COMMIT

PROJECTPLAN

WORKPACKAGES

DELIVERABLES

BUDGET

METIS: DEPENDABLE COOPERATIVE SYSTEMS FOR PUBLIC SAFETY (P12)

Project leader dr. Pierre America

1. Background

Reducing crime, responding effectively to a disaster, and protecting citizens and public assets are significant challenges governments face. How citizens perceive their safety has a direct impact on where they choose to live, work, and play. With lives and economic development at stake, there is significant need for guaranteed public and personal safety, reliability of infrastructures, security of information, etc. Within the context of public safety and security, situational awareness, i.e., the explicit knowledge about events and available assets is a prerequisite for response strategies and related successful decision making.

The goal of this project is to enable next generation systems-of-systems for situational awareness based upon recent developments in cooperative embedded systems. These next generation systems shall be based on flexible information-centric designs that allow run-time adaptations; they shall provide reliable information integration of different information sources, and they shall provide built-in techniques for continuous run-time analysis and support of the system's health, altogether ensuring dependability and thus vested confidence in the ability to rise to the given challenges.

As a vision for these cooperative systems, we strive to embed the means for the application's needs to intelligently drive the systems' setup and behavior given the available resources. Moreover, these systems should allow system-level reasoning to assure their dependability and adaptability. Such goal-driven system-centered awareness, optimization, and operation of cooperative systems form the major novelty of the project, significantly extending the state-of-the-art of today's static systems that require great manual efforts to adapt them to new tasks and situations and that do not offer insights on their reliability. The project builds upon previous research, especially of the successful BSIK Poseidon project on maritime safety and security, but exceeds it in scope of the application area and in the ambition to embed intelligence into the systems, while at the same time providing focus to system-thinking for the design and analysis of systems of this complex nature.

Following this vision, the project contributes to main items on the agenda of the newly formed consortium: The Embedded Systems Institute develops insights in system concepts and design methodologies of next-generation systems, which is essential for its aim of bringing cutting edge research to the Dutch high-tech industry. The industrial partner Thales, together with ESI also the carrier of Poseidon, extends its application field and learns about the extensions to the state-of-the-art generated by the research of the academic partners, i.e., Radboud University Nijmegen, VU University Amsterdam, Delft University of Technology, and Eindhoven University of Technology (compare section 3 and 5 for details), who receive new impulses to their work.

The chosen path to address the society goal of public safety with embedded systems research follows the society-technology impact analysis of COMMIT, and also the European Strategic Research Agenda of Artemis on embedded intelligence. The research objectives themselves address six (3.2-3.7) of the nine themes identified in the National ICT Research Agenda 2005-2010, and are at the core of cooperative embedded systems, a major area within the COMMIT innovation ecosystem for ICT, ensuring full connection to other activities. Overall, the project addresses the challenges control of complexity and increase of confidence listed in the agenda ICT2030.nl with special focus on the technological developments of convergence, networked world, and the explosion of technological networks. Altogether, these links become visible especially in the relation to the proposed COMMIT projects P8 on sensor networks for public safety and P10 on cognitive cooperative networked platforms for public safety. All these projects share their societal goal of public safety and complement each other on their scientific and technical objectives, as we explain in more detail in section 3.

2. Problem description

Public safety and security is an issue of increasing importance and growing concern for society, economy, and industry. It ranges from disaster response to ensuring public availability of critical resources (e.g., water, power, communication supply) to the defense against terroristic threats. Situational awareness, i.e., the explicit knowledge about current events and available responses, is a prerequisite for any successful response strategy and decision making. Such situational awareness must be based upon a large number of inputs of various kinds and from many different sources. Given the ever increasing complexity and quantity of information, this can no longer be achieved by human operators without assistance. Advanced situational awareness systems are needed that provide this assistance for operators in situation rooms and control centers. The development of such systems, which gather, filter, examine, and focus large amounts of information from many different sources in a dependable, adaptable, trustworthy, and flexible manner, is currently a major challenge.

Embedded systems nowadays play an increasing role for improved operation and safety of public infrastructures, in peoples' mobility and connectivity, and in industrial installations. Consequently, a growing number of embedded systems individually observe and react to a multitude of information. These systems become increasingly connected, exchanging data and control messages to perform better. This leads to the new concept of collaborating networks of information-centric embedded systems-of-systems.

This project addresses the problems and challenges of developing cooperative, information-centric embedded systems-of-systems that are dependable, adaptable, trustworthy, and reconfigurable. The major application area for such systems for this project will be situational

awareness for public safety and security. Other potential application domains include traffic control, financial transactions monitoring, maritime safety and security, and fail-safe systems of industrial installations.

The research required to succeed in this cross-cuts several domains, like systems-of-systems engineering, cooperative and adaptive information systems, and dependability and system health analysis. In addition, whereas traditional engineering methods consider these aspects statically, i.e., at design time, we will consider dynamic run-time assessment and improvement of these aspects. Moreover, the needs of such systems contain inherent trade-offs. For example, adaptability and the ad-hoc integration of information sources conflict with dependability, and systems-of-systems approaches for distributed information processing eliminate single points-of-failure, but hinder event recognition as no single node can access all data and thus infer awareness from it.

All of this calls for both intelligence embedded into the envisioned systems, not only for processing the gathered information but also for awareness and control of the system itself. Moreover, new ways to design and analyze these systems are necessary that address design methodology and cross-disciplinary system knowledge at the same time, which is beyond the current state-of-the-art.

Concretely, the following research questions will be addressed:

- how to develop and define system concepts for information-centric, cooperative systems-of-systems, with emphasis on situational awareness systems for public safety and security;
- how to incorporate built-in, system-level, run-time awareness of information flows, dependability, and system health;
- how to support context-dependent, run-time adaptability, and dynamic system reconfiguration;
- how to integrate information of various, semantically ill-aligned sources within such systems and ensure their coherent retrieval and interpretation;
- how to present the information gathered as well as meta-data about the systems-of-systems such that end users can obtain insight and make appropriate decisions.

3. Objectives

Project's goal

The goal of this project is to enable next generation systems-of systems for situational awareness, especially for maritime safety and security, based upon recent developments in cooperative embedded systems. This means that the project will develop techniques and prototype systems that give people working in public safety and security at sea (e.g., the coastguard) the information they need, depending on the actual situation and their own role.

Such a system will face the challenge of combining information from different sources, including various sensors and databases, in a meaningful way. Moreover, the system will have to deal adequately with the fact that the input information is not always accurate, timely, and trustworthy by reconfiguring its way of collecting and processing information accordingly and by indicating the remaining uncertainties visually to the user.

