AB will contribute their expertise and their iPSC platform (differentiation, maturation to hepatocytes) with a new application focus on co-culture and effects of metabolic overload.

These two companies form a consortium with TNO and will work on further optimization of the in-vitro liver model.

Spin-off

In the Netherlands, several initiatives and calls have been announced, indicating the interests and applicability of organ-on-a-chip technology. ZonMW has recently published a [call](#) titled: "Meer Kennis met Minder Dieren - Toepassen van Innovaties", whereby innovations are defined as: organ-on-a-chip models, 3D tissue engineering, organoid culture, stem cell technologies, omics technologies and systems biology. As a consortium with Invitrocue and Takara Bio Europe AB TNO submitted a pre-proposal within this call that will be focusing on application of the jointly developed liver models. The result of the evaluation is pending and will be available January 2016.

11 Seed ERP Submicron Composite Materials

11.1 Management summary

The overall goal of this ERP is to achieve a level of control over structure and chemical composition of materials that enables the development of materials with programmable functionality. Furthermore, we aim to progress from state of the art monofunctional materials via materials with multiple passive functionalities to active and adaptive materials. We will demonstrate the knowledge gained within the framework of this ERP in selected use cases chosen in collaboration with the Brightlands Materials Center and its partners.

As stated in the “Kennis- en Innovatie-agenda 2016-2019” from the Topsector Chemistry, artificial materials are the cornerstone of our global society. Progress in the field of materials chemistry has enabled numerous new technologies and applications ever since the Stone Age, and will continue to do so in the coming decades. The Netherlands have a very strong position in advanced materials, and the long-term goal of materials research in the Netherlands is the development of materials with programmable functionalities, tailored for an application of choice. The functionalities of advanced materials are determined both by the material's chemistry and its micro- or nanostructure.

For the development of advanced materials with programmable functionalities, it is of key importance to understand the relationship between the properties of a material and its chemical composition and nano/microstructure. Furthermore, it is of utmost importance to develop the competences to produce the required materials and structures with the appropriate precision in a technically efficient, and cost effective process. Within the framework of this ERP, we therefore focus on:

- Studying the relationship between the functionalities of advanced materials and its chemical composition and structure.
- Production of materials and structures to manufacture advanced materials with programmable functionalities.

The research within this ERP supports activities of the Brightlands Materials Center (BMC). In collaboration with other partners in BMC, we will select use cases which are of relevance for the following BMC programs:

- Additive manufacturing (AM)
- Optics and electronics (OE)
- Light-weight automotive (LA)

The ERP will achieve its ambition by developing a systematic approach connecting relevant numerical (modelling) and experimental (synthesis, analysis, and characterization) methodologies.

11.2 Program Execution and Results

Technology line 1: Materials for Additive Manufacturing

The research line Additive Manufacturing (AM) has the following overall objectives:

- Development of materials for additive manufacturing processes matching the performance of conventionally processed polymers.
- Development of novel materials capable of delivering properties required by novel applications enabled by Additive Manufacturing.

Research by PhD's at Eindhoven University of Technology

A cluster of 8 PhD projects will be set up at Eindhoven University of Technology in the framework of Brightlands Materials Center, focusing on fundamental understanding of the structure property

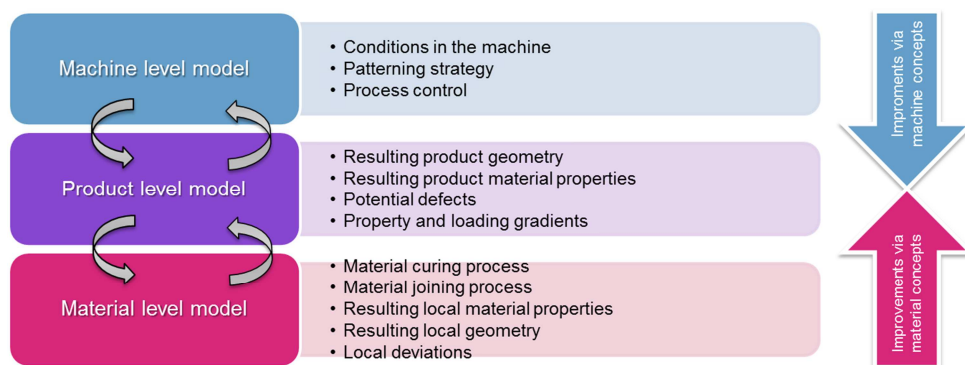
relation of several polymer systems, as well as creating new polymer systems for enhanced vat polymerisation and increased mechanical performance. The following topics were selected for these PhD projects:

