iedere stap vooruit verschuift de horizon

“the ability to adapt your journey to reach new horizons brings forth exciting insights and knowledge to build a better society”
Management summary

Adaptive Multi Sensor Networks (AMSN) is the TNO Enabling Technology Program (ETP) concerning the design of new generations of sensor networks. The primary goal of AMSN was to develop new knowledge for building universal engineering methods and tools for these sensor networks. These methods and tools will enable the development of new generations of sensor network systems capable of on demand delivery of information to fulfil the needs of many users. These sensor networks will also be capable to adapt their performance in real-time to the new emerging information needs of the users.

In 2014, eight core projects have been executed around four lines of essential system properties. These properties: time critical performance, adaptive, multi-use, and scalable are key properties for sensor systems in all application areas.

In the period 2011-2014 many inspiring and successful results have been achieved in the AMSN program, featuring encounters with frontier applications demonstrating the potential of the research outcome both in the industrial as well in the societal domain. Most of the ambitious targets set at the start of the program have been achieved, albeit with ups and downs, keeping the objectives in good balance with the resources. The scientific output in 2013 and 2014 of the AMSN program has been on par with the trends observed in the international science and technology landscape.

In its final year – 2014 – the AMSN projects delivered additional technologies in various research domains such as re-targetable domain specific modelling layer to facilitate system design, Deep Learning Convolution Neural Network to quickly learn new concepts, Utility Based Reasoning for the sake of system efficiency and effectiveness and Elastic Cloud Computing to instantly scale up or down analysis capacity. The program contributed to the IP portfolio of TNO, including several patents, thereby strengthening TNO’s position in its (future) markets.

The potential value of AMSN technology was shown on various occasions to the public, through TV, Radio, newspapers and internet. Specific attention was received on three of the AMSN demonstration projects. Following the successful outreach in 2013 the dissemination effectively doubled in 2014. The continuous dissemination effort in the AMSN program proved to be effective and attracted much attention during the program life cycle even hitting the front pages of national newspapers and national TV news when the Prime Minister addressed the innovation success of Structural Integrity Monitoring at the 2014 Hannover Messe.

The press coverage during the program has been a good indication of the relevance of the AMSN ambition and work. Moreover, the interest of companies to apply technology developed in AMSN is a measure for the industrial relevance of the program. In particular the demonstration projects have received considerable attention from the market and are eligible for contract research, Shared Research Programs and H2020 proposals. This trend is expected to grow in the near future after the end of the AMSN program.
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1 Introduction

The ‘Enabling Technology Programs’ (ETPs) target generic knowledge and technologies which are expected to contribute to the leading issues in the TNO thematic areas. To ensure development of unique knowledge and technology each ETP pro-actively connects to relevant leading centres of academic and commercial research. The research questions are driven from insights in leading developments in the relevant international R&D networks.

Adaptive Multi Sensor Networks (AMSN) is the ETP directed towards knowledge and technology concerning new generations of sensor networks.

It is expected that the number of sensors will continue to grow exponentially. Billions of sensors will be embedded in all parts of the living environment. As part of the public infrastructure as well as part of every individual’s home, vehicles and devices providing data for all sorts of applications to support our daily life e.g. energy supply, security, traffic control, etc. Internet technology enables the interconnection of sensors in networked systems to provide various users access to the data from almost any place, any time.

The AMSN research roadmap is based on the vision that technology is rapidly moving towards full scalable networks of intelligent sensors, consisting of very simple passive sensors (e.g. temperature) as well as very complex active sensors (e.g. phased array radar). The intelligent sensors individually are capable of delivering data in response to human and machine requests one-on-one. As a part of the network they contribute to complex information needs in cooperation with other distributed sensor systems.

The primary goal of AMSN is to build new knowledge eligible to define universal engineering methods and tools. These methods and tools will be used to develop a new generation of sensor network systems capable of on demand delivery of information to meet the needs of many users (multi-use) at present as well as in the future. For instance in AMSN, we aim at enabling multi-layer greenhouses, thus producing factors more on the same area (Theme Urbanisation), which can only be done when the climate can be controlled per layer. Obviously this requires state of the art sensor networks. Another example is the work on Structural Integrity Monitoring (Themes Urbanisation, Industrial Innovation and Energy), where sensor networks are designed and tested that can monitor the state of steel constructions (bridges, pipelines as well as offshore constructions).

This generation of sensor networks will be capable to adapt their performance in real-time to the new emerging information needs of the users. From the insights AMSN gains, methodologies and tools are derived to conceive future large scale complex sensor networks delivering the right information at the right time in the right place to a variety of users, humans as well as machines.

Four lines of essential system properties have been identified to develop the core line of thought for the AMSN breakthroughs. These properties play a role, to a greater or lesser extent, in all application areas:

- time critical performance
- multi-use
- adaptive
- large scale, scalable
The outcome of the research has been enhanced with practical experiments in “live” settings to investigate specific aspects of the application of sensor networks. These experiments demonstrate the value of developed AMSN technology. From the demonstration stage the research outcome can be transferred to implementation projects.

This report concludes the work in the AMSN ETP and addresses the key results achieved in 2014, the final year of the AMSN program and a selection of highlights from the full duration 2011-2014 of the program.

The AMSN team is proud to share the results in this report providing a perfect way to illustrate the exciting lines of thought, breakthrough experiments and lessons learned encountered in terms of technology and societal impact.

In accordance with the guideline of the ministry of Economic Affairs, TNO will publish information related to the AMSN projects and results on its website. This report presents the reader an overview of the research activities with condensed descriptions of the objectives and outcome of the ETP AMSN projects.
2 Program Execution 2014

The core of the AMSN program consisted of 8 projects in 2014. The structure of the program is given in Figure 1 below. The program has been divided into fundamental technology projects and demonstrator projects to try new technologies in a relevant live environment. For the demonstration projects the associated TNO themes which have been actively involved in guiding the projects are listed.

![Figure 1 The structure of the AMSN program in 2014](image)

2.1 AMSN core projects in 2014

Fundamental Research projects
- **System Design:**
  Project name: Dynamic AMSN Architectures (DYNAA)
  Description: Develop system engineering method plus tooling for robust and adaptive sensor systems.
- **Self-Organisation:**
  Project name: Self Organising X (SOX)
  Description: studying run time adaptivity of the system as a whole, including dynamic resources, aiming at maximising of overall system effectiveness
- **Data Analysis:**
  Project name: Big Data analysis of Video and other Sensors (Big Davids)
  Description: innovative applications of affordable large scale (near) real-time big-data analysis technology of video and other sensor streams in various domains
- **Control:**
  Project name: InControl
  Description: applying novel control solutions in networked systems across various application domains, e.g. 3D climate control
Demonstration projects:

- **Time critical performance:**
  Project name: Supported Cooperative Adaptive Driving (SCAD)
  Description: realize a cooperative application facilitating smart manoeuvring (e.g. splitting, taking over and merging) of vehicles on the highway.
  Theme: Urbanisation

- **Adaptive:/ Multi-use:**
  Project name: Gorillas in the Cloud (GiTC) sensor lab
  Description: develop a multi-use sensor network ecosystem that is open to other developers and suitable for end-users with very different requirements
  Theme: Industry

Project name: Sensordata Search: Google for Sensors (Goose)
Description: capability to search semantically for any relevant information within all sensor streams, in near real time, in the entire internet of sensors.
Theme: Defence, Safety and Security and Industry

- **Adaptive:/ Scalable:**
  Project name: Structural Integrity Monitoring (SIM)
  Description: Demonstrate the monitoring of fatigue in steel on real life infrastructure (bridge).
  Theme: Urbanisation, Industry and Energy

2.2 Complementary projects

**AMSN in National/EU projects (FP7, ARTEMIS, etc.)**
Besides these 8 core AMSN projects, the program also participates in several projects that are part of EU or national programs. These are listed below.

- **Protectrail**
  provide a viable integrated set of railway security solution

- **EMC2**
  enabling European manufacturing industries to overachieve Europe 2020 program targets through development of a breakthrough paradigm for cost-effective, highly productive, energy-efficient and sustainable production systems

- **Flexigas**
  Develops components for the biogas chain in order to produce, transport and use in the most efficient manner.

- **Dike Data Service Center (DDSC)**
  Anomaly detection R&D for future use in the Dike Data Service Center.

**Outreach & Management**
Finally, the AMSN program engaged two additional activities in the program concerning overall management and embedding and linking to the academia.

- **Program Management and Outreach:** program management, contact and setting up collaborations with external parties

- **Knowledge Team:** PhD student projects and link to academia via part time professorships and STW projects. The PhD students as well as professors involved are also part of the project teams of the 8 core projects, ensuring optimal interaction.
2.3 Cooperation internal / external

Innovation requires cooperation, bringing together several experts and problem owners. Within the AMSN program the demonstration projects benefit from the results of the fundamental projects. Whereas the fundamental projects receive guidance on their research from the applications. Besides cooperation between projects within the AMSN program, several projects are linked to projects in other ETPs, EU or national programs.

2.3.1 Internal
DYNA - Big Davids - SIM
By using the DYNA tooling DYNA delivers sensor network designs for SIM (both laboratory and demonstration set-up at Van Brienoord Bridge), Big Davids develops anomaly detection and visualization on data resulting from monitoring.

SCAD - InControl - SOX
InControl develops roadside control of cooperative vehicles to let un equipped cars merge into a platoon based on camera observation. SOX develops methods to communicate only when necessary in order to prevent bandwidth scarcity. The SCAD project implements both technologies into the cooperative driving demonstration.

GITC sensor lab - Goose - Big Davids
Big Davids develops annotation methods for use on video data from the GITC sensor lab project. These annotation methods are also used in the Goose project to facilitate semantic searching.

2.3.2 External - with other ETPs
SIM – Faimos (ETP models) - BLSD (VP infrastructure)
The SIM project created both a test set up in the laboratory as well as a real life set-up underneath the Van Brienoord Bridge. The data that this monitoring generates is used to fine tune the models developed in the ETP Models project Faimos. Using the monitoring data and model outcomes the BLSD project (ETP models and VP Infrastructure of Theme Built Environment) creates decision support tooling. The SIM project tunes its experiments to the requirements of the other two projects.

2.3.3 External with EU projects
DYNA - SOX - Demanes
DYNA and SOX work closely together with the Demanes (Artemis) project. Demanes uses the results of both project to complete its tool chain. Demanes will also add functionality to the tools created by the DYNA project, so that these become even more valuable.

Gorillas in the Cloud (GITC) - iCore
The GITC Field Lab builds further on the results of the iCore FP7 project. The GITC Field Lab has become the first live implementation of the technology developed in iCore, for
multi-use of (virtualized, platform independent) hardware and software resources, aiming at the later wider spread controlled and non-conflicting use of the GITC Field Lab hardware and software infrastructure, observation data and meta data. Findings from the GITC implementation are fed back to the iCore project.

InControl - EMC2
InControl results on Model Predictive Control for use in climate control for greenhouses are used in Emc2, (which is about creating green factories). The InControl result has been used successfully in a demonstration of Emc2 in a German factory.

Big Davids - DDSC
The Dike Data Service Center project exchanges anomaly detection techniques with the Big Davids project. Extending the range of data sets that can be processed (e.g. short cyclic, long cyclic, trend)

2.4 Links to Academia and RTO's

2.4.1 Universities
The contacts between AMSN and universities are warm, and with some of them there are strong ties (i.e. MSc projects, PhD positions, professorships) with others it is related to a specific project.

- University of Amsterdam, joint PhD position, part-time professor
- University of Twente, joint PhD position, part-time professor
- University of Eindhoven, several Master students, joint PhD positions
- University of Delft, several Master students, joint PhD positions
- University of Nijmegen, joint PhD positions, part time professor
- Strathclyde (UK), joint PhD position
- Karlsruhe Institute of Technology (D), part time assistant professor

2.4.2 Research organisations
The list of research organisations that AMSN is in contact with to explore possible projects is far larger than the list below, in this list only the ones we actively cooperate with are mentioned.

- Deltares (NL, TO2 institute)
- Marin (NL, TO2 institute)
- NLR (NL, TO2 institute)
- STW (Technology Foundation, PhD positions as well as related projects)
- Fraunhofer Gesellschaft (D)
- Max Planck Institute (D)
- DARPA (USA)
3 Program Results 2014

This chapter presents the results achieved in 2014, starting at the program level and followed by a per project detailed discussion of the results, for both the demonstrator projects as well as the fundamental technology projects. In Figure 2 the AMSN roadmap is illustrated to guide the steps in the AMSN program leading to the goals.

3.1 Goals for 2014

![Figure 2 Roadmap of the AMSN program](image)

Again the four principle aspects of systems are indicated and mapped in the roadmap:
- Multi-use (many user can exploit several sensor networks simultaneously to fulfil his information needs)
- Time Critical (enlarging the system, while remaining or even improving the level of time critical performance)
- Adaptivity (adapting to changes in the tasks/goals of the system)
- Scalability (moving to scalable data processing, in order to turn data into information).

Following the advice of the Strategic Advisory Board the meaning of “Adaptive” is to be seen as an overall property of which Multi use and Scalability are a part.