Planning of all dimensions

In order to meet the challenges involved in reaching the project goal, the project is subdivided into work packages. The work packages are tightly integrated, so that together they will lead to a series of systems that combine semantically heterogeneous data provided by external sources and deals in a satisfactory way with several quality aspects of the data, including the following:

- Accuracy (confidence intervals, error rates, false positive and negative rates, …)
- Timeliness (update frequency, delays, response times, …)
- Trust (responsible organization, due diligence, security, reputation, …)

The technical health of the data providing subsystems is not in itself a quality aspect of the information, but it can be very effective in predicting other aspects and it is typically very useful for the user to be aware of.

Each work package is working towards a specific goal, described briefly as follows:

- *WP1 Domain Requirements, Use Cases, and System Concepts – led by Thales*
  This activity investigates and defines use cases and domain requirements. Moreover, it collects representative input data that can be used in developing, validating, and demonstrating the prototype systems. Finally, this work package aims at identifying suitable system concepts for information-centric, cooperative embedded systems-of-systems, with emphasis on situational awareness for public safety and security. It must be assured that these systems support the objectives of the project, such as dynamic adaptability, reconfigurability, and built-in self-awareness for continuous, on-line dependability. In this way we ensure that the techniques developed in the project can be validated in realistic cases and that the contribution to the domain of public safety and security can be demonstrated.
- *WP2 System State Assessment and Prognostics – led by RU*
  This work package aims at developing techniques for the assessment of the quality of information in the system and its environment, integrating a semantic model of the system and its health and control information. The techniques will satisfy the requirements imposed by the domain, which means that they should be built-in, allow system-level reasoning, and support run-time awareness of both flow and quality of information, based on system health and other appropriate input. These techniques will be supported by tools that work at run-

time and that can deal with the level of dynamics occurring in the systems through adaptations and reconfigurations. Automated model-based diagnosis and on-line monitoring will play a role as well as prediction or what is going to happen using probabilistic models, such as Bayesian networks.

- *WP3 Information Integration – led by VU* This activity addresses semantic information integration to enable the understanding of situations, tasks, information sources, and contexts even across the boundaries of systems and information spaces. In other words, it addresses the challenge to transform the data available from various sources (including public and non-public databases as well as sensors) into the information needed by the user at a particular moment. An example is cross-referencing satellite data about movement of objects, such as ships, with amateur spotter data about these ships. The techniques to achieve this can often be generalized among widely different domains (including for example the domain of cultural media explored in COMMIT P6), but they need to be tailored considerably towards the particular application domain. A particular additional challenge in this project is the need to generate several alternative data transformation paths that provide options for adaptation and reconfiguration, whenever required.
- WP4 Adaptation and Reconfiguration – led by TUD. This work package addresses the issues of adapting and reconfiguring the system in case of subsystem failures and/or confidence issues with respect to situational awareness. System reconfiguration and adaptation can be triggered by, for example, insufficient quality of information, or failing or newly available sources of information. Integrated system-level reasoning about identified causes and possible solutions by system adaptation or (re) configuration forms a major challenge. Combining adaptability and reconfiguration with continuous, guaranteed levels of dependability adds a further challenge. WP4 will provide methods and tools to perform this sequential diagnosis and reconfiguration process in an ad-hoc, dynamic, and on-line context.
- *WP5 User-Defined Visualization of Heterogeneous, Uncertain Information – led by TU/e*. This activity studies how large amounts of heterogeneous and possibly uncertain information, along with information about the current health and configuration of the system that has produced it, can be presented to end-users. This will result in a User-Defined Operational Picture (UDOP), providing specifically tailored situational awareness based on the current situation and the role of the user.
- *WP6 Integration, Knowledge Consolidation, and Dissemination – led by ESI*. This activity aims at integrating the results of the various work packages into working systems that can be tested, validated and demonstrated. It will provide for the capability to connect individual contributions to each other and to existing systems. Furthermore, it will provide access to information sources and simulations to supply hard data for proofs-of-concept and evaluations. The work package also supports knowledge consolidation and dissemination outside the contributions to the academic community. This is done partly via the

demonstrators, but also includes publications for a wider audience, workshops, courses, and joint activities for information exchange with other projects.

Results

The project will deliver techniques for building systems-of-systems for situational awareness that significantly advance the state of the art. These techniques are not only described in reports and published papers, but they will also be implemented in concrete software components that are combined in a series of fully working prototype systems. By testing, validating, and demonstrating these systems, the project will ensure that the newly developed techniques actually work in practice and that they significantly enhance the way that safety and security professionals can be supported in their work. Moreover, the project will actively contribute in applying the project results in other contexts, including various other COMMIT projects.

Deliverable Impact and Valorization

The Metis project will develop techniques and prototype systems-of-systems for situational awareness in the safety and security domain. The prototypes will focus on naval applications, where several organizations may benefit, such as the coastguard, navy, police, and harbor authorities, but also Rijkswaterstaat and Marin. The project will actively seek contact with those institutions in order to take their requirements and feedback into account. We will work towards trial deployment of our prototype, which by it self may already help to make the North Sea safer. Subsequent products, of which development might even start during the Metis project, will have a much larger impact, possibly reaching far beyond the Dutch territorial waters. Together with other COMMIT projects, Metis is going to develop joint prototypes in the area of safety and security, which will also contribute to safety and security on land, inside and outside the Netherlands. Also here we will actively establish contact with relevant institutions, and where possible establish trials of our prototypes. The individual techniques, developed in work packages 1, 3, 4, 5, and 6, will probably have a much wider impact. For example, interest has already been expressed in applying them to diagnosis and maintenance of complex systems.

Deliverable Dissemination

Besides journal and conference papers, Ph.D. theses, and a book, as specified above, the project results will be disseminated in numerous ways, including the following:

- Technical magazines, such as De Ingenieur, Bits&Chips, and possibly the general press. specially the visualization results have proved to be attractive for such publications
- Standard development, among others by the active involvement of the VU Amsterdam in W3C standards related to the Semantic Web
- Courses, including the ones organized by ESI
- Specifically targeted ESI dissemination activities (e.g., presentations, workshops, and

consultancy) towards high-potential organizations

International Imbedding

All six partners contributing to the Metis project are internationally known contributors to their respective fields. They will make sure that the work in the project is of a high quality standard and will lead to internationally recognized unique contributions. The project as a whole will definitely be unique in combining and applying various techniques dealing with heterogeneous and uncertain information to the domain of maritime safety and security. Here we follow the tradition of the Poseidon project.

Deliverable Synergy

The Metis project is planning synergetic activities with the following approximately) other COMMIT projects:

- *P6*: Exchange of algorithms, software, and test results in order to exploit cross-domain commonalities (mainly focusing on WP3).
- *P8*: Development of a joint prototype system-of-systems for public safety and security, more in particular on crowd monitoring, where sensor networks provide basic data, which is integrated with other data sources and presented to the user by a Metis-based system (deliverables D6.3 to D6.7).
- *P11*: The budgeting techniques of WP1 of project P11 will be applied to the system definition in WP1 of Metis. Furthermore, we will investigate the possibilities to use the model-based testing techniques of WP2 of project P11 for health monitoring in WP2 of Metis.
- *P19*: Joint work on data representation of tracks (recordings of movements by vehicles or other objects in space and time) (deliverables D1.3 and D6.4 of Metis). Moreover, database expertise and software from P19 will be strongly considered for deployment in the Metis integrated prototypes.