1. Structure-property relations and long-term performance of sintered polyamide
2. Computational modelling of viscoelastic non-isothermal sintering process
3. Experimental characterization of the sintering process and generated microstructure
4. Manipulating morphology by nano-particles (photocurable). Responsive 3D objects.
5. 3-D manufacturing of plastic products by melt jetting
6. Reversible Multiple Networks for 3D printing materials
7. Controlled Polymerizations in stereolithography
8. Intrinsic mechanical properties for photocurable polymers

In 2015, PhD students were hired for projects 1,2,3,6 and 8.

Research at TNO

Within this ERP project (period 2015/2016) we aim to build a multi-scale model of a layer wise photocuring process that predicts thermomechanical behaviour and geometry of 3D products prepared by vat photopolymerization, and can be used to understand the relation between material parameters and process settings and to optimize process parameters to improve thermomechanical as well as geometrical quality. Also, the project aims to develop a screening method for new photocurable materials that links to input parameters for this model.



Schematic representation of multi-scale modelling.

Progress realized:

Within this subproject, progress was made with respect to:

- Defining a modelling framework.
- Definition of a product level model in COMSOL + phasing to include the relevant physical and chemical effects in step wise manner.
- Literature survey + models at a material level.
- Definition of transfer of material models to product level simulations.

Technology line 2: Materials for Optics and Electronics

Within this technology line, the use case selected in collaboration with the Brightlands Materials Center and partners is a dust repellent coating for solar applications (PV modules) to prevent soiling of PV module covers.

The objectives of this project are:

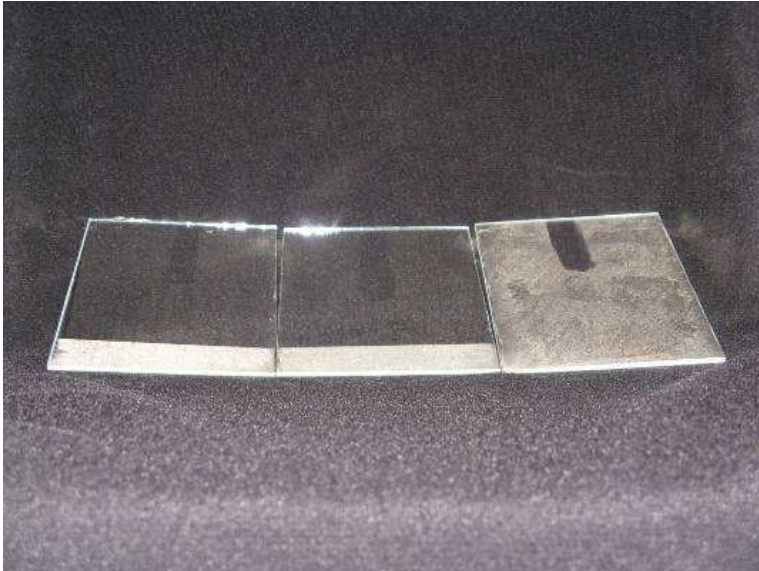
- Anti-dust coating that can be applied worldwide on PV panels.
- Understanding of the relationship between a surface texture and surface chemistry of the coating and its ability to repel dust.
- Fundamental understanding of the structure formation of nanotextured coatings using smart combinations of nanoparticles and other coatings ingredients.
- Rational optimization of the anti-dust properties of current coatings system.

This project is being performed in cooperation with external parties.

Progress realized:

A literature study has been prepared describing anti-dust coatings and in particular those types developed by Fraunhofer ISC, next to a more general part of the literature survey about anti-soiling coatings. Soiling is defined and insight in the complex mechanism of soiling is achieved.

A work plan for 2016 has been defined together with the partners involved.



Picture from experimental lab-work at Fraunhofer.

left: coated with anti-dust coating, right: not coated.

Technology line 3: Materials for Light-Weight Automotive

The first uses of sub-micron particles in polymers for automotive were aimed at improving mechanical and structural properties, such as stiffness, and impact behaviour. These composites are traditionally manufactured by the random introduction of micron or sub-micron sized particles into polymer matrices. Although significant improvement of properties have been seen, another step can be taken when the ordering of the added particles can be controlled better. With the hierarchical functional materials thus obtained (using sub-micron particles and fibers of any materials), new materials can be designed with specific mechanical properties.