3.2 Achieved results on program level

The high level goals of the AMSN program are to make breakthroughs on four desired system properties that are essential in order to broaden the application possibilities for sensor networks. These four properties contribute largely in the paradigm shift of ‘design-time’ towards ‘run-time’ optimisation, and shifting from data-driven to adaptive demand driven sensor networks. These four crucial system properties have guided the research agenda for the ETP AMSN. The research challenges addressing these key system
properties are expected to lead to technical breakthroughs that unlock the next generation of applications of sensor systems promising innovative applications to support societal and economical advances.

The four system properties can be mapped on four technology areas which are embedded in the ETP AMSN program: System Design, Self-Organisation, Data Analysis and Control Design.

The fundamental knowledge will be brought to reality in algorithms, methods and tools. For each of these four technology areas, there is a dedicated project in ETP AMSN, on top of these four projects ETP AMSN builds demonstrations, that give a hint of the application potential.

The performance of sensor networks is highly related to the application, whereas it is a huge challenge to have a timely system response within one second in one application (e.g. cooperative driving), in other applications timely means minutes (e.g. climate control) or milliseconds (e.g. mobile communication). Therefore, the four system properties are discussed in relation to the chosen demonstration application.

3.2.1 Time critical performance:
The associated demonstration project was SCAD.
The goal for 2012 was to implement a system capable of going below 0.9 seconds time headway (the gap between two vehicles expressed in time), while still being save. The total reaction time of the demonstration system (cooperative driving cars in longitudinal movement) as a whole has been reduced further to 0.25s while driving at the speed limit in the Netherlands (130 km/h). In practice, while testing on public roads, a distance between the cars corresponding to 0.5s has been used.

In 2013 the total system was expanded significantly, by adding lateral movement (steering) and communication between the vehicles and the infrastructure (e.g. cameras, radar). The goal for 2013 was to keep the time critical performance at the 2012 level even though the system was expanded, which was achieved.

In 2014 more complex manoeuvring was undertaken (merging and splitting), and again the time critical performance was kept constant. In 2014 a use-case is defined that concerns an automated split-and-merge manoeuvre, which can be broken down into four phases, i.e., platooning, split, gap creation, and merging, as depicted in Figure 3 below.
3.2.2 Adaptive
In 2012 the goal was to reach “graceful degradation” as well as “easy expansion”, meaning the sensor network can cope with changes in the sensor network (e.g. new sensors, or sensors breaking), but also with changes in the available information (e.g. its reliability, timeliness). Adaptive on system level has been reached in several ways in 2012.

One aspect of adaptive behaviour of a sensor network system is “self-configuration”. This has been implemented to accommodate the addition or removal of new sensors, so that the sensor network can grow to several times its original size efficiently and without human intervention. And moreover, self-organization has been achieved in distributed sensor networks i.e. the system decides itself to change means or frequency of communication and/or accuracy of the algorithm.

The fundamental projects of AMSN resulted in achieving the goal of 2013: adapting to changing tasks of the system. This was done by developing distributed solutions for decision making and resulted in the capability of dealing with various & varying user (driver) needs, changing goals, variable communication resources, processing power and sensing capability.

In 2014 the first practical implementation of Utility Based Reasoning demonstrated that systems can reason about their optimal configuration, and continuously adapt to new situations by moving to the next optimal configuration. Thereby AMSN clearly demonstrated that not only the sensor system itself can change over time, but also has the capability to cope with scarce resources, new tasks and situations.

3.2.3 Multi use
The goal related to this aspect was to demonstrate that several complex sensor networks can be used by many different users each with different information needs. Two projects demonstrated this in 2014: the Goose project and the Gorillas in the Cloud sensor lab, both of them show a clear multi use of “n to m”, where both n and m are large numbers.
Gorillas in the Cloud (GITC) sensor lab
In 2012 the goal was to demonstrate that one complex sensor network can be used by at least three completely different user groups. This was materialized by the development of a multi-use sensor network in the Apenheul. In 2013 focus shifted to achieving robust detection and tracking with cameras. In 2014 various extensions showed the multi-use aspect: from face-recognition to automatically analysing behaviour, it was all implemented based on the same sensor network (multiple applications, multiple sensors).

Goose
The Goose project successfully demonstrated the capability to enable trained users to search in high volumes of sensor data from different video sensors. In 2013 this was done for pre-recorded data. Goose extended itself to multiple live video streams in 2014. Moreover a large step was taken to cross the semantic gap, enabling use of the Goose system by virtually everyone that is capable of working with a computer.

3.2.4 Scalability
Corresponding demonstrator project is Structural Integrity Monitor (SIM). The goal set on this aspect was to be able to design a network for a laboratory set-up, and then expand the design to a real life situation without any changes to the design. The demonstration for this aspect is the structural integrity monitoring of large steel structures (i.e. bridges), so the design needs to be expandable to more than 1000 m².
Self-configuration and self-organisation contribute to scalability of the sensor network, in addition tooling has been developed to evaluate the efficiency of the network design. So on the network level scalability can be achieved with the results of 2012. In 2013 this was be put to the test in practice since TNO moved from a laboratory set-up of 8 m² to an actual bridge, being the Van Brienenoord Bridge of several 10,000 m². Terabytes of data per day were retrieved. This brings us to the other big step for 2013: scalable data processing, to retrieve the data from sensor networks and transform it into information. Several data-analysis technologies have been developed (e.g. sensor clustering, anomaly detection), all aiming to reduce the amount of data and extract information. The technologies developed in 2013 have proven to be successful.

The challenge that remained open for 2014 is to analyse in real time and to find generic methods. This challenge was met since in 2014 the sensors were automatically coupled to advanced models (made by ETP Models), so that sensor data is translated in real time into predictions of remaining service lifespan. A generic data analysis method is also covered in the highlights below.

3.3 Highlights: Technological breakthroughs
All projects have been working on challenging technology quests. Each of which delivered new insights, knowledge and sometimes practical implementations of advancements in the AMSN research areas. From all projects a selection of the 2014 results has been made is presented here to illustrate the significance of the AMSN program outcome. First the technology is mentioned (where patents were filed a more general description is given), followed by the application and societal relevance.
3.3.1 **System Design: Dynamic AMSN architectures (DYNAA)**
At the SASO 2014, the Eighth IEEE International Conference on Self-Adaptive and Self-Organizing Systems held in London, UK (8-12 September 2014), the DYNAA project received the best demo award. Important key capabilities which have been added to DynAA in 2014 are a second, smarter optimizer, important additions in communications simulations and a re-targetable domain specific modelling layer which has improved DynAA user friendliness and enhances possibilities of using DynAA in various application domains. This important step is a breakthrough that turned the DYNAA tool into a tool for the design community.

3.3.2 **Data Analysis: Big Data analysis of Video and other Sensors (Big Davids)**
A stunning example of scalable data processing was performed in 2014, by instantly scaling up video analysis from one computer and one camera to cloud based analysis of 24 video streams of cameras performed by 164 cores and feeding back the analysed data in less than one second.
For any party that has varying needs in computation power, this is a very flexible, high performance yet low cost solution.

3.3.3 **Multi use: Gorillas in the Cloud (GITC) sensor lab**
In the image processing society several challenges are researched one at a time (e.g. changing light conditions, altering background/surroundings etc.). In the GITC case at Apenheul all these challenges are present simultaneously.
Two years after the start of the GITC project the team succeeded in detecting the Gorillas from in their natural habitat at the unique island in the Apenheul zoo in a robust way in a dynamically changing natural (structured) environment.
The team applied various techniques to obtain these results, from dynamic background distinction, to adaptive filtering of detections, tracking of gorillas and consecutive filtering of tracks.
The current application serves multiple purposes: the GITC sensor lab is fully operational as a test bed for further research and various applications, e.g. patient monitoring (hence the interest of parties active in healthcare) but also increases entertainment value for zoo visitors by real time gorilla localisation and visualisation to the visitors.

3.3.4 **Multi use Sensordata Search: Google for Sensors (GOOSE)**
The Goose project has reached the stage of a demonstrator system capable of real-time semantic search in sensor streams. This was the first time the Goose concept was brought to the real world.
State-Of-The-Art semantic reasoning (e.g. Stanford Parsers) and concept detection (e.g. Deep Learning Convolution Neural Network (which is the current winner of the International ImageNET object detection benchmark)) technologies were combined and expanded to create a demonstration that is capable of answering a human’s question by searching sensor data. Currently the demonstration is aimed at video and recognizes a limited set of concepts, the project has paved the way forward by allowing easy expansion with new concepts, and other sensor types. This is a field of research that is in its infancy, where TNO has made a significant step, making sure that TNO is a sought after partner.
3.3.5 **Time critical performance: Cooperative Driving: Supported Cooperative Adaptive Driving (SCAD)**

The objective of the SCAD 2014 project was to create a self-organizing system of nodes, consisting of vehicles and roadside units that cooperatively create a dynamic map. The dynamic map will be based on the combined sensors of the nodes, where information is exchanged via communication, optimized with respect to traffic efficiency and safety and to cope with the scarce bandwidth available for V2X communication. In 2014 the next breakthroughs were realized:

1. Efficient information exchange: adaptive systems concepts including Utility Based Reasoning were specified for safety in CACC. A UBR algorithm is developed that determines the safe distance between vehicles taking all uncertainties and non-ideal communication into account. The UBR algorithm determines when to transmit event based message for CACC safety. A distributed UBR Algorithm was developed that determines the optimal frequency at which each vehicle transmits its messages (in cooperation with SOX).

2. Distributed object state estimation in road-side and vehicle systems: a new ITS-G5 message type - Detected Object Message (DOM) - is defined and implemented to increase the cooperative awareness of roadside and vehicle ITS stations. A DOM contains information about a non-cooperative object that is detected by a cooperative ITS station, including information about the probability of the detection being an object and certainty (accuracy) of its position. Roadside systems sent out DOMs for objects – detected via Video Based Monitoring - that are not cooperative and that have not been detected by other cooperative vehicles (i.e. that have not sent out DOMs for this object). This way, cooperative vehicles receive information about objects they had not yet detected themselves, such as vehicles approaching from behind or from side (crossing) roads. Cooperative vehicles fuse detections from in-car sensors with information from CAMs and DOMs for target tracking. This information is added to the LDM in the vehicles to increase situational awareness for in-vehicle applications. An example is the blind-spot detection of vehicles approaching from behind while changing lanes.

3. Higher-level hierarchical control: a generic interaction protocol was developed. This protocol is characterized by a sequence of manoeuvres to execute the scenario and a corresponding wireless message sequence for vehicles engaged in the execution of the scenario. To obtain a generic solution, the manoeuvres are defined so as to represent general vehicle movements, such as splitting, merging, gap making, platooning, etc. Each manoeuvre is executed by a set of certain “agents”, i.e., a controller that specifically performs part of the required manoeuvre. Examples of agents are CACC (for platooning), Obstacle Avoiding (for gap making), and Lane Changing (for merging). The resulting controller software was implemented in real-time in three Toyota Prius test vehicles and repeatedly tested on a test track. In addition, several demos were performed, among others for Innovam and on the ISN Congress.

4. Low-level vehicle motion control: two types of low-level steering controllers were developed: 1) a yaw rate controller and 2) a steering angle controller. Both have been implemented on the Prius test fleet and extensively tested, upon which it was decided to further build on the steering angle controller, which appeared to show the most predictable behaviour. In order to practically implement the low-level controllers, a significant change in the vehicle interface (MOVE) has been made, utilizing the native power steering in park-assist mode. A high-level vehicle-following controller was developed that allows the follower vehicles to
automatically steer in order to either follow the preceding vehicle (in lateral sense) or to perform lane-keeping. These controllers were fully integrated to enable the execution of the specified scenario. As a result, it can be concluded that the scenario can be automatically executed, albeit that robustness with respect to position measurement (which is based for the larger part on GPS measurements due to the limited on-board sensor set of the Prii) must be improved.

5. iVSP: A real-time architecture and prototype of iVSP has been created and tested based on the real-time operating system Xenomai. The prototype includes real-time versions of the Sensor layer and the newly developed Actuation layer.

3.4 Highlights: Societal impact

In 2014 AMSN projects continued to demonstrate and disseminate the relevance of the research and results to the general public. It can be concluded the impact of the AMSN knowledge and technology will contribute to innovations for society and industry.

The AMSN team is especially proud to make record of the speech Prime Minister Mark Rutte held at the Hannover Messe, referring to what he called the “Smartest Bridge in the world” meaning the TNO AMSN demonstrator system on the Van Brienenoord Bridge. A part of his speech is quoted here (in Dutch):

“Helaas konden we een van de meest overtuigende bewijsstukken daarvoor niet meenemen. Maar neemt u van mij aan: de slimste brug ter wereld vindt u in Rotterdam. Dat is de Van Brienenoordbrug, die deel uitmaakt van een van de drukste verkeersaders in ons land. Sinds een paar maanden is deze brug uitgerust met een uitgekiend high tech sensorsysteem dat zelf kan bepalen wanneer onderhoud nodig is.”