4. Economic and social relevance

- *Societal problem.* Public safety is an issue of increasing importance and growing concern for society, economy, and industry. It involves disaster response, ensuring public availability of critical resources (e.g., water and power supply), protection of critical infrastructures (e.g., airports, harbours), and the defence against hostile or terroristic threats.
- *Societal objectives.* The project aims to provide methods and techniques for developing systems that provide decision makers and authorities with better, faster, more flexible, and more reliable information to enable them to recognize and adequately respond to situations that threaten public safety.
- *Technical challenges.* An important aspect of any method for increasing public safety is

situational awareness, i.e., the explicit knowledge about what is happening around us. Situational awareness involves large, on-line information flows of various sorts and from many different sources (e.g., radar-, weather-, financial transaction-, communication-, airplane-, and surveillance camera information). Dealing with these large and complex information flows can no longer be achieved by human operators alone. Systems are needed that support the gathering, filtering, fusing, examining, and focusing of information. Developing such systems for situational awareness that consist of cooperating components, that are information-centric (i.e., able to deal with large amounts of information from many different sources), that are adaptable (allow new information sources to be quickly integrated), dependable (they must not fail), and that provide (quantifiably) reliable information, is currently a major challenge.

- *Economic objectives*. The project aims at improving the starting position for the Dutch industry's efforts to succeed in the competitive new market of safety and security systems, which is enormously growing in size and importance world-wide.
- *Opportunities*. The knowledge to be gained will be transferable to related domains such as (air) traffic control systems, fail-safe control systems of industrial installations, financial transaction monitoring, and hospital information systems, where similar cooperative, information-centric, adaptable, dependable, and reliable systems play a key role.
- *Public funding*. Due to their diversity and complexity it is very unlikely that any Dutch company can individually resolve all issues related to such public safety systems, so public funding is required to initiate the necessary collaboration. The diversity and complexity involve the many stakeholders such as the population, authorities and decision makers, owners of infrastructure, government agencies (police, fire brigade), medical agencies, and information providers, as well as the diversity and complexity of combining several domains, such as cooperative and distributed information systems, dependability, adaptability, system health and diagnosis, semantic technologies, information fusion, and embedded systems as well as system-of-systems engineering.
- *Knowledge infrastructure*. Public funding facilitates the achievement of objectives for the knowledge infrastructure of the Netherlands: (i) increased problem awareness within academia and industry to further the understanding of the involved complexity, and the chances that exist for all who become proficient in this area; (ii) valuable advances of the state of the art as expressed in section 3 to enable academia to better educate the next generation of engineers as well as to provide necessary knowledge to industry; (iii) the ability to train the Dutch engineering force on systems of this nature to ease the transition to next-generation solutions for the ever increasing demands of a complex and connected world.
- *Threat*. The development of public safety systems within the Netherlands is especially important as such systems are highly tailored and their development may require access to confidential information that should not be shared. Public funding of such activities

facilitates public control of these confidentiality issues. Not having the appropriate knowledge about public safety and security systems may put the Netherlands in a dependent and vulnerable position. The availability of state-of-the-art systems from other countries is not given in advance, as many, like the U.S., hinder the flow of such first-rate defense-related technologies to third parties.

- *Urgency*. It is urgent to address this research, due to two reasons. First, as described in section 2, the dynamics with which embedded systems start to penetrate all aspects of society are growing. Thus, research is now needed to ensure the dependability of cooperative and networked embedded systems before, e.g., unforeseeable failures endanger the public, personal well-being, privacy, or wealth. Second, the envisioned application of public safety itself excludes hesitation, as it is our common responsibility to ensure that we are able to handle potential threats to public safety and security without waiting for a disaster to strike before we start the necessary research. Obviously, such disasters would also have an enormous economic impact.
- *Consolidation*. Different consolidation activities will be organized. (i) The project will be organized as an industry-as-lab project led by Thales and ESI, i.e., the industrial context of Thales will be used as laboratory for the researchers to develop new ideas, to experiment with them, and to validate the results. This guarantees that the research activities have the required ties to the Dutch high-tech industry to ensure that their results are relevant, that they will become beneficial to subsequent development activities, and the results will be consolidated within Thales. (ii) ESI's tight links with the Dutch high-tech industry will guarantee that the results, if applicable, will be used in other contexts and domains. (iii) ESI maintains an extensive industrial course program where the results of this project will be included for the benefit of future course attendants. (iv) Since a number of ESI research fellows are at the same time lecturer or professor at universities, the results of the project will also flow into university courses. (v) ESI maintains knowledge repositories with knowledge of ESI projects. These repositories consist of documents that describe methodologies and methods, supporting software tooling in maintainable (SW) libraries, relevant HW sets, industrial reference cases and demonstrators, designs, documentation, manuals, etc. The results of this project will also be included in the repositories which will allow stakeholders to access a highly relevant and valuable knowledge base that allows for early adoption of validated solutions by industry and societal appliers.

5. Consortia and collaboration

This project is setup as an industry-as-lab collaboration between academia, the carrying industrial partner *Thales Netherlands*, and the *Embedded Systems Institute*.

The mission of the *Embedded Systems Institute* (ESI) is to advance academic excellence and industrial innovation in embedded systems engineering for high-tech systems, acting as a bridge between the Dutch industry and the 3TUs. In addition to its unique knowledge on industry-as-lab projects, ESI provides project and knowledge management, as well as extensive system architecting research capabilities. ESI's goal within the project is to advance the state-of-the-art on designing information-centric and cooperative systems.

Thales Netherlands is a high-tech company led by the mission to make the world a safer place by providing integrated solutions to meet three objectives: make reliable and secure, monitor and control, protect and defend. Thales provides the industrial challenge to the project, as well as in-depth technical expertise as systems-integrator of information- and network-centric systems. Specifically, they provide application scenarios and use-cases, offer expertise and resources to research the required systems jointly with ESI, and bring in the simulation and demonstration capabilities for the validation and evaluation of the results.

The *Algorithmics Group* in the *Software Technology Department* at *Delft University of Technology* (TUD), Prof. Cees Witteveen, aims at the development of advanced distributed algorithms for autonomous systems operating in dynamic environments. Most research topics they are working on are inspired by topics in algorithmic game theory, computational methods like planning and satisfiability solving, and distributed incident management. On the application side they are especially interested in applications in ICT, transportation, safety and security, and healthcare.