The second half of 2015 will be used to develop and select a use case for 2016 in collaboration with BMC and partners.

Progress realized:

A memo describing the potential BMC LA – TNO Defence synergy. The synergy is found in particular in the field of light weight army vehicles, helmets and body armour where high protective properties must be combined with little weight

11.3 Building the Eco-System

The primary ecosystem we focus on is the Brightlands Materials Center and industrial partners located on or in close proximity to the Chemelot Campus in Sittard/Geleen. Together with these parties, we will select use cases to demonstrate and validate the technological advances realized within the framework of this ERP.

Within the framework of this ERP, we cooperate with Eindhoven University of Technology for the development of advanced materials for additive manufacturing.

Furthermore, we aim at partnering with DWI-Leibniz Institute for Interactive Materials e.V. at RWTH Aachen University (Aachen, Germany) and Zuyd University of Applied Sciences in Heerlen for the development of advanced materials for optics and electronics.

We are currently in discussion with potential academic partners and industrial partners in the field of light-weight automotive.

12 Orchestrating Innovation

12.1 Highlights

Orchestrating Innovation Guidebook

State-of-the-art Orchestrating Innovation tools that are used within TNO are explained and visualized in the Orchestrating Innovation Guidebook. This has led to the development of a practical guide that provides an overview of tools for starting, shaping, managing and expanding innovation ecosystems.

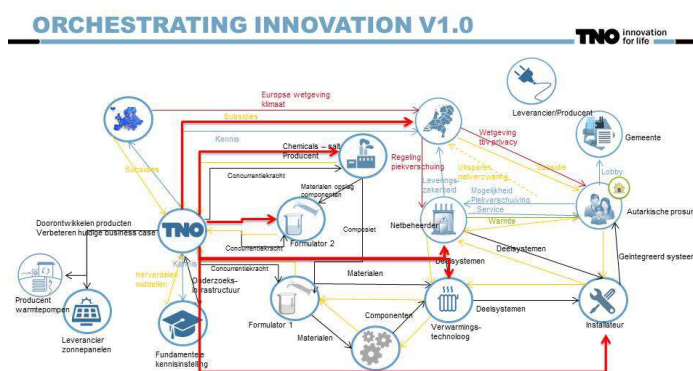
Show case VoltaChem

The Shared Research Program between TNO and ECN has been supported by Orchestrating Innovation team members. This was done by the development and completion of an 'Innovation Centre Business Model Canvas': a schematic representation of the most relevant cohesive elements to be determined for the SRP. This clarified elements that were still underexposed, and elements that were not consistent with each other. It also was used to monitor the progress of VoltaChem and set priorities.



Show case Thermal Battery

To support the technology of thermochemical storage in developing an exploitation strategy, the Orchestrating Innovation team members performed several analyses and held three workshops. These analyses and workshops helped clarify the role of thermochemical storage in the future energy system, understand external factors that influence this technology, find out the strengths and weaknesses of the technology and analyze the value chain and its stakeholders.



Show case Flexible Power Alliance Network

For the Flexible Power Alliance Network, in a relatively short period of time, Orchestrating Innovation team members found out that board members had different points of view on important subjects and

they proposed concrete recommendations and new strategic options. The board of FAN suggested to present these findings and recommendations during their board meeting.



12.2 Output

1. Koen Dittrich, Wietske Koers, Frank Berkers, Julianna Becker, Carlos Montalvo, *A Value Case Approach for Analyzing Goal Alignment in Multi-Stakeholder Networks: The Case of Sustainable Product Manufacturing in the Electronics Industry*, conference paper for DRUID15 THE RELEVANCE OF INNOVATION, Rome, 15-17 June 2015
2. Koen Dittrich, Frank Berkers, Marc van Weelden and Carlos Montalvo, *A Value Case Approach for Analyzing Goal Alignment in Multi-Stakeholder Networks*, article in: Industry & Innovation – special issue on "The Relevance of Innovation for Ethics, Responsibility and Sustainability" (ERS)
3. Mirjam Groote Schaarsberg, *Shared Value Creation*, presentation for: Integrated Reporting Business Network, Dusseldorf, 28 October 2015
4. Frank Berkers, Jenny de Boer, Rosalinde Klein Woolthuis, *Orchestrating Innovation Guidebook*, Den Haag, October 2015
5. Rosalinde Klein Woolthuis, *FEWEB Column*, <http://www.avenironline.nl/#!5-FEWEB-Column>

13 Signatures

Delft, 24 February 2016



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