The SCAD Cooperative Driving project after all media attention last year, received several invitations to give demonstrations both nationally as well as internationally. This year TNO was again invited by the Royal Institute of Navigation to present and demonstrate its research on the Autonomous Road Vehicles conference at the University of Nottingham. This invitation was a follow-up on the conference and demonstration in 2012 with the first AMSN CACC cars at the MIRA proving ground which is one the largest, most comprehensively specified and truly independent automotive proving grounds in the world, located in the Midlands at the heart of the UK automotive cluster.
With the AMSN cars many conference delegates enjoyed a perfect demo of the AMSN SCAD technology concept live at the university campus. Among the delegates were taken the test ride were Mr Roger McKinlay, President, Royal Institute of Navigation, UK, Mr Stephen Metcalfe MP, Member of the Science & Technology Committee, UK.

Further demonstrations are planned in the UK for members of Parliament and in Austria in 2015.

As of the park opening in April 2014 the visitors of Apenheul can find the location of the gorillas by means of two screens located at different locations near the gorilla island. In a special Gorilla pavilion an animation explains the joint Apenheul-TNO project to the visitors. An all-time high number of visitors came to the Apenheul in 2014 (581.000) in the year Apenheul called the “year of the gorilla”.

3.5 Results per project

In all AMSN projects are listed. The project description and project goals per project are followed by the results in knowledge and technology development in 2014. This will show that the results can be used for a wide range of applications.

Fundamental Research projects

3.5.1 System Design: Dynamic AMSN Architectures (DynAA)
Plan 2014

The DynAA project has been continued in 2014 to follow the originally defined goals and strategy. Specifically, the research and development targets for 2014 are twofold:

1. Extend the optimization capabilities of the tool completed in 2013. This accounts for joint system architecture and communication network optimization.
2. Increase the usability, accessibility and maturity of the tool, so that it can be used after the project / program end.

Objectives

The DynAA Model Construction and DynAA Simulation tools were already developed during the first phase of the project. The main targets for 2013 and 2014 were to transform the existing DynAA design evaluation (simulation) tool to an automatic system design optimizer tool – research, design and implement the remaining components of the optimization loop.

DynAA aims to develop a system evaluation and design method for robust and adaptive sensor systems. The method should be implemented in a software tool, which allows system designer to quantify the emerging key performance indicators (KPI evaluation in the figure above; often generic indicators for distributed sensor systems, like battery life, processor load, network load, but possibly also case specific performance indicators as defined and modelled by the system designer) of the various design alternatives (and thus gives the foundation for making informed design decisions) and for selecting design scenarios to carry out automatic design optimizations (e.g. optimal topology choice, protocol parameterization, optimal task allocation). In 2014, the focus was on completing the parametric design optimization and particularly on adding an additional more efficient, smarter optimization strategy which would not simply walk through the whole design space. Parametric design optimization means that the designer provides a parameterised set of architectures, and the design tool should produce the optimal parameter settings, combined with the achieved values of the different emerging system characteristics.

The secondary goal was to improve / extend the previously developed network models (the Model Construction tool in the above figure). An important element in distributed system performance, and especially an important source of performance variations, is the performance of the network connecting the individual nodes. In 2012 we have only modelled the individual links of the network. The goal for 2013 was to extend our models to include 1) the Mac layer, i.e. effects of the shared usage of the medium, 2) the network layer, and especially the effects of using multiple wireless hops, and dynamic routing effects. Focus in the research was on the protocols implemented in commonly used sensor network nodes. The main challenge was to arrive at sufficiently low-complexity models to allow efficient simulation and optimization in DynAA.

Knowledge and technology development

The DynAA project as a whole, in its own right and as part of the bigger AMSN program, has substantially enforced the knowledge and technology position of TNO, comprising the following topics:

- The knowledge to turn the evaluation of adaptive reconfigurable networked embedded systems (i.e systems that adapt themselves, e.g. to changes in the environments, or to new tasks) into a methodology which can be implemented and transformed into an operational tool (DynAA Core)
• **Automatic design space exploration and design optimization methodologies** of the adaptive reconfigurable networked embedded systems. An architecture of a complete DynAA optimization framework was researched, designed, implemented and evaluated. The designer has to provide a system model description and specifications on the optimization problem (which concerns the parameter space of the model, functions that constraint the parameters and the objective function that is to be optimized). At each loop iteration, DynAA is fed with models (experiments) that are constructed based on the model description, but with different parameterizations, according to the settings provided by the optimizer tool. The DynAA simulation in turn provides the target Key Performance Indicators (KPIs), which are fed back in the optimizer. Based on the results, the optimizer proposes a new model parameterization and advances the space exploration.

• **Modelling and implementation of DynAA multilayer communications.** In the DynAA project, TNO has been able to “reinvent” the simulation of an entire wireless communications network, from physical layer up to and including the network layer, encompassing different types of (real-life) protocol solutions. We have been able to keep the complexity fairly low which leads to acceptable runtime performances of DynAA simulations. Although such functionality also exists in dedicated network simulators today, TNO succeeded in inherently embedding such complex functionality in a systems simulation environment. This combination is quite unique. Through comparative tests with an actual wireless sensor network set-up in a lab setting, we have been able to prove the correctness of the simulation results and the subsequent capability to produce trustworthy predictions about data throughput, actual power consumption and battery lifetime.

• **Ability to develop simulation models faster, more user friendly and much less application domain specific** through an **additional modelling layer** in the DynAA framework which allows the use of meta model descriptions including some powerful modelling patterns (like multiplication) which are translated into the DynAA specific simulation models. This is supported through a graphical modelling tool. This work has been achieved in close cooperation with the Demanes project and its use has been tested and demonstrated publically.

The whole collection of tools is tightly integrated and forms ‘unique package’. This was clearly visible during the presentation of various DynAA papers at conferences in 2013 and 2014 and during the ISN conferences in Eindhoven in both years, where the stand/demo of DynAA was visited by many interested potential users.

**Continuation**
Within TNO DYNAA will become a standard tool for designing systems. Several partners in the Demanes project are also adopting the tool for their design challenges. Particularly in 2014, the DYNAA team has approached a series of companies to attract their interest and which will lead to continued interactions.
To launch an MKB Technology Cluster project in 2015 with at least five interested companies, creates the opportunity on one hand to share and discuss with these companies more in depth our vision on the challenges in the design of next generation wireless sensor networks and on the other hand improve our understanding of their design issues and the type of tooling used. DynAA in its current state can be an
interesting enabler.
The conclusion of the DynAA project is that it has true market potential.

3.5.2 Self-Organisation: Self-Organising X (SOX)

Plan 2014
Building further on the previous results of the SOX project, the SOX project in 2014 was directed to methods for designing runtime adaptive systems. This means that not every aspect is decided upon prior to the deployment of the system but that some aspect are left open so that the system itself makes a decision suitable to the situation at hand. In order to make such decisions, an architecture has been developed where design models are used as an exploration space by a combination of decision making and optimization algorithms. A literature study on these two latter algorithms was performed in SOX 2013 and assessed in some basic case studies of runtime adaptive systems. These implementations are based on heuristic solutions and expert rules, which means that a sound development of solutions making runtime design decisions is still open. There are three reasons for developing such sound solutions when comparing them to the current heuristic ones:

• The performance of the ‘Reasonar’ will be improved;
• The predictability of the ‘Reasonar’ will be improved;
• The set of considered run-time actions will be extended

These aspects are desired, either for a designer or for a customer/user, when deploying runtime adaptive systems in the real world.

Objectives
For clarity, our ideas are illustrated in the Figure 4 a schematic setup of the total system is shown. One Primary function $f_i(.)$ is picked from the system having an input ‘$x$’ and an output ‘$y$’ (a Primary function is a function essential to meet the goal of the system, e.g., object tracking). A Reasonar is able to act via $a$ to change the parameters of this function $f_i(.)$, to select an alternative function $f'_i(.)$ or to send information to other functions. Also, the Reasonar sends a utility function of ‘$x$’ back to the system, indicating its desired quality of input ‘$x$’. Similarly, a utility function of ‘$y$’ is received indicating the quality of ‘$y$’ desired by the system. To what extent this quality can be will be determined by the Reasonar according the actions ‘$a$’ it computes. To that extent, the Reasonar makes use of input from the Modeller, which models the effect of a particular input $x$ and particular set of actions $a$ on the expected output ‘$y$’. For SOX2014, the following research directions & development were chosen

• Performance models of algorithms
• Developing advanced reasoning
• Stability of the decisions made
Knowledge and technology development

A fundamental new concept of (run-time) utility based self-optimisation and self-organisation has been developed and an architecture model that is suitable to design such systems. In addition the basic Reasonar algorithms for system function and system resource management were developed.

The fundamentally new method has been successfully applied to utility based state estimation for climate control, utility based information management between autonomous cars and roadside for on-ramp merging of vehicles and between cars for safety in cooperative adaptive cruise control and for utility based self-optimisation for dynamic situations in smart grids.

Continuation

1. Application oriented research in scope of ERP Complexity, for cooperative driving applications.
2. Application in ERP Energy storage and Conversion, for optimization and reconfiguration of smart energy grids.
3. A first real life application in the international i-GAME (GCDC2) demonstration application, application of optimization of safe headway distance (critical headway) under varying communication conditions and taking into account uncertainties in individual vehicle states and changing (environmental) conditions.

3.5.3 Data Analysis: Big Data analysis of Video and other Sensors (Big Davids)

Plan 2014

In the Figure 5 the work packages and their relations are depicted.
Objective
Goal of this project is to become one of the important players in the world of innovative applications of affordable large scale (near) real-time big-data analysis technology of video and other sensor streams in various domains.

Knowledge and technology development
In 2014 work was done on several building blocks for data analysis:

- SensorClustering: In 2013 a clustering technology based on dendograms to get insight in multi-sensor behaviour via a changeability sensor was implemented (TRL 4 in 2013). In 2014 a scalable streaming version was build (TRL 5/6 in 2014)
- Distributed big data processing: The proof of principle (TRL 4 in 2013) based on Storm to process in real-time video and 1-d sensor streams is developed and brought to Open Source community (TRL 6/7 in 2014)
- StormCV platform used to create distributed image processing pipelines (TRL 5/6 in 2014)
- Big data visualisation: Component for generating space-efficient pixel-based visualisations of (raw) big sensor data (TRL 5/6 in 2014).

Continuation
In the STOOP3 project (together with utility network companies) the development of the FlowManager from the project will continue. Projects for the Ministry of Defence incorporated in the Big Data Contour starting next year may also use the platform for processing data from manned/unmanned vehicles. Some of the new ERP programs (e.g. ERP Structural Integrity, ERP Sense making of Big Data) will be using the platform in near future with scaling their models. The team made a list of possible propositions this has led to the creation of a Technology Cluster.

3.5.4 Control: InControl
Plan 2014
In 2014 the InControl project addressed the following topics:

- Optimization of very complex dynamics:
• Monitoring of very complex dynamics
• Modelling of very complex dynamics
• Event based sampling for packet dropout:
• Estimation and control solutions for event based sampling

Objectives
The three research questions addressed in this project were the following:

1. Optimization of very complex dynamics
   a. Can we expand the optimization algorithm that was developed in 2013 to a truly holistic controller?
   b. Can we make use of and/or compare with recent developments in optimization of coupled partial differential equations, known in a small academic society of mathematicians?
   c. Can we assimilate a CFD model with measurements in a linearly scalable fashion?
   d. Can we couple our algorithms with the core of the open source CFD software suite OpenFoam?

2. How to develop a feedback control loop based on event sampled measurements?
   a. And how to apply this event based strategy in implementable CACC algorithms so to reduce communication load?

3. A choice of the following
   a. Can Lattice-Boltzmann be a suitable alternative for CFD and can we develop better monitoring and control algorithms based on it?
   b. Can we use quadrotors as mobile sensors to measure temperature and air flow velocity?
   c. Can the emergent behaviour of complex systems better be predicted when using bond-graph models?

On the first objective, questions a and c have long remained unanswered, despite research efforts. Very recently, an idea has popped up that might answer both questions. Question b relates to the (adjoint) SQP method.

Regarding the second question, no application of event based control in the CACC application was performed from the InControl project, since the SCAD project already succeeded with their event based control solution. As such, there was little purpose in developing another control strategy and application areas were sought for in the underwater communication and robotics domain.

For the third objective, a choice was made to invest in the Lattice-Boltzmann approach. A controller was developed based on a Lattice-Boltzmann model. Properties as the reduction of computational demand do not seem to outweigh the increased memory requirements. Further research is required to answer the question for which cases Lattice-Boltzmann models outperform traditional CFD-models. Also, two concepts for new flow sensing techniques were thought up and we tried to set up cooperation with the NLR.

Knowledge and technology development
- Real-time climate monitoring & control
  Continuation of our real-time monitoring and real-time control algorithms for Navier-Stokes based processes. Some improvements have been made, as well as a better comparison to state of the art. A new idea, might solve some of the bigger issues (monitoring scalability and coupling of fields, bringing this a leap forward.
- Event-based networked control with packet loss.
  A novel approach for coping with package loss of event sampled measurements with a corresponding state estimation algorithm. The succeeding control algorithm making use of the state estimation results is yet under development.
- Exploratory research.
  An algorithm to optimize a temperature distribution using a Lattice-Boltzmann model based controller was pioneered. Leading to understanding about the nature of the model and it's applicability to the control of indoor climate.