The *Semantic Web Group* at *VU University Amsterdam* (VU), Prof. Guus Schreiber, has received world-wide recognition for their work on semantic knowledge representation and search, e.g., by winning the Semantic Web Challenge. Within this project, they advance their techniques for integration and semantic alignment of information sources, both in regard to the application of public safety, and to attributes of systems, their behavior, and dependability, linking to the work of TUD and providing foundations for the work of all groups.

The *Model-based Software Development* (MBSD) Section of the Institute for Computing and Information Sciences *at Radboud University Nijmegen* (RU) headed by Dr. Peter Lucas, brings in expertise on intelligent systems and their model-based development, analysis, and diagnosis, and the use of probabilistic graphical models in this context. Their research focus is the development and exploitation of models as a basis for software development. The section's methods and tools have proven applicability on challenges as encountered in society, industry, and other scientific disciplines. This makes them an ideal partner to provide the reasoning that link all investigated aspects of the systems under research to each other and to the application goals.

The *Visualization Group* in the Department of Mathematics and Computer Science at Eindhoven University of Technology (TU/e), Prof. Jack van Wijk, is doing world-class research in the areas of information visualization, visual analytics, scientific visualization, mathematical visualization, and interaction.

This consortium covers all research areas laid out in section 3. As the chosen industry-as-lab approach offers unique advantages for research inspired by industrial challenges, it is ensured that the cooperation is focused by real-world challenges while at the same time progresses the state-of-the-art in each field.

6. Workplan

ESI and the carrying industrial partner Thales plan to lead this project according to a well-established process suitable for industry-as-lab projects that ensures consistency and cooperation: The content-oriented research plans of the academic partner's gain their inspiration and application focus through a series of scenario-driven use-cases. These use-cases describe consistent high-level goals for all partners, thus ensuring that the same project objectives are addressed throughout the project.

All use-cases define form and content of a series of successively more complex demonstrators. These demonstrators range from feasibility prototypes to a full system-of-systems demonstrator that integrates major research results at the end of the project period. Given this layout, the following milestones are planned (see work package descriptions for specifics):

- Report on task-relevant state-of-the-art in academic partners' fields
- Report on initial requirements analysis and main scenarios defining use-case 1
- Report on identified research needs and approach directed by use-case 1
- Reality-check test cases within individual activities examining initial approach
- Feasibility prototypes within each research work package for use-case 1 and 2
- Report on impact of initial results, listing necessary adaptations to research program
- Feasibility test cases within each research work package examining use-case 2
- Joint proof-of-concept demonstrator addressing system concepts and use-case 2 and 3
- Integrated system-of-systems demonstrator validating research and system concepts
- Project consolidation and knowledge dissemination

The research activities are structured by the work packages 1 to 5 plus a work package that provides for overall project goals (see work package descriptions for details). The addition of the latter counters two major risks for projects of this nature: Inadequate access to real data or realistic simulations and inappropriate burdens on researchers regarding the implementation of demonstrators, especially at the end of the project.

WP1	Domain Requirements, Use Cases, and System Concepts – led by Thales This activity investigates and defines use cases and domain requirements. Moreover, it aims at identifying suitable concepts for realizing a complete working system.
WP2	System State Assessment and Prognostics – led by RU This activity aims at techniques for estimating system health and information dependability.
WP3	Information Integration – led by VU This activity addresses ad-hoc information integration to enable the understanding of situations, tasks, information sources, and contexts even across the boundaries of systems and information spaces.
WP4	Adaptation and Reconfiguration – led by TUD This activity addresses the issues of adapting and reconfiguration in case of system failures and/or confidence issues with respect to situational awareness.
WP5	User-Defined Visualization of Heterogeneous, Uncertain Information – led by TU/e This activity studies how large amounts of heterogeneous and possibly uncertain information, along with information about the current status and configuration of the system that has produced it, can be presented to end-users.
WP6	Integration, Knowledge Consolidation, and Dissemination – led by ESI This activity supports the research by integrating the elements resulting from the previous work packages into a single system, thus enabling experiments and demonstrations via software development and simulations. Finally it also addresses knowledge consolidation and dissemination.

WORKPACKAGES

Project **Metis (P12)**	
WP title & acronym	WP1: Domain Requirements, Use Cases, and System Concepts
WP leader	Thales

Objectives

WP1 investigates and defines use cases and domain requirements. This activity includes the examination of processes and infrastructures in the public safety domain, starting with the topic of protection of critical infrastructures, especially ports and energy distribution, as well as the analysis of exercises in disaster response. The gained knowledge is then used to define requirements and use cases that inspire, lead, and focus the iterative process of the research activities within the project. The use cases shall encompass normal operations to be monitored for safety purposes, monitoring on heightened alert states based upon the integration of intelligence data, and reactions to emergencies that include a failure of parts of the infrastructure. The increasingly complex scenarios of the use cases will be used to define the demonstrators that validate the research. Moreover, this work package aims at identifying suitable system concepts for an information-centric, cooperative embedded system-of-systems for situational awareness in the area of public safety. It must be assured that the Metis system supports the objectives of the project, such as dynamic adaptability, reconfigurability, and built-in self-awareness for continuous, on-line dependability.

Project Metis (P12)	
WP title & acronym	WP2: System State Assessment and Prognostics
WP leader	Dr. Peter Lucas (RU)

Objectives

This work package aims at developing techniques for the assessment of the quality of information in the system and its environment, integrating a semantic model of the system and its health and control information. The techniques will satisfy the requirements imposed by the domain, which means that they should be built-in, allow system-level reasoning, and support run-time awareness of both flow and quality of information, based on system health and other appropriate input. These techniques will be supported by tools that work at run-time and that can deal with the level of dynamics occurring in the systems through adaptations and reconfigurations. Automated model-based diagnosis and on-line monitoring will play a role as well as prediction or what is going to happen using probabilistic models, such as Bayesian networks.

Project Metis (P12)	
WP title & acronym	WP3: Information Integration
WP leader	Prof. dr. Guus Schreiber (VU)

Objectives

WP3 addresses ad-hoc information integration. Integration of information from various, semantically ill-aligned sources is required to enable the understanding of situations, tasks, information sources, and contexts, even across the boundaries of systems and information spaces, and to ensure its coherent retrieval and interpretation. This involves the alignment of information for public safety, but also the alignment and use of meta-information about the environment, the system-of-systems configuration, sub-systems, components, and information flows and their reliability to support system-level reasoning about health, dependability, and possible (re)configurations. The integrated use of meta-information for reasoning about global system status, adaptation, and reconfiguration is cross-disciplinary and new, and it will require tight links to the other WPs.