Continuation
For indoor climate, there are three applications:
- Use of algorithms in design optimization
- (Real-time) indoor climate (or other process) monitoring
- (Real-time) indoor climate (or other process) control

The first is technically the easiest. We will approach CFD software companies and simulation companies to investigate if we can cooperate or maybe even sell our algorithms. Though it seems likely that one (partially) subsidized is needed to really proof added value in a coupled situation. Surely all kinds of challenges will pop up when trying to couple with other software. There is an opportunity to do this in the new 3D greenhouse climate project, as that is aiming to develop a design tool to help optimize climate installations for homogeneous greenhouse climates. A perfect fit

The second has been proven as concept in Braunschweig. We are now trying to find partners to set up a subsidized project. Amongst these partners will also be simulation and sensing partners, so our role will be on the algorithms and system integration. The project should be a pilot. This pilot will validate the technology and also become a basis to define a business case for the next step:

Control will be the step with the biggest pay-off for end users. Only some applications find value in monitoring alone, most of them will need control too to save energy and improve the climate. This step is the farthest from the market, mostly because no one will let you try out new control algorithms in real environments if they have not been proven yet. Therefore, we need to focus in the monitoring first, build a business case and continue toward control.

Demonstration projects

3.5.5 Time critical performance: Cooperative Driving: Supported Cooperative Adaptive Driving (SCAD)

Technology goal
The primary goal of SCAD is the creating of situation awareness in rapidly changing circumstances, focusing on time critical performance. This means sharing relevant
information in real-time between cooperative systems and real-time fusion of available information based on requirements of the control-unit. In 2014 the technology goal was to implement (interactive) communication and in-car algorithms for tracking, safety checker and high-level and low-level vehicle control to demonstrate complex manoeuvres.

Societal goal
Cooperative driving enables a better and safer traffic flow both in urban areas and on motorways. The effects are reduction of traffic jams, reduction of the number of casualties in traffic, and lowering CO$_2$ emissions.

Plan 2014
2014 fully focussed on the following topics to support the technology goal:
- Combined longitudinal and lateral low-level steering control. Instead of car following, it will be possible to execute the complex manoeuvres explained in Figure 3 autonomous.
- Higher level hierarchical control, focusing on configuration of platoons, as well as managing different sub-stages of complex manoeuvres (e.g. coordinating the sub-stages platooning, splitting, gap-creating, merging).
- Object state estimation: Improvement of the object state estimation by sharing not only ego positions of vehicles, but instead of this entire world maps. Information of the roadside is actively used for this. As a result, the object state becomes more complete, and allows more advanced automated manoeuvres.
- Efficient information exchange, reducing the required communication bandwidth at the communication level (via Dynamic Congestion Control at the radio access layer as well as the information level via Utility Based Reasoning algorithms.

Objective
- The main objective was to demonstrate complex manoeuvres. This is shown in live-demo’s and a video was developed for communication purposes.

Knowledge and technology development
In Figure 6 the three main sub systems of the SCAD concept are given.
- Efficient information exchange
  - Adaptive systems concepts including Utility Based Reasoning specified for ramp metering and safety for CACC. Necessary Adaptation of Roadside and vehicle architecture are identified. Algorithm developed that determines the safe distance between vehicles taking all uncertainties and non-ideal communication into account. UBR algorithm that determines when to transmit event based message for CACC safety. Distributed UBR Algorithm developed that determines the optimal frequency at which each vehicle transmits its messages (in cooperation with SOX).

- Distributed object state estimation: Contributions have been realized in the Road-side and vehicle systems:
  - A new ITS-G5 message type is defined and implemented to increase the cooperative awareness of Road side and Vehicle ITS stations. The working name of this new message type is the Detected Object Message (DOM). A new message type is defined to distinguish it from standard ITS messages that contain information from cooperative ITS stations, such as the CAM. A DOM contains information about a non-cooperative object that is detected by a cooperative ITS station, including information about the probability of the detection being an object and certainty (accuracy) of its position. With the DOM we deliberately follow a different approach from the CPM message developed in the KOPER (KOFAS) project.
  - Road-side systems continuously track vehicles from road side and vehicle based information sources, such as the video-based monitoring (VBM) system at the road side, and messages received from vehicle, including DOM messages. DOMs from vehicles are fused with VBM detections to refine the situational awareness at the road side in the DYNAMAP.
  - Road side systems sent out DOMs for objects that are not cooperative and that have not been detected by other cooperative vehicles (i.e. that have not sent out DOMs for this object). This way, cooperative vehicles receive information about objects they had not yet detected themselves, such as vehicles approaching from behind or from side (crossing) roads.
  - Cooperative vehicles continuously track neighbouring objects with their own sensors. Vehicles sent out DOMs for non-cooperative objects they detected from their on-board sensors, to inform neighbouring vehicles and road side units.
  - Cooperative vehicles fuse own detections with CAMs and DOMs (target tracking). This information is added to the LDM in the vehicles to increase situational awareness for in-vehicle applications. An example is the blind-spot detection of vehicles approaching from behind while changing lanes in the Use Cases.

- High-level hierarchical control in a platoon of vehicles:
  - The use case has been further specified by means of so-called Sequence Diagrams. In addition, the use case scenario was linked to the scenarios as defined in the EU-project iGAME to be able to utilize some synergy.
  - A generic interaction protocol was developed. This protocol is characterized by a
sequence of manoeuvres to execute the scenario and a corresponding wireless message sequence for vehicles engaged in the execution of the scenario. To obtain a generic solution, the manoeuvres are defined so as to represent general vehicle movements, such as splitting, merging, gap making, platooning, etc. Each manoeuvre is executed by a set of certain “agents”, i.e., a controller that specifically performs part of the required manoeuvre. Examples of agents are CACC (for platooning), Obstacle Avoiding (for gap making), and Lane Changing (for merging).

- Before being implemented to the benchmark vehicles, the agents have been designed on a simulation level, to which end the existing simulation model was extended with functionality to simulate lateral movements.
- The resulting controller software was implemented in real-time in three Toyota Prius test vehicles and repeatedly tested on a test track. In addition, several demos were performed, among others for Innovam and on the ISN Conference.
- In addition, a professional movie is currently being made to be used at congresses and for acquisition purposes, for instance.
- Based on the current work, a new initiative was taken: in ERP Complexity, the topic of Consensus seeking, as a means to implement manoeuvring in road traffic, will most likely be included. A report regarding higher-level hierarchical control is currently written; a conference publication will be planned for 2015.
- In order to guarantee (longitudinal) safety while performing the required manoeuvres, a safety concept was developed, based on the existing (but improved) safety checker (patent pending), combined with a newly developed collision avoidance controller. This concept was tested in practice on a test track.
- The longitudinal safety concept is extended so as to include packet loss. So far, the safe distance calculation is based on whether there is wireless communication or not. However, there is also a "grey area in between": sometimes a message arrives and sometimes a message is lost. To include this phenomenon, the probability of packet loss, during a certain time window is determined. This probability is used to determine the expected time of receiving the next message at a predefined certainty. The safe distance is extended with this time.
- An extensive internal report has been written on the longitudinal safety concept, and a conference paper is planned for 2015 (ITSC).

- Low level steering controllers:
  - Two types of low-level steering controllers were developed: 1) a yaw rate controller and 2) a steering angle controller. Both have been implemented on the Prius test fleet and extensively tested, upon which it was decided to further build on the steering angle controller, which appeared to show the most predictable behaviour.
  - In order to practically implement the low-level controllers, a significant change in the vehicle interface (MOVE) has been made, utilizing the native power steering in park-assist mode.
  - A high-level vehicle-following controller was developed using the Linear Quadratic Regulator method (both employing low-level yaw rate control and low-level steering angle control). This controller allows the follower vehicles to automatically steer in order to either follow the preceding vehicle (in lateral sense) or to perform lane-keeping. These controller have been implemented in the test fleet.
  - To allow for smooth lane change manoeuvres, trajectory generation in the absolute sense was not possible since this would have required a very accurate position estimation. Instead, it was decided to apply (lateral) error smoothing, such that a lane change can be performed by letting the vehicle track a preceding vehicle on the next lane (merging), or by increasing the desired lateral position with respect to a preceding vehicle in the same lane (splitting).
  - WP4 and WP5 activities were fully integrated to enable the execution of the
specified scenario. As a result, it can be concluded that the scenario can be automatically executed, albeit that robustness with respect to position measurement (which is based for the larger part on GPS measurements due to the limited on-board sensor set of the Prii) must be improved.

- An internal report on the lateral vehicle control has been written. External publication will be performed in conjunction with the work of WP4.

- Real-time architecture and prototype of iVSP

A real-time architecture and prototype of iVSP has been created and tested based on the real-time operating system Xenomai. The prototype includes real-time versions of the Sensor layer and the newly developed Actuation layer. Both layers allow real-time network and serial CAN operation. Real-time communication queues are used combined with executing real-time tasks in primary mode, which takes advantage of all real-time capabilities of Xenomai nucleus.

Continuation
Part of the research work done in WP2/4/5 in this project will be continued in EU project iGame. Also some topics in WP2/4 are identified for continuation in the ERP Complexity.

Some of the knowledge / solutions developed in SCAD / ASA are already deployed in projects with market parties via the themes e.g. in the Spookfiles A58 project of the action program Beter Benutten of the Dutch ministry of infrastructure and environment (I&M) For the next year the knowledge of distributed state estimation with support of roadside systems and applications will be deployed in SPITSlive, a 14 MEUR public-private cooperation project.

The real-time iVSP platform developments will be used in the EU-FP7 project VRUITS to create a real-time sensing and communication solution for distributed sensing of VRUs at crossings.

3.5.6 Multi use: Gorillas in the Cloud (GITC) sensor lab

The GITC demonstration project is a joint effort of the Apenheul Foundation, Hollander Techniek BV, Doorrood BV, InfoCaster BV, Compudac AutomatiseringBV. The joint team designed a dedicated logo for the living lab.

Technology goal
To develop a multi-use sensor network ecosystem that is open to other developers and suitable for end-users with very different requirements (industry, consumers, education and research).
Societal goal
The GITC sensor lab acts as a test bed for various applications, e.g. patient monitoring (hence the interest of parties active in healthcare). The GITC sensor lab increases entertainment value for zoo visitors by real time gorilla localisation and visualisation to the visitors. Finally it is also used to demonstrate the attractiveness/potential of ICT in order to attract more students to ICT studies. The portal to view the captured video content selected by the AMSN algorithms is shown in Figure 7.

Plan 2014
In 2012, the basis of the GITC sensor lab in the Apenheul was realized. On top of the systems contributed by the partners (cameras, broadband network, servers and workstations), AMSN implemented processing and architecture as a reference platform. In 2013, TNO developed further on this base and further enhanced features such as detection and tracking with special attention to the reliability and robustness of the gorilla detections to avoid false detections.

Objective
1. To transfer the control of the operational GITC sensor lab at the end of 2014 to Apenheul and partners so that it is self-maintaining and growing. This requires
   a. It can carry out reliable and robust detections among all relevant conditions
   b. Ease of operation and maintainability by third parties, including achieving targeted documentation, technical transfer, workshops
2. Extend the possibilities of the GITC sensor lab as a research platform for TNO, Apenheul and others for multiple types of uses and users:
   a. multi-party / multi use: add management functionality to the Field Lab in order to allow expansion with new sensors and software / hardware.
   b. Face recognition of monkeys (in cooperation with Fraunhofer) can be added to the perception chain as new data extraction function and also serves as an example for other parties to add functionality to the Field Lab.
3. Testing what is an effective approach for (semi-automatic) annotation of video data that is easier to search for immediate or later use. Together with AMSN Big Davids project This is also of importance in the development of new methods of interpretation, such as for the detection, tracking, classification, identification, behavioural analysis, anomaly detection.
4. Dissemination: Continue making the GITC Field Lab known in both industry and research institutions as a research platform, in order to establish that (national and international) research is attracted to the field of sensor networks.

Knowledge and technology development
New knowledge has been developed in the field of robust adaptive detection and tracking of moving objects (gorillas) in changing observation environments. Complicating factors were (and are) combinations of dynamically changing illumination (light level, shadows, colouring), different structured and changing backgrounds (due to vegetation, wind, sun, moving shadows, seasonal colouring), low contrast situations of the moving object with respect to the background, and lack of object movement complicating continuous detection. Several detection and filtering methods have been investigated and implemented aiming at minimizing the number of false positives (false detections) and minimizing the number of false negatives (e.g. missed detections).

Building further on the FP7 iCore project concept knowledge, new application knowledge has been developed in 2014 in the field of multi-use of virtualized hardware and software resources, aiming at later wider spread controlled and non-conflicting use of the Apenheul Field Lab hardware and software as well as observation data and meta data.

Continuation
The Living Lab at Apenheul is handed over to partners that will keep it operational, so that any interested party can join and expand the functionality of the lab.

Besides this TNO has business development activities ongoing targeting other zoos, and in the field of general observation of animals / persons in a complex changing environment.