Project Metis (P12)	
WP title & acronym	WP4: Adaptation and Reconfiguration
WP leader	Prof. dr. Cees Witteveen (TUD)

Objectives

This work package addresses the issues of adapting and reconfiguring the system in case of subsystem failures and/or confidence issues with respect to situational awareness. System reconfiguration and adaptation can be triggered by, for example, insufficient quality of information, or failing or newly available sources of information. Integrated system-level reasoning about identified causes and possible solutions by system adaptation or (re)configuration forms a major challenge. Combining adaptability and reconfiguration with continuous, guaranteed levels of dependability adds a further challenge. WP4 will provide methods and tools to perform this sequential diagnosis and reconfiguration process in an ad-hoc, dynamic, and on-line context.

Project Metis (P12)	
WP title & acronym	WP5: User-Defined Visualization of Heterogeneous, Uncertain Information
WP leader	Prof. dr. Jack van Wijk (TU/e)

Objectives

WP5 aims at the development of methods to present large amounts of heterogeneous information about the situation being monitored, in combination with meta-information about the system that has collected this information. This will result in a User-Defined Operational Picture (UDOP), providing specifically tailored situational awareness based on the current situation and the role of the user. Topics are the presentation of data-quality, the presentation of uncertain data, the coupling between information and its source, as well as the presentation of the system configuration and its status.

Based on the approach and results of the other WPs, especially WP1, a number of typical scenarios are identified and studied in depth. An example of a generic use case here is monitoring of moving objects by a net of sensors, where collisions with (possibly also moving) areas have to be avoided, and directions must be given. Dependent on the status of the sensors, information can be more or less reliable, and also, future positions are by definition uncertain. Prototype simulators are developed that act as data generators, novel visualization methods are developed to present these, and via user testing these are evaluated, all with the aim to develop generic insights in how to present meta-information optimally.

Project Metis (P12)	
WP title & acronym	WP6: Integration, Knowledge Consolidation, and Dissemination
WP leader	Dr. Pierre America (ESI)

Objectives

This activity aims at integrating the results of the various work packages into working systems that can be tested, validated and demonstrated. It will provide for the capability to connect individual contributions to each other and to existing systems. Furthermore, it will provide access to information sources and simulations to supply hard data for proofs-of-concept and evaluations. The work package also supports knowledge consolidation and dissemination outside the contributions to the academic community. This is done partly via the demonstrators, but also includes publications for a wider audience, workshops, courses, and joint activities for information exchange with other projects.

DELIVERABLES

Number of important journal paper
15

Number of important conference contributions
20

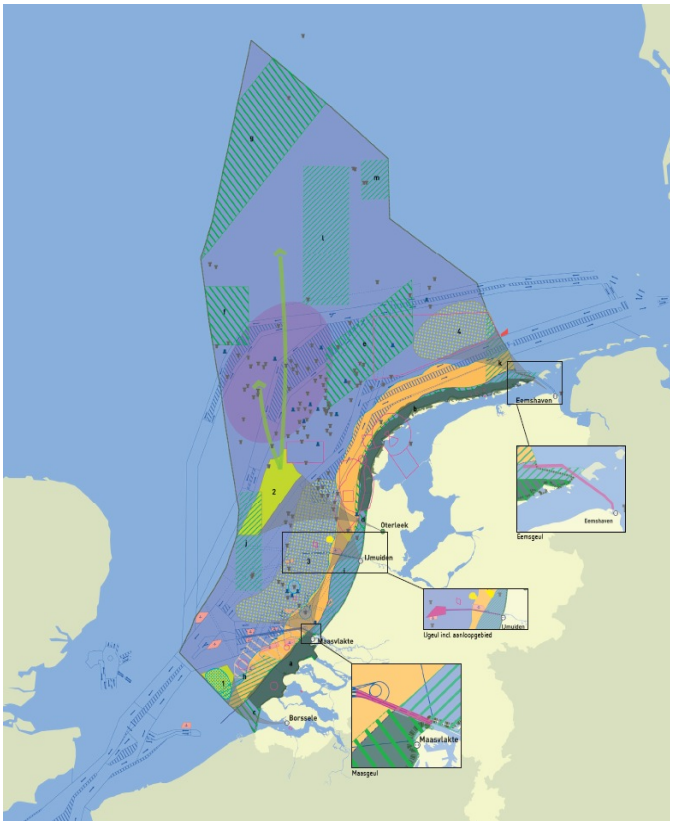
Products

1. D1.1 Report on initial requirements analysis and main scenarios

   Main responsible: Thales

   The domain of the Metis project is safety and security. In order to make this concrete enough for experimental validation of project results and to align it with the area of expertise of Thales, the main industrial partner, this is specialized to *maritime* safety and security, in particular on the North Sea (in principle, the Exclusive Economic Zone of the Netherlands, see figure below). To arrive at system requirements, we will analyze a number of scenarios related to safety (e.g., oil spill, shipping accident, search & rescue) and security (e.g., illegal fishing, illegal immigration, smuggling, terrorism). For each of the scenarios an initial assessment will be made of on the one hand the information that professionals need and on the other hand the information that could be obtained from various sources, so that the gap that the Metis system must fill, and therefore its initial requirements, become clear.

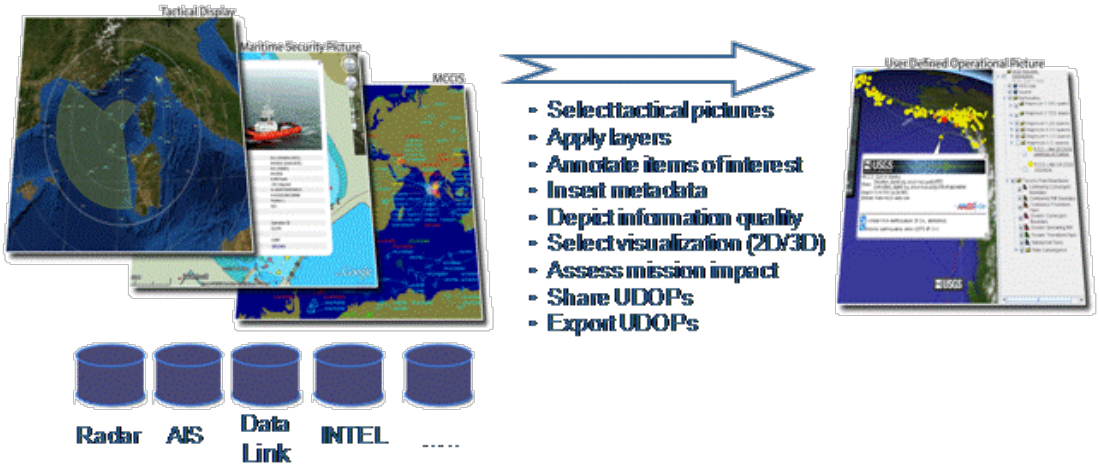
   - WP 1 YP 2011



2. D1.2 Use case 1 definition

   Main responsible: Thales

   From the scenarios described in D1.1, one must be chosen to be worked out into a use case definition. (Only when D1.1 is finished we have enough information to choose the first use case.) Such a use case definition contains a detailed description of the interaction between the user and the system. This description will be based on documented domain knowledge and on interviews with experts and practitioners. Since we strive towards a UDOP (User-Defined Operational Picture, see figure below) in this project, the most important element of the use case will be a description of the *information* that the system will present to the user and criteria on how this information is represented. On the other hand, the information sources (sensors and databases) that the system can use for this purpose will be specified in detail, so that WP6 can ensure the availability of suitable data sources to develop, test, and demonstrate the system.



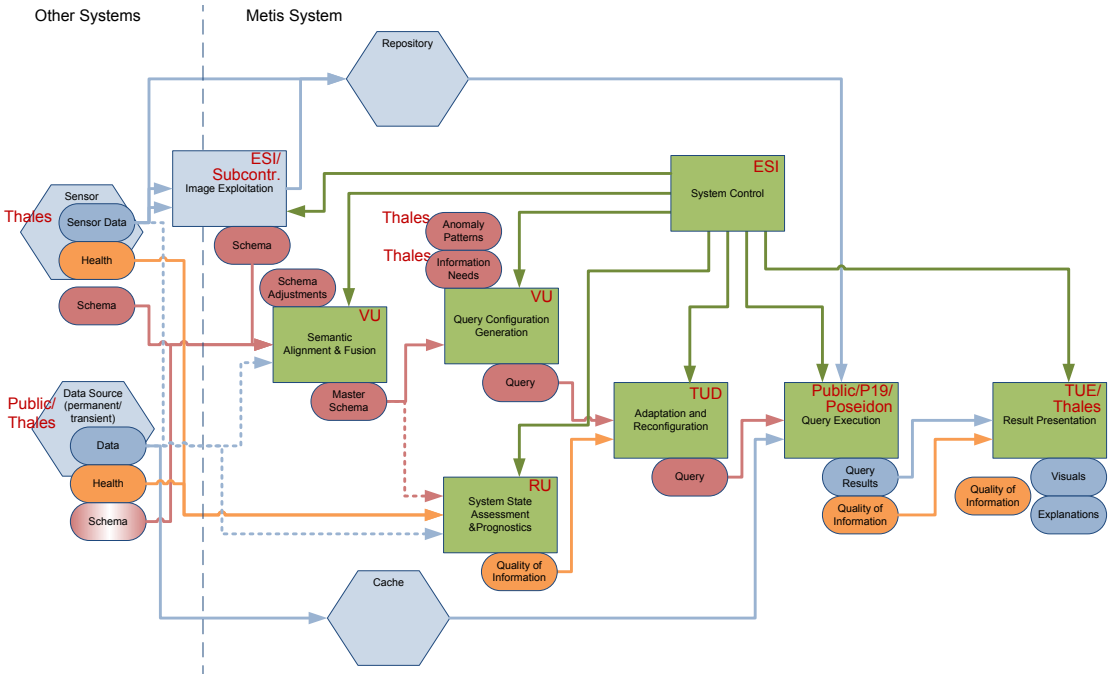
   - WP 1 YP 2011

3. D1.3 Report on initial system concepts for information centric embedded systems for public safety

   Main responsible: ESI

   In order to fulfill the requirements as laid out in D1.1 and D1.2, a suitable system must be constructed. The main innovative elements of such a system are elaborated in work packages 2 to 5, but success in those work packages does not lead automatically to a working system. For the latter purpose, we need a structure for the complete system, where the innovative elements are integrated with other components that are either available off-the-shelf or developed in other projects, e.g., Metis's predecessor Poseidon. A preliminary sketch of this structure is shown in the figure below. In addition to the overall structure we need initial descriptions of the interfaces between the components, developed together with the people

working in the other work packages. Finally we need an initial assessment whether a system as defined could meet the requirements as described in D1.1 and D1.2.



- WP 1 YP 2011

4. D2.8 Report on techniques for system state assessment and prognostics in dynamic systems-of-systems for public safety and security and other application domains

   Main responsible: Radboud University

   This report describes the techniques for system state assessment and prognostics as developed in this project. These techniques aim at assessing and predicting the quality of information available in a system-of-systems, based on the current health and control state of the various subsystems. The techniques are specifically aimed at serving the needs of safety and security professionals, but the applicability in other domains is also taken into account. On the one hand, the quality of information is an important criterion to be considered in dynamic reconfiguration of a system-of-systems. On the other hand, the dynamic nature of such a system means that the situation to be assessed can change frequently. The techniques described in this report have undergone limited validation in the context of the complete system; further validation will take place in the last year of the project.

   - WP 2 YP 2013

5. D3.8 Report on dynamic and ad-hoc techniques for information integration in systems-of-systems for public safety and security and other application domains

   Main responsible: VU Amsterdam

This report describes the techniques for information integration as developed in this project. These techniques aim at transforming data available from a large variety of sources into fully qualified and interlinked information accommodating the needs of the user. The techniques are specifically aimed at creating situational awareness for safety and security professionals, but the applicability in other domains is also taken into account. Whereas many existing techniques work with data from databases and websites, the Metis project explicitly includes data from various sensors, possibly arriving in a continuous, real-time stream. Moreover, the Metis techniques should offer several alternative ways for integrating data into information, thus offering opportunities for dynamic system reconfiguration. In turn, they should be able to deal with changes caused by dynamism inside and outside the Metis system-of-systems. The techniques described in this report have undergone limited validation in the context of the complete system; further validation will take place in the last year of the project.
- WP 3 YP 2013

6. D4.8 Report on techniques for adaptation and reconfiguration in systems of-systems for public safety and security and other application domains
   Main responsible: TU Delft
   This report describes the techniques for adaptation and reconfiguration as developed in this project. These techniques aim at establishing an adequate (if possible, even an optimal) system configuration at all times, even in the presence of subsystems that fail and become available dynamically or provide data with a changing degree of uncertainty. For this purpose, the Metis techniques will take into account various alternative paths for transforming available data into desired information, generated by WP3. They will combine these with an assessment of the quality of information streams, generated by WP2, and based on this input they will determine the best system configuration and cause this configuration to be established. The techniques are specifically aimed at serving the needs safety and security professionals, but the applicability in other domains is also taken into account. The techniques described in this report have undergone limited validation in the context of the complete system; further validation will take place in the last year of the project.
   - WP 4 YP 2013

7. D5.8 Report on visualization of uncertain, heterogeneous information in dynamic systems-of-systems for public safety and security and other application domains
   Main responsible: TU Eindhoven
   This report describes the techniques for visualizing uncertain, heterogeneous information as developed in this project. These techniques not only aim at a so-called UDOP (user-defined operational picture), containing various different kinds of information, but also strive to give the user an immediate grasp of the degree to which the information can be trusted. Whenever

desired, the system should be able to explain to the user how the displayed information was derived from the available sources. The techniques are specifically aimed at serving the needs safety and security professionals, but the applicability in other domains is also taken into account. Of course, the visualization techniques should be able to deal with dynamic changes inside and outside of the system. The techniques described in this report have undergone limited validation, separately (see D5.6) and in the context of the complete system; further validation will take place in the last year of the project.