3.5.7 Multi use Sensordata Search: Google for Sensors (GOOSE)

Technology goal
The GOOSE (GOOgle for SEnsors) project has the challenge to research possible way to provide the capability to search semantically for any relevant information within “all” (including imaging) sensor streams, in near real time, in the entire internet of sensors. Similar to the capability provided by presently available search engines which enable the retrieval of information on “all” pages on the internet.

Societal Goal
Goose will provide users – military as well as civil the access and the tools to potentially query all sensor sources in the internet. This will happen in the intelligence process, where it now is limited in analysis capacity as well as during mission execution where situational awareness of a larger areas will be made available. For example, the system will also made available to the platoon level what is happening after the next corner in the road.

Besides this GOOSE connects well to the roadmap Big Data Evolution in which data interpretation and integrity of big data are important research items.

Plan 2014
For the GOOSE 2014 project the desired situation is to be able to improve the accuracy of the search capability by closing the semantic gap. This Semantic Gap is wide, and for
2014 it was proposed to work on three pillars which should provide support to bridge this semantic gap without too large stretches:
(1) improve semantic analysis by matching ontologies;
(2) improve concept detection in sensors and
(3) better concept definition using user feedback

Objective
The GOOSE project was to make an initial demonstration system, allowing semantic search on videos.

Knowledge and technology development
- Knowledge and technology how to apply a Deep Learning Convolution Neural Network (DLCNN)
- Knowledge and technology how to train new concepts to a Deep Learning Convolution Neural Network as Second Stage classifier
- Domain-independent GOOSE demonstrator framework
- Semantic Interpretation using Stanford Parsers and links to external ontologies

Continuation
- Partial continuation is foreseen in the MIST/A1 project “Image Understanding”, which will reason based on sensory inputs using a level of self-consciousness. It is expected this self-consciousness will benefit from the GOOSE semantic reasoning on sensor concepts.
- Partial continuation is foreseen in the ERP Sense making of Big Data program.
- Partial continuation is foreseen in the EU Horizon2020 project “ONESELF”.
- Partial application is foreseen in the MinDef program “Big Data”; the NCTV project HARVEST and its associated SMO project VINDIGO.
3.5.8 **Scalable: Structural Integrity Monitoring (SIM)**

![SIM demonstrator host: Van Brienenoord Bridge, Rotterdam, The Netherlands](image)

**Technology goal**

System adaptivity & scalability; To develop a scalable system that monitors both the conditions that cause degradation and the degradation itself. This requires that the system is capable of localizing degradation areas, ‘hot spots’, where additional sensors can be placed to monitor the extent of the damage (sizing). This requires flexibility and adaptivity to permit up-scaling and sensor integration of the sensor network.

Ease of deployment and robustness; Ease of deployment means, that sensors can be easily installed at accessible locations, without special surface preparation. The sensor should provide information about a certain area around the sensor, avoiding installation at a location difficult to access. The concept requires for random (temporarily) placement of the sensors.

**Societal Goal**

Structural Integrity Monitoring (SIM) systems should provide up-to-date information about the past and current condition of the infrastructure, as well as a reliable prediction of the remaining structural life.

Permanently installed monitoring systems can provide up-to-date information at any desired moment without interfering with the operation of the asset. Because permanent sensors can be remotely monitored, the number of expensive inspections on site can be decreased. With an effective use of the monitoring data, users can optimally plan maintenance and prolong the life span. This will limit maintenance costs, failure probability or costly repairs and increases availability.
Plan 2014
The Structure Integrity Monitoring AMSN demonstrator project has a planned duration of 4 years. It started in 2011 and planned to finish in 2014 by means of successful lab trail tests (SIM breadboard) and demonstration in a real life environment (BLSD project). In order to achieve this goal, several tasks have to be performed which are schematically presented as a flow logic below in Figure 10.

In 2011, the unique TNO approach to Structural Integrity Monitoring has been defined. The use of an advanced sensor network architecture is however heavily related to the measurement techniques that are available now and will become available in the future. Therefore assessment of the available sensor- and modelling techniques was necessary. Parallel to the technical work packages attention was given to the business cases related to the application fields: bridges, wind turbines at sea and piping.

In 2012 a lab scale demonstrator (breadboard) was realised which served for testing and validation of several sensor- and modelling techniques. The breadboard also functioned as a means of demonstrating the possibilities of distributed processing in a sensor network architecture to facilitate scalability. In parallel with the breadboard related work, preoperational work has been performed for realizing a future field demonstrator.

In 2013 the lab scale demonstrator (breadboard) was used for further testing and validation of sensor- and modelling techniques in combination with variable amplitude loading. In parallel a measurement and validation program has been setup on the Van Brienenoord bridge in Rotterdam (Figure 8) in the framework of the BLSD project. Besides the technical aspects, considerable effort has also been put in the business case for a steel bridge and sharing the outcome (and its input parameters) with potential users.

In 2014 the project will be organised along the measurement- and modelling techniques as schematically presented above. The main techniques are: remaining life time prediction based on TOFD measurements (inspection data) and the guided wave crack monitor technology, distributed vibration monitoring, acoustic emission monitoring and data presentation. Implementation of these techniques will make use of scalable wireless implementations and adaptive sensor networks. Predominantly tested on the breadboard but also on the Van Brienenoord bridge.
Objective
In 2014 the project is organised along the measurement- and modelling techniques. The main techniques are: remaining life time prediction based on Time Of Flight Diffraction (TOFD) measurements (inspection data) and the guided wave crack monitor technology, distributed vibration monitoring, acoustic emission monitoring and data presentation. Implementation of these techniques will make use of scalable wireless implementations and adaptive sensor networks. Predominantly tested in the laboratory on the SIM breadboard but also on the Van Brienenoord Bridge (VBB).

Figure 10 SIM project flow logic
Breadboard tests are performed to verify the enhanced models that incorporate crack acceleration and retardation as a result of load sequence effects. The breadboard test will also be used to verify the performance of the Guided Wave crack monitor on a more complex steel structure such as a bridge deck and a new algorithm developed for Acoustic Emission (AE).

Tests on the Van Brienenoord Bridge Field Lab will be used to measure the load spectrum that will be used for the breadboard crack growth experiments. The AE measurements on the Van Brienenoord Bridge will be continued to obtain experience with a permanent AE installation and the effects on for instance degrading of components or coupling. Wired vibration sensors on the Van Brienenoord Bridge will be used to study the performance of the Random Decrement Frequency Domain Decomposition (RD-FDD) method. A wireless vibration sensor network will be installed on the Van Brienenoord Bridge to verify the operational performance predicted by DynAA simulations.

Knowledge and technology development

The overall project objective to monitor small and large cracks in large steel structure to ensure safety at all times, prevent unforeseen down-time and minimize maintenance costs is realized by means of a real time & innovative sensor system that:

1) Predicts remaining life time by load measurement (Strain) and ideally supplemented with current crack size information
2) Is able to detect large cracks or fractures (Vibration)
3) Is able to detect & locate small cracks (Acoustic Emission)
4) Is able to quantify the size of a small crack (guided wave)

1) Prediction of remaining life time; We make use:
   • Of enhanced fatigue life prediction model that incorporates variable amplitude loading in combination with crack measurement data
   • In the BLSD project, probabilistic tools are used to extrapolate local monitoring results over the entire structure
2) Detect large cracks or fractures (vibration); We make use:
   • Of novel algorithms that can be applied in a layout with wireless sensor nodes
that are easy to install and avoid the costs of installing long cables

3) Detect small cracks (Acoustic Emission); We make use:
   • of the quasi-beamforming (QBF) method to accurately localize the crack, and estimate the crack growth by decomposing the AE signals to fundamental guided wave modes
   • of the novel algorithms for the QBF analysis that can be implemented in a wireless layout with easy-to-install hardware which can cover a large area, radius is currently 4 m (50 m²); 2013; to be enlarged to 6 m (110 m²); 2014

4) Quantify the size of a small crack (guided wave);
   • No other technique can monitor the exact size of a small crack at the intersection of deck plate-trough-cross beam without asphalt removal

In all the four items mentioned above we have unique knowledge. The unique knowledge for item 3 and 4 is protected with a patent. For item 1 our algorithms are unique, currently it is foreseen to keep this confidential and implemented the algorithms as a black box in an asset management tool for life time prediction. For item 2 it is unknown what can be patented since there are a number of other players working on this subject as well. The first question to be addressed here is to find out how unique the novel algorithms are, and if the outcome is positive we could apply for a patent as well.

Continuation
The Living Lab at the Van Brienenoord Brug will be continued by TNO and RWS.

The new ERP "Structural Integrity" program is defined which in part builds on the knowledge generated in the SIM project, but also shifts attention to concrete structures.

3.6 Patents

4 patents/premier depots resulted from AMSN in 2011-2012:
1. Sample Rate Changeability (patent)
2. Safety Checker (premier depot)
3. Smartphone Time of Arrival precision positioning system (premier depot)
4. Automatic video based action classification (premier depot)

In 2013 4 new patent applications have been submitted:
1. Premier depot January 2014 “Navier-Stokes based optimization”
2. Internal depot PLT 2013123 Decentralized and Quantitative Acoustic Emission for Crack Monitoring
3. Internal depot PLT 2011148 Baseline generation for crack detection
4. Internal depot December 2013, “Navier-Stokes based estimation”

In 2014 no new patents have been submitted
3.7 ISN conference 2014

The results of the AMSN projects have been successfully presented on the fifth annual ISN conference on November 4th, 2014 at the High Tech Campus in Eindhoven. The event was promoted internationally to attract potential sensor networks users and researchers either as presenter or as visitor of the conference. To achieve a substantial growth of the footprint of the ISN conference and more importantly, to ensure a sustainable life after 2014 the concept and organization has been handed over to a commercial event organiser. This led to the fruitful cooperation with Jakajima BV which will continue the series. As a result a multi-tier program could be presented including international key note speakers and workshops in the field of sensors, applications of sensor networks and AMSN systems technology. Many delegates from industry, universities as well as government organizations actively participated the event. Speakers included Deloitte, Cisco, NXP, SAP, Thales, Axians (a.k.a. Imtech ICT), Graz University of Technology, Cambridge University, Sensalytics, Planet OS, PTC Thingworx, Mira, Riverrun, Actility, VORTech, Orange, Twilight and Utterberry.

![Partners and presenters at the ISNConference 2014](image)

The plenary session was moderated by Pieter Hermans, Matchmaker for innovators, Jakajima.
During the conference a demo market place was set up accessible for the delegates featuring demonstrations from companies and several AMSN projects. The live demonstrations were immensely successful, with many attendees that were challenged by Jelle Galema (forward of the Dutch national hockey team) to get the fastest shot on goal with Hockeytracker.nl, and enthusiastic reactions on the opportunity to drive along in a platoon of cooperative cars. Experiencing the power of sensors.

In the afternoon a total of eight breakout sessions were organized covering application areas for ISN systems featuring topics:

- Sensor Networks Infrastructure
- Sensor and Science
- Connected Cars
- Media / Creative industry
- Building Management
- Infrastructure
- Sensor Technology & Sport
- Sensor Tech Start-Ups

The conference was visited by an all-time high number of delegates.

Figure 13 Impression of the 5th ISNConference at the HighTech Campus Eindhoven
3.8 Publications

For a program of the size of AMSN between 24 and 40 peer reviewed publications is considered on par in international benchmarks. In 2012, there were 17 accepted publications, in 2013 these numbers almost doubled to 32 publications. In 2014 an even higher number of publications was published. Thus AMSN has improved its scientific output in the last 2 years, and is performing in correspondence with its benchmarks.

Besides the scientific peer-reviewed papers, the activities in the projects of AMSN have resulted in several other types of publications and publicity in 2014. Especially the coverage in the press has grown, almost doubling compared to an already successful 2013 as can be seen from the overview below (Figure 14).

![Figure 14 Overview of AMSN publications and presentations](image)

The numbers of 2014 are indicated in Figure 15 below, followed by an overview per project of all publications.

![Figure 15 Number of AMSN publications in 2014](image)
3.8.1 **System design: DYNAA:**

- Relja Djapic, Yohan Toh, Job Oostveen, “*Radio channel characterization of a metal bridge segment at 868MHz and 2.4GHz*”, ACM MSWim 2013.

accepted/published short papers, workshop papers, and posters

- *Poster and demonstration during the ISN Conference in Eindhoven in November 2014.*

- *Demonstration at the IEEE Sosa Conference in 2014 in London. Received Best Demo Award*

news articles, interviews, and other types of publicity.

- A website has been established: https://www.tno.nl/content.cfm?context=thema&content=prop_case&laag1=892&laag2=920&laag3=121&item_id=2254
- Tutorial video has been produced which is available on the public Internet: [http://youtu.be/ZP6q9J5wX4k](http://youtu.be/ZP6q9J5wX4k)

3.8.2 **Self Organisation: SOX:**

- Leon Kester, Maarten Ditzel, “Maximizing effectiveness of distributed mobile observation systems in dynamic situations”, paper for Fusion 2014 conference

submitted full papers (not yet accepted)

invited / keynote presentations

- Special session at the Fusion 2014 conference, co-chaired by Leon Kester (TNO): “Sensor Scheduling and Resources Management”, special track “goal oriented sensor, resource and function management”, with Uwe Hanebeck (Karlsruhe Institute of Technology / Institute for Anthropomatics and Robotics) and Alexander Charlish (Fraunhofer Forschungsinstitut für Kommunikation, Informationsverarbeitung und Ergonomie FKIE)
- Leon Kester, Designing for adaptivity in distributed observation systems, 5th ISN conference, Eindhoven, Nov. 4 2014

3.8.3 Data Analysis: Big DAvids

peer-reviewed, published

- “A new approach for structural health monitoring by applying anomaly detection on strain sensor data”, presented on SPIE, Smart Structures/NDE 2014

submitted full papers (not yet accepted)

- Dynamically Scaling Apache Storm for the Analysis of Streaming Data, submitted to CLOSER 2015.
- “StormCV a scalable computer-vision platform”, submitted to “IEEE Journal of Transactions on circuits and systems for video technology”

invited / keynote presentations

- ISN Conference 2014: Presentation “Elastic, streaming, cloud based, sensor data processing”

accepted/published short papers, workshop papers, and posters

- ISN Conference 2014: Poster Elastic Stream Processing

demonstrations

- ISN Conference 2014: Goose/BigDAVidS-demonstration

news articles, interviews, and other types of publicity

- Open Source software
- Presentation to be held on Big Data Groningen meetup (14-1-2015)

3.8.4 Control: InControl

peer-reviewed, published

- Time-periodic state estimation with event-based measurement updates
  J. Sijs, B. Noach, M. Lazar and U. Hanebeck
- A study on event triggering criteria for estimation
  J. Sijs, L. Kester and B. Noack
  In the Proc. of the FUSION 2014, Salamanca, Spain

invited / keynote presentations

- 3D Climate monitoring, presentation on ISN Conference 2014, Eindhoven
accepted/published short papers, workshop papers, and posters

- ISN Conference 2014: Poster 3D Climate Control

3.8.5 Cooperative driving: SCAD

peer-reviewed, published

- Ir. Ellen van Nunen and Dr. Ir. Jeroen Ploeg, Safety aspects of cooperative automated driving, Nav. Series Autonomous Road Vehicles, Nottingham UK, April 29, 2014
- Gerdien Klunder, Henk Taale, Leon Kester, Serge Hoogendoorn, Information Utility for Ramp Metering, IFAC, Kaapstad South Africa,
- Bart Netten, Igor Passchier, Harry Wedemeijer, Rou Bours, Scaling up penetration rates in field tests by emulating V2X communication, ITS World Congress 2014, Detroit, Sep.7-11 2014.
- Bart Netten, Steps towards Standardization of Cooperative Adaptive Cruise Control, ITS World Congress 2014 (SIS68), Detroit USA, Sep. 7-11 2014

invited / keynote presentations

- Jeroen Ploeg, Cooperative manoeuvring in road traffic, 5th ISN conference, Eindhoven, Nov. 4 2014
- Leon Kester, Designing for adaptivity in distributed observation systems, 5th ISN conference, Eindhoven, Nov. 4 2014

accepted/published short papers, workshop papers, and posters


demonstrations

- TNO SCAD team, TNO's Cooperative Driving experience, 5th ISN conference, 4-11-2014

news articles, interviews, and other types of publicity

- RADIO - BNR Nieuwsradio: Cooperatief rijden
- DIGITAL - Eindhovens dagblad: Coöperatief rijden met auto's: veilig en goedkoop
- DIGITAL - Eindhoven Nieuws: Coöperatief rijden met auto's: veilig en goedkoop
- Newspaper - Volkskrant: Veel te dicht op elkaar, maar toch veilig
- DIGITAL - Verkeersnet.nl: Coöperatief rijden komt dichterbij
- DIGITAL - Tweakers: Veilig bumper kleven tegen files
- DIGITAL - Dichtbij: Demonstratie coöperatief rijden: kort op elkaar rijden door draadloos communicerende auto's
3.8.6 Sensordata Search: Goose
submitted full papers (not yet accepted)
- “Knowledge Based Query Expansion in Complex Multimedia Event Detection”, Maaike de Boer, Klamer Schutte, Wessel Kraaij, Submitted to Multimedia Tools and Applications, 15 November

invited / keynote presentations
- Fast re-ranking of visual search results by example selection”, John Schavemaker, Martijn Spitters, Gijs Koot, Maya Sappelli, submitted, European Conference on Information Retrieval, Vienna, 2015
- Applying Semantic Reasoning in Image Retrieval, Maaike de Boer, Laura Daniele, Paul Brandt, Maya Sappelli, submitted, The International Workshop on Knowledge Extraction and Semantic Annotation (KESA), Barcelona, 2015
- Klamer Schutte, Henri Bouma, John Schavemaker, Laura Daniele, Maya Sappelli, Gijs Koot, Pieter Eendebak, George Azzopardi, Martijn Spitters, Maaike de Boer, Maarten Kruijff, Paul Brandt, “Interactive detection of incrementally learned concepts in images with ranking and semantic query interpretation”, submitted, Annual ACM International Conference on Multimedia Retrieval (ICMR), Shanghai, 2015

accepted/published short papers, workshop papers, and posters
- “VIREO-TNO @ TRECVID 2014: Multimedia Event Detection and Recounting (MED and MER)”, Chong-Wah Ngo, Yi-Jie Lu, Hao Zhang, Ting Yao, Chun-Chet Tany, Lei Pang, Maaike de Boer, John Schavemaker, Klamer Schutte, Wessel Kraaij

Demonstrations
- Intelligent Sensor Networks Conference 2014, 4 November, Eindhoven

3.8.7 Gorillas in the Cloud Sensor lab
demonstrations
- Live demonstration & presentation on the ISN conference on 4 November 2014 (Eindhoven).

news articles, interviews, and other types of publicity
- “TNO test beeldherkenning in Apenheul”, article in Computable (www.computable.nl) on 15 July 2014
- Live interview about GITC on Radio Apeldoorn on 15 July 2014, Martin van Rijn.
- Interview by / article in De Ingenieur about GITC on 30 June 2014, by Apenheul (Coen de Ruiter) and TNO (Berry Vetjens)
- Interview by / article in Telegraaf about GITC on 19 July 2014, by Ad van Heijningen
- Interview by / article in De Ingenieur about GITC on 4 September 2014, by Martin van Rijn
3.8.8 Structural Integrity Monitoring: SIM
peer-reviewed, published

- Van de Sande e.a., A wireless distributed sensor network with low-cost vibration sensors for structural health monitoring, ISMA, Leuven 2014
- Pahlavan e.a., Acoustic Emission Health Monitoring of Steel Bridges, EWSHM 2014, Nantes 2014
- Volker e.a., Crack Depth Profiling Using Guided Wave Angle Dependent Reflectivity, QNDE 2014

submitted full papers (not yet accepted)
- Pahlavan e.a. ‘Fatigue Crack Sizing in Steel Bridge Decks Using Ultrasonic Guided Waves’, Journal NDT&E
- Lotfollah Pahlavan, PhD; Gerrit Blacquiere, PhD; Arno Volker, PhD, Quantitative Crack Sizing Using Ultrasonic Guided Waves, Ultrasonics Journal

invited / keynote presentations
- ISN Conference 2014: Presentation Structural Integrity Monitor

accepted/published short papers, workshop papers, and posters
- ISN Conference 2014: Structural Integrity Monitor / Bridge Life Span Demonstrator
- Themamiddag renovatie van stalen bruggen, 2 december 2014
- Symposium ‘Onderhoud van stalen bruggen bij lokale overheden’ 18 juni 2014 Utrecht

news articles, interviews, and other types of publicity.
- Prime minister Mark Rutte at Hannover Messe 2014:

3.8.9 Knowledge team (the PhD positions in AMSN a.o.)
peer-reviewed, published

- Internet Factories, R. Strijkers, PhD-thesis University of Amsterdam, 2014
- Analysis and design of controllers for cooperative and automated driving, J. Ploeg, PhD-thesis Eindhoven University of Technology, 2014
- Look Ma, No Hands! Aspects of Autonomous Vehicle Control, W. van Willigen, PhD-thesis Vrije Universiteit van Amsterdam, 2014
- Fusion Strategies for Unequal State Vectors in Distributed Kalman Filtering, B. Noack, J. Sijs, U. D. Hanebeck, In the Proc. of the 19th IFAC World Congress (IFAC 2014), Cape Town, South Africa, August 2014

3.8.10 Flexigas, Protectrail, DDSC, Emc2
peer-reviewed, published
• Jan Willem Marck; Henri Bouma ; Jan Baan ; Julio de Oliveira Filho ; Mark van den Brink, Finding suspects in multiple cameras for improved railway protection, Proc. SPIE 9253, Optics and Photonics for Counterterrorism, Crime Fighting, and Defence X; and Optical Materials and Biomaterials in Security and Defence Systems Technology XI, 92530H (October 7, 2014) submitted full papers (not yet accepted)
• Paul Booij, 3D Thermal Emission Monitoring in Factory Buildings 22nd CIRP conference on Life Cycle Engineering
invited / keynote presentations
• Mark van den Brink, Multi-level approach to land transport security, IWGLTS meeting, The Hague (May 15, 2014)
accepted/published short papers, workshop papers, and posters
• Jeroen Broekhuijsen, second Conference of the European Biogas Association, September 30 –October 2 Alkmaar, the Netherlands
• Jeroen Broekhuijsen, Biomass Conference & Exhibition, June 23-25, Hamburg Germany
news articles, interviews, and other types of publicity
• Official opening DDSC by Provincie Groningen on 14 nov. 2014 performed by Yvonne van Mastrikt.(see http://www.provinciegroningen.nl/nc/actueel/kalender/_kalender/item/2014/detail/november/46/14/opening-dijk-data-service-centrum/)
4 Valorisation

After 4 years of research, what is the value of the results (knowledge, tools, facilities etc)? There are many ways in which the valorisation of the results can occur. An important sign is the interest of companies to obtain technology developed in AMSN. Strictly speaking, this is not the intention of an ETP, which is meant to develop knowledge that is of importance in the long term (2-5 years). The VP programs of TNO are intended to then take this knowledge and technology and to make it market ready. In particular, the demonstration projects have received considerable attention and demand in the market. Although not all interest has resulted in commercial agreements, chances are this will happen in the near future but after the end of the AMSN program.

To be as transparent as possible, we distinguish 4 categories for valorisation:

1. **B2B: Business to Business**: results are/will be sold to a market party
2. **SRP: Shared Research Program**: results are the basis of a joint project between TNO and market parties, with investments of all parties involved
3. **Sub**: (inter)national subsidised research program: results are used in e.g. H2020 projects
4. **TNO**: TNO program in strategic period 2015-2018: results are the basis for TNO research programs in the next strategic period (Early Research Program or “Vraaggestuurd Programma”).

Per project, Table 1 below indicates in which ways valorisation the project results takes place:

<table>
<thead>
<tr>
<th>project</th>
<th>B2B</th>
<th>SRP</th>
<th>Sub</th>
<th>TNO</th>
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<tbody>
<tr>
<td>SCAD</td>
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<td>Goose</td>
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<td>Gorillas in the Cloud</td>
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<td>SIM</td>
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<td>InControl</td>
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<td>Big DAVIDS</td>
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<td>SOX</td>
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<td>DYNAAN</td>
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Table 1 overview of expected valorisation of the AMSN projects

4.1 **B2B Business to Business**

The GITC project is currently handing over the concept they developed to a commercial party, who will not only maintain the living lab, but also actively approach the market with this concept. Discussions are ongoing with a second interested party.

The SIM project has led to interest from the USA to China. Contact was made throughout the entire chain of parties involved (infrastructure owners, engineers, monitoring companies, contractors). Negotiations about licenses on TNO technology have been taking place with several European players, but have not yet reached a conclusion. Meanwhile, Rijkswaterstaat has asked for a TNO project to continue the work on the Living Lab at the Van Brienenoord for at least 4 more years.
The DYNAA and InControl projects are currently talking to several parties, which is promising although in a somewhat early stage. For DYNAA the goal is to license the tool that was created, whereas InControl is aiming at applying the 3D climate model in various situations (from green houses to factories or data centres)

The Ministry of Defence has defined a project for TNO on big data which continues the Goose vision in 2015.

4.2 SRP Shared Research Program

The results of SCAD will be the foundation of a consortium with TNO, DAF, The port of Rotterdam and sector association Transport en Logistiek Nederland that will work towards public road tests in real traffic that will have to demonstrate that the automatic driving of trucks not only makes road transport more efficient and green but also safer. Driving in ‘train carriages’ is part of automated driving. Vehicles driving close behind each other reduces fuel consumption, from the last and the first in the train. The transport sector is tracking developments in this area very closely; it hopes that through techniques like trucks driving in columns or ‘platooning’, as the jargon calls it, the sector can stay at the head of its international rivals. This is already possible with two trucks. If two trucks drive close together, 10-20% fuel can be saved, which results in 10-20% lower CO2 emission.

Another SRP is in the making, it involves the monitoring of high value assets, strongly related to the SIM project. As a first step the province Zuid Holland started a project to monitor a bridge, where TNO cooperates with market parties.