- WP 5 YP 2013

8. D6.4 Report on computational representation techniques for quality of information in dynamic systems

   Main responsible: ESI

   For the complete Metis system to work, several components must interchange not only basic data, as obtained from various databases and sensors, but also metadata representing the several aspects of the quality of that data (e.g., accuracy, timeliness, and trustworthiness). In order to form a contiguous chain from source data to visualized information, all components need a common notion of what the relevant quality aspects are and how they are represented inside the system so that all components can handle these metadata correctly and efficiently. This report presents a computational framework for achieving this. It is compiled from contributions by all work packages in the project.

   - WP 6 YP 2012

9. D1.9 Report on system concepts for information centric embedded systems as in demonstrator

   Main responsible: ESI

   This report describes the concepts, mechanisms, and principles that form the basis of the whole Metis system. Each of the work packages 2 to 5 will contribute a component of the system, each embodying one or more innovative techniques it its own field of research. These components need to be combined with a number of off-the-shelf components and possibly some custom software, and

   finally composed into a complete system (which in turn forms a part of a larger system-of-systems). In order for this system to work well, it needs a well-defined structure and interfaces between its components.

   - WP 1 YP 2013

10. D1.10 Report on result validation via experiments and analysis with demonstrator

    Main responsible: Thales

    When the contributions of all work packages have been integrated into a common demonstrator system (in WP6), an evaluation will take place of the resulting system. This will assess whether

each components works well in this system and whether the complete system exhibits the desired behavior. Questions will be elaborated, such as the following:

- Does the user receive the necessary information to perform his task in a particular situation, as defined in a use case?
- Can new information sources be integrated quickly and accurately?
- Is the quality of information provided by the various data sources estimated accurately?
- Is the quality of the resulting information derived correctly from the quality of the input?
- Is the quality of the resulting information made clear to the user by the visualization that the system employs?
- Does the system reconfigure itself quickly and adequately as a response to external events, such as the failure of a subsystem?

- WP 1 YP 2014

Software

1. D2.9 Final prototype of system state assessment and prognostics for dynamic systems-of-systems for public safety and security and other application domains
   Main responsible: Radboud University
   This is the final software contributed to the Metis system by work package 2. This component is responsible for estimating the quality of information (including accuracy, timeliness, and trustworthiness) from different sources, such as websites, databases, and various sensors. Although the challenges of WP2 are rather varied (different information sources, different aspect of information quality) the techniques dealing with this variety should be integrated into a single component, which in turn should be fully integrated into the rest of the system, following the common principles and adhering to the agreed interfaces. This component is tuned to the needs of safety and security professionals, but other application domains are also taken into account. It should be able to work in a dynamically configured system.
   - WP 2 YP 2014

2. D3.9 Final prototype of information integration for dynamic systems-of-systems for public safety and security and other application domains
   Main responsible: VU Amsterdam
   This is the final software contributed to the Metis system by work package 3. This component is responsible for integrating data from different sources, such as websites, databases, and various sensors, into fully qualified and interlinked information that serves the needs of the user in a particular situation. This component is tuned to the information needs of safety and security professionals, but other application domains are also taken into account. Although there are a few separate challenges for WP3 (such as generating multiple data transformation paths and rapid, autonomous integration) the techniques dealing with this variety should be

integrated into a single component, which in turn should be fully integrated into the rest of the system, following the common principles and adhering to the agreed interfaces. This component should be able to work in a dynamically configured system.
- WP 3 YP 2014

3. D4.9 Final prototype of adaptation and reconfiguration for dynamic systems-of-systems for public safety and security and other application domains
   Main responsible: TU Delft
   This is the final software contributed to the Metis system by work package 4. This component is responsible for finding, at the appropriate times, an adequate (if possible, even optimal) configuration of the system in the presence of subsystems that dynamically become available and fail, or whose information quality changes over time. For this purpose, it should take into account the various alternative data transformation paths generated by WP3 and the information quality assessments by WP2. Although there are a few separate challenges for WP4 (such as different aspects of information quality) the techniques dealing with this variety should be integrated into a single component, which in turn should be fully integrated into the rest of the system, following the common principles and adhering to the agreed interfaces. This component is tuned to the needs of safety and security professionals, but other application domains are also taken into account.
   - WP 4 YP 2014

4. D5.9 Final prototype of system information visualization for dynamic systems-of-systems for public safety and security and other application domains
   Main responsible: TU Eindhoven
   This is the final software contributed to the Metis system by work package 5. This component is responsible for presenting to the user the information that he needs, based on a particular situation and his own role (the so-called UDOP, user-defined operational picture). This component is tuned to the needs of safety and security professionals, but other application domains are also taken into account. There are different kinds of information to be represented, only some of which are associated naturally to points in a two-dimensional space. Moreover, the various aspects of (lack of) information quality should be made clear to the user in an intuitive way. Despite these separate challenges, the techniques dealing with this variety should be integrated into a single component, which in turn should be fully integrated into the rest of the system, following the common principles and adhering to the agreed interfaces. Moreover, the component should function adequately in a dynamically changing system configuration.
   - WP 5 YP 2014

5. D6.3 Initial prototypes integrated in a common context
   Main responsible: ESI
   In the first year, each of the work packages 2–5 will produce a first prototype of a system component. These first prototypes will not be perfectly integrated with each other. In WP6 we will nevertheless put these prototypes in a larger context, based on the reference platform (see D6.1), including the necessary other components (off-the-shelf or from other projects, such as Poseidon) that are needed to construct a complete Metis system. In this way each of the prototypes can be tested, its contribution towards the first Metis use case (see D1.2) can be demonstrated, and gaps in the fulfilment of overall system requirements become apparent and therefore actionable.
   - WP 6 YP 2011

6. D6.5 Feasibility prototypes integrated in a common context, tuned towards domain requirements
   Main responsible: ESI
   In the second year, the work packages 2-5 will produce a new prototype each, which is optimized towards the requirements of the safety and security domain. These prototypes should also be integrated more tightly than in the first year, so that some cooperative actions can be tested and their contributions towards the first two Metis use cases (D1.2 and D1.5) can be demonstrated and validated. At the latest in this second year, but preferably earlier, all Metis-developed software will be brought under common source code control, so that the status of the software at any moment is clear.
   - WP 6 YP 2012

7. D6.6 Joint proof-of-concept demonstrator
   Main responsible: ESI
   In the third year, the prototypes developed by work packages 2-5 are further optimized to work in a dynamically reconfiguring system-of-systems. This means that besides local improvements and optimizations in each component, the way they work together must be carefully designed, implemented, and tested. For this purpose we need not only common source code control, but also systematic testing and issue tracking. The resulting system should demonstrate support for all three Metis use cases (D1.2, D1.5, and D1.8).
   - WP 6 YP 2013

8. D6.7 Integrated system-of-system demonstrator, aimed at public safety and security and other application domains
   Main responsible: ESI

This is the final prototype resulting from the Metis project. This is expected to clearly demonstrate all the achievements of the project. This applies especially to the integration of various information sources, the assessment and visualization of uncertainty in the information, and dynamic, event-driven reconfiguration. The prototype should support all three Metis use cases, and its suitability for other application domains should be carefully evaluated, where possible by practical experiments. Various professionals in safety and security should be shown the system and allow to try it out, and where possible their feedback should be accommodated into the system.