4.3 Sub: (inter)national subsidised research program

In this category there is quite a variety, it ranges from programs for the “Samenwerkingsverband Regio Eindhoven” (SRE) related to SCAD to several proposals for the Infravation (EU program on Innovation for Infrastructure) related to SIM. Projects such as Goose, Gorillas in the Cloud, Big Davids and InControl have submitted or will submit a total of 6 proposals in various EU H2020 calls (mainly security and ICT). A special remark on the Goose project. For the proposals from this project, the Goose team was actively approached by consortia to contribute its unique concept, a nice compliment which was the result of the team vision and consecutive implementation. Artemis and ITEA proposals have been less successful in 2014, proposals on Smart Cities and Cyber Physical systems did not receive funding.

4.4 TNO

Four of the new Early Research Programs of TNO will build upon results from five AMSN projects, these are:

- Complexity \(\rightarrow\) SCAD, SOX
- Energy Storage and Conversion \(\rightarrow\) SOX
- Structural Integrity \(\rightarrow\) SIM
- Sense making from big data \(\rightarrow\) Big Davids, Goose

This ensures that also the more fundamental research questions that remain after the end of the AMSN program will be addressed.
5 Ambitions and Results 2011 – 2014

In each year of the duration of AMSN, an annual report was issued. To present a brief overview of the entire duration, this chapter states the ambitions at the start of projects, the realisation of these ambitions followed by the highlights.

5.1 DYNAA

5.1.1 Ambitions at project start
DynAA aims to develop a system evaluation and design method for robust and adaptive sensor systems.

5.1.2 Realization of these ambitions
Many planned activities were executed and most goals have been achieved. Specifically per main topic:

DynAA Core
During the second year significant work on communication channel and protocol modelling and a complete redesign and implementation of the simulation core was carried out and the interface to the visual modelling front-end was specified.

Design automation.
The model-based system evaluation tool was embedded into an optimization framework. Via the optimization user defined performance criterion (derived from emerging system characteristics) can be maximized while maintaining user defined constraints. The optimization framework allows for interfacing problem specific optimization solutions

Network performance modelling.
Low-level communication models:
A new model has been implemented and tested in combination with DynAA simulator and optimizer, on a number of design cases.
High-level communication models:
Application modelling and evaluation are supported by a communication protocol library.
Re-targetable domain specific modelling
The re-targetable domain specific modelling concept was implemented to assure clear interfaces between these two components. This is the key for enabling the easy implementation of new modelling languages dedicated to certain application domains.

5.1.3 Highlights 2011 – 2014 (knowledge, impact, breakthroughs)
The whole collection of tools is tightly integrated and forms ‘unique package’. This was clearly visible during the presentation of various DynAA papers at conferences in 2013 and 2014 where the stand/demo of DynAA was visited by many interested potential users. Winning the SaSo best demo award in 2014 was another confirmation. Launch of an MKB Technology Cluster creates the opportunity on one hand to share and discuss with companies more in depth our vision on the challenges in the design of next generation wireless sensor networks and on the other hand improve our understanding of their design issues and the type of tooling used.

5.2 SOX

5.2.1 Ambitions at project start
Study and implement a software framework for autonomous run-time self-organization and self-optimization of (distributed) systems as a means to improve the robustness and maximize the effectiveness of real time systems under changing internal and external circumstances.

5.2.2 Realization of these ambitions
A framework for self-organizing state estimators has been developed, as well as a methodology and software framework “Utility based reasoning” for the optimization / reconfiguration process, in order to determine the system’s best possible adaptation to achieve maximum system effectiveness. In 2014, two demonstrator cases have been developed and shown to stakeholders, to show the optimization capabilities of a software framework using the UBR methodology.
The first demonstrator considers the safe headway times of individual cars in a cooperative driving application, making it possible to guarantee safe platooning under all conditions. Here, the safe headway time is optimized under changing interplatoon communication quality conditions, while taking into account uncertainties in vehicle state and environment. The second demonstrator considers a smart grid (island) case in which, by using Utility based reasoning, after a planning disturbance, re-optimization is achieved by adaptation of the planning for the demand/supply resource matching in such a way that it results (again) in minimal total cost.
The developed knowledge, a.o. illustrated by the demonstrator cases, seem to lead to a follow up in one or more application oriented TNO VP (and/or TNO ERP) projects, in the field of Mobility (autonomous driving) and in the field of Smart Energy Systems (control of smart grids).

5.2.3 Highlights 2011 – 2014 (knowledge, impact, breakthroughs)
The SOX (2012-2014) project has resulted in the development of new knowledge in the field of run-time adaptive reconfiguration / optimization of real time (distributed) systems and a general new methodology guiding this reconfiguration/optimization. This has led to a number of scientific publications (3, 3 resp. 6), 1 book chapter, 1 IEEE Journal article, (also invited) presentations on several conferences (a.o. the Fusion 2012/2013/2014
conferences) and the co-organization and co-chairing of a special session at the Fusion 2014 conference.

5.3 Big Davids

5.3.1 Ambitions at project start
Ambition of this project is to become one of the important players in the world of innovative applications of affordable large scale (near) real-time big-data analysis technology of video and other sensor streams in various domains.

5.3.2 Realization of these ambitions
With the publication of our results via papers, presentations and demonstrations we have shown that we developed important new knowledge.
Via the publication of our software development (SensorStorm) via the Open Source community we made an important step to become a player in the world of innovative applications of affordable large scale (near) real-time big-data analysis technology of video and other sensor streams.
Depending on the adoption of our software we can say if we are an important player (not yet known)
The use of the platform/building block for several demonstrators (SIM, GITC, Goose, Livedijk) shows that we aimed at innovative applications in various domains.

5.3.3 Highlights 2011 – 2014 (knowledge, impact, breakthroughs)
- We published several papers
- Several results are already landing in new projects (STOOP3, SDF2, WeKnose, COMMIT)
- Breakthrough: Adding Elasticity to the Storm Platform
- Breakthrough: Scalable Streaming Video Analysis.
- Successful PoC of StormCV by analyzing 24 parallel video streams within the Amazon cloud

5.4 InControl

5.4.1 Ambitions at project start
TNO as a well-known pioneer for applying novel control solutions in networked systems across various application domains.

5.4.2 Realization of these ambitions
We have shown to be pioneers in control solutions. Our challenging work on control of complex dynamics has paid off with exciting new algorithms that bring new applications into the realm of real-time feasibility. Indoor climate monitoring and control is the most dominant in our work, but these results are also applicable to myriad other fluid dynamic problems. We are ready, for at least part of our technology, to partner up and approach the market.

Since our work on control of complex dynamics has been patented, publications and therewith international visibility had been less pronounced on this topic. However, our work on event-based control has been widely published with papers on international conferences, journal papers and invited book chapters.

5.4.3 Highlights 2011 – 2014 (knowledge, impact, breakthroughs)
- 2 Patent applications
• Numerous papers, articles, book chapters and (international) presentations
• Usage of InControl knowledge in FP7 project EMC2 Factory
• A proof of concept on real-time 3D indoor climate monitoring
• Developed (probably the world’s first) Lattice-Boltzmann based controller.
• Personal development of involved TNO employees
• 4 MSc candidates have successfully completed an internship for their graduation work. One stayed with TNO and active in InControl.

5.5 SCAD

5.5.1 Ambitions at project start
The ambition at the start of the project was to add robustness needed for upscaling of cooperative driving with realistic and complex traffic scenarios. For this a use case approach was used to define these scenarios. A demonstration was realized of the complex manoeuvres within a platoon of cars. For this several components were needed, e.g. low-level steering control of the Toyota Prius vehicle, a high-level interaction protocol between vehicles and support from roadside for detection of unequipped vehicles for safe lane changes. Also research was done on efficient information exchange, both at low level radio communication via simulations of Dynamic Congestion Control via frequency and power adaptation in G5 and on higher level on Utility Based Reasoning in information exchange. Also research was done on increasing situational and cooperative awareness by the development of the Local Dynamic Maps (LDM) in vehicle and road side units (DYNAMAP is the product name of the LDM at the road side), and the concept of Detected Object Messages (DOM).

5.5.2 Realization of these ambitions
The demonstration of complex manoeuvres within a platoon of cars was realized in 2014. However, this was not yet fully automated due to safety constraints. For fully automated manoeuvres external triggers (e.g. info from navigation system, roadside signs) have to be integrated and more in-vehicle sensors (360 degree view) are needed to detect vehicles on left or right-side of car.

The concept of DOMs and emulated CAMs is implemented at the DITCM-F test site for demonstration and (commercial) testing.

The design, implementation and extensive testing of a modular real-time version of iVSP was realized. Due to time constraint it was decided not to include the current Object and Host Tracking algorithms.

The effect of DCC at radio communication and Utility Based Reasoning was evaluated via simulations on the safety checker algorithm of CACC.

5.5.3 Highlights 2011 – 2014 (knowledge, impact, breakthroughs)
• Cooperative driving demonstration for minister Schultz, and item in Dutch 8 o'clock news
• Cooperative test site (DITCM facilities – TASS) with systems and software developed in ASA and SCAD, like Dynamap.
• Commercial application of the Dynamap in products of two consortia in the A58 Spookfile project.
5.6 GITC

5.6.1 Ambitions at project start
The ambitions at project start (2011) were high, taking into account the state of the art of the various subjects that were planned to research and to (integrally) demonstrate in scope of a GITC demonstrator.

These subjects were:
1. Demonstrate an intelligent cooperative camera sensor system i.e. a reliable camera based gorilla detection & tracking system suitable for integration and combination with other sensors like radar.
2. Implement multi-use functionality and (through extension of the Apenheul infrastructure) offer an open environment for knowledge institutes to access the GITC system for the purpose of cooperation with TNO and/or the Apenheul foundation and/or SMEs.
3. Study and integrate gorilla identification, behavior recognition and health analysis.
4. Integrate with Social Media, and setup a Community Cloud on the SARA processing center in Amsterdam by storing and making available content from the Apenheul foundation and enable external users to load and analyze video content, perform own analyses and add resulting metadata and annotations to the existing datasets.
5. Cooperate with 3rd parties in new developments building further on the knowledge that has been built up in scope of the GITC field lab development.

5.6.2 Realization of these ambitions
The dominant functionality, namely the reliable and robust detection of gorillas under all relevant weather conditions, and the reliable selection of the “best” camera based on the number of detected gorillas in the 11 live camera streams, appeared to be more complex than initially foreseen. Reliable and robust detection and tracking of the gorillas, is an operational boundary condition for the existence of a GITC field lab. Therefor this task caused a shift of effort from the other intended research items to this prio-1 functionality.

In 2014 these efforts resulted in the delivery of a robust, reliable detection & tracking system. Given the already high performance of this visual detection system, and the underestimated technology aspects it was decided not to add complementary sensors to the detection system.

A multiuse demonstrator has been developed, by applying and further developing a generic scalable access control concept originating from the European FP7 iCore (Internet Of Things) project. This demonstrator shows a flexible software control layer for the GITC observation system, which facilitates non-conflicting use of hardware/software resources by simultaneous users with different roles and different users’ rights. Such functionality enables the open use of the GITC field lab system by other users, while isolating this use from the normal operation of the system. Further, such multi use control layer, in combination with a media server, is essential for addition of new streaming applications to the fieldlab, to be viewed by users inside and/or outside the park.

Gorilla identification functionality has been studied in a gorilla face recognition experiment. On the one hand the resolution of the cameras that have initially been selected for gorilla detection tracking, fell short for direct use for face recognition. However, using PTZ camera (zoomed) registrations resulted in promising first results (using Open source software and FhG software). This functionality appeared to be limited by the big amount and variety of training data needed on the one hand, and observation limitations on the other hand (high camera positions in combination with gorillas mostly
looking downwards, thereby complicating the visibility of the face). For operational application higher resolution cameras and additional software development is necessary (coupling of recognition with detection positions, dealing with absence of movements, labeling of detections, intelligent measures for ensuring recognition reliability, etcetera). Such additional development was outside the scope of this AMSN GITC project. Aiming at multi use of video content, for example by primate behavior-scientists, a Surfsara account has been set up and a BSc. student has investigated the type of database structure suitable for this purpose. Apenheul decided not to implement this functionality any further. A comparable result holds for the recognition of gorilla behavior. In co-operation with the AMSN BigDavids project, an experiment for behavior recognition has been performed, using essential parts of the training & recognition algorithms. A selection of gorilla behavioral movements was chosen for recognition, taking into account the limited resolution of the cameras. After manual preparation (manual annotation of dataset, manual time division of video sequences into fragments per movement type) the results were very promising - about 80% recognition rate for 6 types of movements. For operational use, additional development is needed to automate the current manual processing steps. Such activity fell outside the scope of this AMSN GITC project. Aiming at multi use of video content, for example by primate behavior-scientists, a Surfsara account has been set up and a BSc. student has investigated the type of database structure suitable for this purpose. Apenheul decided not to implement this functionality any further. To investigate the possibilities of direct application of the detection & tracking algorithms as well as further development with other companies (including the Apenheul foundation), several contacts have been and will be explored, aiming at a.o. applications in other zoos.

5.6.3 Highlights 2011 – 2014 (knowledge, impact, breakthroughs)
In 2013 and 2014 essential new choices have been made in the detection and tracking algorithms which resulted in high reliability in the gorilla detection system under all relevant weather conditions. This is a relevant achievement especially for observation in a natural environment in which almost all thinkable combinations of complicated observation conditions occur. Last but not least, the demonstrator software / hardware system at Apenheul has proven to be able to operate unattended for more than several months, which is operationally relevant for future use/maintenance by 3rd party companies. We believe that the GITC project publicity by TNO and Apenheul, in scope of the gorilla theme year 2014, has certainly contributed to the rise in visitors in the Apenheul park in 2014.

5.7 GOOSE

5.7.1 Ambitions at project start
The goal of the project is to develop technology and business models to allow simultaneous many-user, many-query, many-usage exploitation of large of public and private sensor networks.

5.7.2 Realization of these ambitions
Realization of technology models to allow simultaneous many-user, many-query, multi-usage exploitation of several sensor networks.
(i.e. initial ambitions were higher than what has been realized,)
5.7.3 **Highlights 2011 – 2014 (knowledge, impact, breakthroughs)**

- Demonstrator system capable of real-time semantic search in sensor streams
- Submission 2013 for the International TRECVID-MED system, including zero-example video retrieval
- Submission 2014 for the International TRECVID-MED system together with Hong Kong based VIREO team
- Knowledge on text interpretation to known concepts, including semantic matching using ontologies

5.8 **SIM**

5.8.1 **Ambitions at project start**
The ambitions at the start of the SIM project are addressed in Figure 1 roadmap SIM.

![SIM technology roadmap](image)

**Figure 16 SIM technology roadmap**

5.8.2 **Realization of these ambitions**
The project effectively started in the second half of 2011. The half year was used to define the types of integrity inducers, target applications and their requirements. In 2012 the first experiments were started at different TRL stages. In 2013 the Van Brienenoord project was started that gave a boost to the technology development. The VBB acted as life Field Lab and was/is used to verify critical components of the Structural Integrity Monitor developed in the lab within TNO.

As shown in the roadmap all the major components shown have been addressed successfully which is a major achievement and something to be very proud of.

5.8.3 **Highlights 2011 – 2014 (knowledge, impact, breakthroughs)**

- Realizing our objectives set at the start of the project
- Demonstrating it at the Van Brienenoord Bridge and in the Laboratory of TNO
- Filing two patents for critical monitoring components
- Having published results in the media and Mark Rutte stating that the TNO monitor for bridges is high tech and unique
6  Management Opinion 2011-2014

To start with a quote from the 2013 report conclusion: “Parallel to the technology research planned in the last year of the program, a stronger focus will be put on effective transfer of the knowledge to enable successful application of the AMSN outcome in society and industry. The results so far have shown that the achieved breakthroughs have the potential to open up new solutions and applications essential for a better society. In 2014 AMSN must find partners in industry who are willing to commission (shared) research programs with TNO based on the demonstration projects. In parallel we will build consortia with partners to participate in the European Horizon 2020 program to strengthen the development of more fundamental knowledge and technology.”

What has become reality of this conclusion? Looking back on 4 years of AMSN, what were the most important results? Questions to be answered in this section.

First of all, let us take a look at the improvements planned in 2014 and their results.

6.1  Results of improvements made in 2014

In the 2013 report section 4.3 was all about the improvements to be made in 2014, based on, amongst others, Strategic Advisory Board outcomes. The exact text of section 4.3 was copied, then per improvement the actions taken and results achieved are given.

6.1.1  Improvement 1: Dissemination

In 2014 the project portfolio of AMSN will be similar to 2013. Since 2014 is the final year, it is essential to shift the focus towards finalizing and demonstrating the results of the program. Thus the fundamental project work is reduced while more effort will be allocated to both applied project work as well as dissemination.

Actions

In the plans made for 2014, extra attention was given to finalizing and demonstrating the results. During the course of the year the more fundamental projects incorporated their results into the demonstration projects, making their work tangible.

Result

Compared to 2013 dissemination and demonstration of results were intensified in all projects. This is clear from the number of publications, which was significantly higher than in 2013, specifically the number of publicity items rose significantly.

6.1.2  Improvement 2: Focus

Instead of the larger number of relatively small projects which was the situation in 2012, in 2013 larger coherent projects were run. This was mainly done to simplify interaction between projects by reducing the number of interfaces, and it paid off in terms of improved synergy.

In 2014 the remaining projects will be linked even stronger than before. Special attention will be given to the few projects that did not benefit fully from each other in 2013 (i.e. Big Davids, Goose and GITC Sensor lab).

Actions

The three projects were linked from the start, not only by gearing the plans towards each other, but also by “sharing project members”. In this way a person working on Big Davids
as well as Goose could easily be the interface between the projects and make sure that results can be reused.

**Result**
The Goose project benefitted from the Big Davids data analysis platform, and build its user interface on top of the video analysis module. Secondly, the Big Davids project used the GITC infrastructure and detections/tracking for further analysis in terms of behaviour.

### 6.1.3 Improvement 3: Valorisation

In 2013 there was quite some interest from external parties (in the scientific community as well as among companies) in the work AMSN is doing. Materializing this interest with industry partners has proven to take more time than anticipated, whereas setting up new cooperation with universities and research institutes was successful on multiple occasions. In 2014 AMSN should be able to commit a few parties in strategic research together with all relevant themes and their business developers. This will lead to building more and stronger relations with research organizations, university and industry that will last beyond the duration of the AMSN program.

**Actions**
The actions for improvement 1 brought more attention in the media for the results. Together with the various TNO theme's Business Developers, AMSN project members visited over 50 companies in 2014. More details are mentioned in the chapter on valorisation above.

**Result**
Shared Innovation Programs (joint undertakings of companies as well as TNO/other research institutions) are being set up around two AMSN projects: Cooperative Driving and Structural Integrity.

### 6.2 Highlights

In its four year duration the outcome of the AMSN projects show the potential impact on the grand challenges of society.

Three AMSN projects were covered extensively in the national press. In 2013 at prime time in the 8 o’clock news on November 12th an item on Cooperative Driving was shown in which the minister of Infrastructure and Environment joined one of our TNO colleagues for a test drive in a CACC enabled car on a public motorway in Amsterdam. The sequence of events that followed led to more press coverage, several new initiatives and even law modifications in 2014 (see: “Schultz past regels voor testen met zelfrijdende auto’s aan”: [http://www.rijksoverheid.nl/nieuws/2014/10/20/schultz-past-regels-voor-testen-met-zelfrijdende-auto-s-aan.html](http://www.rijksoverheid.nl/nieuws/2014/10/20/schultz-past-regels-voor-testen-met-zelfrijdende-auto-s-aan.html)).

A press release in 2013 featuring the SIM project experiment to monitor the condition of the Van Brienenoord Bridge was picked up by several newspapers amongst others de Telegraaf, and het Algemeen Dagblad and was also addressed in radio news items.

To be followed in 2014 by the third demonstration project Gorillas in the cloud, to be featured in newspapers and in radio news items.
6.3 Conclusions

The period 2011-2014 proved to be inspiring and successful for the AMSN program featuring encounters with frontier applications demonstrating the potential of the research outcome both in the industrial as well in the societal domain.

The scientific output in 2013 and 2014 of the AMSN program is on par with international developments of science and technology. The program extended the IP position of TNO, including several patents, to strengthen TNO’s position in future markets.

In the public domain the potential value of AMSN technology was disseminated through TV and Radio channels, through newspaper featured articles on three of the AMSN demonstration projects. The news attention doubled in 2014 compared to an already successful 2013.

The press coverage is a good indication of the relevance of the work. Another important sign is the interest of companies to obtain technology developed in AMSN. Strictly speaking, this is not the intention of an ETP, it is meant to develop knowledge that is of importance in the long term (2-5 years). The VP programs of TNO are intended to then take this knowledge and technology to the market. However, in particular the demonstration projects have received considerable attention and demand in the market. Although not all interest has resulted in commercial agreements, chances are this will happen in the near future but after the end of the AMSN program.

The more generic projects have contributed to various EU H2020/Artemis/ITEA proposals, for many of which the decision whether the proposal will receive funding is not yet known, these are expected in the first halve of 2015.
7 Signature

The Hague, 3 March 2015

Peter Werkhoven
Managing Director Technical Sciences

[Signatures]
8 Personal notes

Four years of AMSN have gone by, an eventful period in the world, in the Netherlands and within TNO. If anything is clear from our present situation it is that Adaptivity is key in many aspects.
The program itself has adapted itself regularly, to accommodate various changes, but without losing sight of our goals.
Are we done? No, obviously not since “iedere stap verschuift de horizon” (poorly translated into: “the horizon shifts with every step”). Many steps have been taken, and as a result the horizon is filled with new possibilities and new research questions.

I would like to take the opportunity to thank each and every one who contributed to AMSN in these four years. A few people I like to mention in particular:
Huib Pasman, whose relentless positive energy has been a great inspiration.
Joris Sijs, full of sparkling ideas without whom I would have been completely lost in technology.
The AMSN project leaders, who have never let me down and have shown that working together across the organisation can be tough, but rewarding.
The AMSN Steering committee for their commitment, help and constructive feedback.
The involved Research Managers who have always supported the program and were most eager to get the results.
Pieter Hermans of Jakajima, with whom it was a pleasure to work, organising the ISN Conference, looking forward to many more editions!
Ernst Meijer, fellow ETP manager for ETP models, I enjoyed sharing our visions.
The Strategic Advisory Board for their insights and feedback, which have resulted in an ambitious yet smoothly running program

Peter Laloli

The people of AMSN have shared their impressions of the program via personal notes, a selection of which is given below.
“Ik vond het leerzaam om in een multidisciplinair team te werken aan de ambitieuze doelstelling om de kloof te overbruggen tussen automatische beeldinterpretatie en een semantische beschrijving.”
Henri Bouma

“In het AMSN GOOSE project hebben we vanuit een samenwerking over meerdere disciplines de eerste successen geboekt om op een intuïtieve -Google-like- manier te zoeken in beeld en video informatie.”
Wessel Kraaij

“Van Gorilla’s kun je veel leren.”
John Schavemaker

“In Apenheul stonden we eerst voor apen.”

“Multidisciplinair team verdiept de kloof van het ‘Semantic Gap’… tot fundamenteel onderzoek!”
Paul Brandt

“Maar als je ziet hoe de gorilla detectie nu werkt, mogen we best even borstroffelen.“

“I was appointed as project leader within the demonstration project ‘Structural Integrity Monitor middle of 2011. At the start of the project it was not clear what the main monitoring challenge was. That became clear end of 2011 and in 2012 we started with tests in the laboratory that continued up to an including 2014 and “living lab tests” on the Van Brienenoord Bridge in 2013 and 2014.

What I really enjoyed was the fact that as a team we set high ambitions in 2011 and achieved almost all of them in 2014. This project was also a good demonstration of the combination of different technologies from different areas within TNO being: sensor techniques, modelling and network architectures. This resulted in a next generation monitoring system with a spin-off in 2014 were we installed the next generation monitoring monitor on a steel bridge in Delft (Kruithuisbrug) on request of the Province “Zuid Holland”.

A highlight for me was to realize our objectives set at the start of the project, demonstrating it at the Van Brienenoord Bridge and in the Laboratory of TNO. Finally having these results published on conferences and in the media. Especially Mark Rutte stating at the Hannover Messe that the TNO monitor for bridges is “high tech and unique”.”

Rob Jansen
“Apen wegfilteren tot je de goede overhoudt.”

“Great to be part of a team so motivated, skilled and eager to make a success of AMSN”
Bram v/d Ende

“[,] x miljoen = visualisatie =inzicht! “
Erik Boertjes

“Dear complex spatio-temporal processes,
Thanks to 4 years AMSN, we control you now. Do as we say!”
Paul Booij

“Spectaculair Indrukwekkend Machtig! Bedankt AMSN voor het bieden van een platform om iets moois te ontwikkelen. “
Tom Basten

“I presume my one-liner will optimize itself in something meaningful in this context.”
Jeroen v/d Sande

“We zijn (youtube) LIVE!”
Victor Klos

“Abstract knowledge development especially gains ground when the potential of it is illustrated by a concrete concept demonstrator.”

“AMSN technologie is een fantastische kans voor TNO om impact voor Nederland te generen.”
Klamer Schutte

“To Boldly sense what nobody has sensed before.”
Huib Pasman
“Great program great program manager & outcome that makes me proud of being a part of it.”
Pooria Pahlavan

“Great project with a multidisciplinary team that can make the difference.”
Maaike de Boer

“The reward of Utility Based Reasoning (UBR): the utility of having a concrete concept demonstrator has proven to be more than the cost of developing it.”

“AMSN got me in touch with a lot of different TNO’ers and gave me a wonderful kick-off for my TNO career.”
Alex Sangers

“Na vier jaar AMSN heb ik de positie van TNO in sensorgedreven applicaties sterk zien groeien. En hebben we door disciplines samen te brengen echt nieuwe mogelijkheden ontgonnen. Of dat nou realtime zoeken in streaming beeldmateriaal is, of het in realtime herkennen van gedrag bij gorilla’s. Vooral levert dit ons inspirerende verhalen, waarmee we klanten kunnen verbazen. En daar maak ik dagelijks dankbaar gebruik van”
Berry Vetjens