- WP 6 YP 2014

User studies

1. D1.11 Assessment of applicability of project results for situational awareness for public safety
   Main responsible: Thales
   When the project is halfway, it is a good moment to assess whether we are on the right track. For this purpose, we will contact various professionals fro which maritime situational awareness is relevant. Besides Thales in-house domain experts, this may include the Dutch coastguard, police, and Navy, who mainly need real-time information. It may also include institutes such as Rijkswaterstaat and Marin, for whom suitably aggregated historical data may be more relevant. Each of these experts can be presented with the preliminary project results and asked for their feedback regarding the fulfillment of their information needs. This feedback can then be taken into account in the continuation of the project.
   - WP 1 YP 2012

2. D1.12 Assessment of applicability of project results in other domains
   Main responsible: Thales
   Although maritime situational awareness is the main focus for the Metis project, the project results will probably be applicable to other domains as well: There are many application areas where systems would be useful that can deal with the complications of having many different information sources. To assess this we will consider various adjacent domains. The other COMMIT project may offer good opportunities for that, but we will not limit ourselves to those. Where possible, we will perform practical experiments based on the Metis prototypes.
   - WP 1 YP 2014.

3. D1.13 Evaluation of impact of dissemination to government agencies
   Main responsible: Thales
   During the project, there will be many instances of contact with government agencies. These may include the coastguard, navy, police, and harbour authorities, but also Rijkswaterstaat and Marin. At these contact moments the Metis project will show its intermediate or final results

and will ask for immediate feedback. However, we also expect that the Metis project will give the agency people a glimpse of a possible future of their way of working, which may change the way they think about their work. At the end of the project we want to evaluate whether and how the new techniques developed in Metis could influence their work, and whether this causes a change in attitude of government agencies towards these techniques.
- WP 1 YP 2014

4. D5.6 Evaluation of new visualization methods for uncertain, heterogeneous information
   Main responsible: TU Eindhoven
   Work package 5 aims a presenting uncertain, heterogeneous information to a user in such a way that he immediately grasps the meaning of the information and its associated uncertainty. In order to assess to which degree this goal is reached, we plan to do a number of user tests with current or former safety and security professionals, e.g., from coastguard, police, or navy. These tests will be carefully evaluated and the results will be used to guide further research within the project.
   - WP 5 YP 2013

Other results

1. D2.10 Ph.D. thesis on system state assessment and prognostics for systems-of-systems
   Main responsible: Radboud University
   This is the main academic result of work package 2. It describes the techniques that the Metis project has developed to assess the quality (in terms of, among others, accuracy, timeliness, and trustworthiness) of information from various sources (such as websites, databases, but also sensors). The added value of this work is that it has been validated in the larger context of a complete system serving the needs of professionals in the domain of safety and security at sea, where the quality of information is not only presented in a meaningful way to the end user, but also provides adequate criteria for dynamic adaptation of the system to a changing outside world.
   - WP 2 YP 2014

2. D3.10 Ph.D. thesis on information integration for dynamic systems-of-systems
   Main responsible: VU Amsterdam
   This is the main academic result of work package 3. It describes the techniques that the Metis project has developed to semantically integrate information from various sources (such as websites, databases, but also sensors). The added value of this work is that it has been validated in the larger context of a complete system serving the needs of professionals in the domain of safety and security at sea, where the information is not only presented in a

meaningful way to the end user, but where the sources and processing of the information are adapted dynamically to a changing outside world.
- WP 3 YP 2014

3. D4.10 Ph.D. thesis on dynamic adaptation and reconfiguration in systems-of-systems
   Main responsible: TU Delft
   This is the main academic result of work package 4. It describes the techniques that the Metis project has developed for dynamic adaptation and reconfiguration of a system that collects and processes information from various sources (such as websites, databases, but also sensors). The added value of this work is that it has been validated in the larger context of a complete system serving the needs of professionals in the domain of safety and security at sea, where the information is not only presented in a meaningful way to the end user, but where the sources and processing of the information are adapted dynamically to a changing outside world.
   - WP 4 YP 2014

4. D5.10 Ph.D. thesis on visualization of uncertain, heterogeneous information in dynamic systems-of-systems
   Main responsible: TU Eindhoven
   This is the main academic result of work package 5. It describes the techniques that the Metis project has developed to visualize uncertain, heterogeneous information collected from various sources (such as websites, databases, but also sensors). The added value of this work is that it has been validated in the larger context of a complete system serving the needs of professionals in the domain of safety and security at sea, where not only the information, but also its quality (in terms of, among others, accuracy, timeliness, and trustworthiness) is presented in a meaningful way to the end user, and where the sources and processing of the information are adapted dynamically to a changing outside world.
   - WP 5 YP 2014

5. D6.8 Book on Dependable Cooperative Systems, possibly published in the ESI series or in the Springer series on Embedded Systems
   Main responsible: ESI
   ESI has the tradition to publish a book for each project it leads. This offers the project participants to make the result of their work available to a larger audience. Typically such a book contains a chapter for each identifiable component of the project, plus a broad introduction and a reflection on the project itself. The target audience for such a book is not only academic, but also practitioners are explicitly addresses, and in this way the impact of the work is increased. In the beginning, ESI itself published these books, but recently Springer has shown interest in publishing them, which has already led to one Springer book for an ESI

project, with more being planned. This drastically improves the worldwide availability of the book, both in hardcopy and in electronic format.

- WP 6 YP 2014

6. D6.9 Consolidation of project results for course development

   Main responsible: ESI

   At the end of the project, the results must be consolidated in a way that permits adequate further use. This further use might be continued research, but we are also especially aiming at use in industry. For the partners participating in the Metis project, further use would be sufficiently enabled by simply storing the project deliverables and making them available, because they already have the implicit background knowledge from the project. By itself, this already requires significant attention, so that a complete and consistent set of artefacts is retained. For other institutions, however, a more thorough introduction will be needed to make the project results accessible. Therefore the project plans to develop course material, which enables research and developers to absorb the project results and build on top of them.

   - WP 6 YP 2014