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Project Partners: **ATB, Electrolux, IKERLAN, OAS, ONA, The Open Group, University of York**

PROJECT PARTNER CONTACT INFORMATION

ATB Sebastian Scholze Wiener Strasse 1 28359 Bremen Germany Tel: +49 421 22092 0 E-mail: scholze@atb-bremen.de	**Electrolux Italia** Claudio Cenedese Corso Lino Zanussi 30 33080 Porcia Italy Tel: +39 0434 394907 E-mail: claudio.cenedese@electrolux.it
IKERLAN Trujillo Salvador P Jose Maria Arizmendiarrieta 20500 Mondragon Spain Tel: +34 943 712 400 E-mail: strujillo@ikerlan.es	**OAS** Karl Krone Caroline Herschel Strasse 1 28359 Bremen Germany Tel: +49 421 2206 0 E-mail: kkrone@oas.de
ONA Electroerosión Jose M. Ramos Eguzkitza, 1. Apdo 64 48200 Durango Spain Tel: +34 94 620 08 00 jramos@onaedm.com	**The Open Group** Scott Hansen Rond Point Schuman 6, 5th Floor 1040 Brussels Belgium Tel: +32 2 675 1136 E-mail: s.hansen@opengroup.org
University of York Leandro Soares Indrusiak Deramore Lane York YO10 5GH United Kingdom Tel: +44 1904 325 570 E-mail: leandro.indrusiak@york.ac.uk	

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EXECUTIVE SUMMARY

The SAFIRE project is addressing the need within European Manufacturing for rapidly adaptive smart production systems by providing features for intelligent reconfiguration of both production processes and smart products. Manufacturers need more information about how product use affects the lifecycle of a product, and how product design affects production processes and to use this information to improve production capabilities and to deliver new product services.

SAFIRE aims to improve the efficiency, costs, security and adaptation capabilities of both manufacturing systems, and the smart products they produce. SAFIRE will deliver innovations in big data analytics, situation awareness, security-policy enforcement, as well as advanced optimisation and reconfiguration engines to enable European Manufactures to be more adaptive and efficient in production and to deliver smart products that are more responsive to user needs.

This document summarises the motivations that are driving the project innovations and presents the technological concepts of the SAFIRE solution. This SAFIRE concept provides the overall description of the detailed architecture based on the results of the completed tasks of analysing multiple Manufacturing scenarios to identify the core technologies that will substantially improve European Manufacturing and enable more responsive smart products. A detailed architecture of the SAFIRE Framework is provided along with the expected workflow and the actors involved in a typical SAFIRE deployment.

1. SAFIRE PROJECT

1.1 MOTIVATION

Manufacturing of products has become increasingly complex and driven to greater flexibility due to an increasing diversity of product portfolios, demand for more customised products, and shorter time-to-market requirements. To face these challenges there is a need for rapidly adaptive smart manufacturing systems with features for intelligent reconfiguration of production processes and of smart products.

In traditional models of manufacturing, the information flow from product design, over production processes, to the manufactured product has been unidirectional as information flows from the product and process design tools into planning tools and on to production equipment control systems.

In order to improve the manufacturability and re-configurability of products, the product designers need to have more information about how product use affects the lifecycle of a product, and how product design affects the production processes. Currently, product use and product production activities are often separated, leading to low efficiency and high costs for both users and manufacturers. Some of these required optimisations can be carried out by adjusting production control parameters (e.g. improve production quality by adjusting parameters), while others require the reconfiguration of manufactured products.

SAFIRE addresses these opportunities and aims to improve efficiency, security, costs and context based adaptation of manufacturing systems and products themselves, based on big data analytics, situation determination, security-policy description languages and engines, as well as optimisation and reconfiguration engines.

This SAFIRE concept provides the overall description of the detailed architecture, software technologies, service infrastructure and implementation framework based on the results of the manufacturing scenarios analysis task, along with the tasks to specify the research and industrial requirements and optimisation metrics, and associated manufacturing infrastructures.

1.2 OBJECTIVES

The primary objective of the SAFIRE project is to develop cloud-based analytics and reconfiguration capabilities that provide:

1. Both reactive and predictive reconfiguration for both production systems and smart products

2. Flexible run-time reconfiguration decisions during production rather than pre-planned at production planning time

3. Real-time reconfiguration decisions for optimisation of performance and real-time production and product functions.

The SAFIRE project targets two related technology challenges for smart factories that present new opportunities for improving production, products and services:

1. Interconnected Systems of Production Systems (SoPS) within smart manufacturing environments, where individual production systems and the SoPS as a whole, have hardware and software requirements to be addressed to achieve specific business objectives, such as scheduling, power consumption, throughput, and maintenance.

2. Connected Product Networks (CPNs) where networked smart products collect data, can be adapted in the field, and can deliver extended services to customers through optimisation of smart product performance parameters and customisation of products to environments, usage patterns and other dynamic factors.

The advanced analytics and reconfiguration capabilities to be developed in SAFIRE will be based on mastering the big data challenges associated with manufacturing (sensor and process data), enterprise and smart product data, to allow manufacturers to address production-system-behaviour forecasting, and to establish optimisation methods that are integrated in the design and product chain. The project will deliver big data analytic capabilities that meet real-time requirements so that dynamic run-time reconfiguration decisions are made during production time rather than pre-planned at production-planning time.

The project will allow both SoPS clients with limited resources to leverage the smart services running in the cloud to perform complex optimisation algorithms on their behalf to maintain and improve performance of the SoPS within a dynamic smart factory production environment, as well as data from CPNs to be analysed using cloud resources, to drive production optimisation decisions. SAFIRE aims to demonstrate that by performing reconfiguration in the cloud, continuous optimisation of the system can be achieved, which enables far better reconfiguration control and accuracy than if performed in either a pre-planned or online manner.

The technologies and innovations that will be developed in the SAFIRE project include the following:

- New techniques for reconfiguration and optimisation of production systems and products based on predictive big data analytics of data generated by exploiting situational awareness during production and product use.
- A set of tools and services to support:
  - Dynamic and predictable reconfiguration and optimisation
  - Predictive big data analytics
  - Cloud resource management

- New cloud based secure infrastructure for reconfiguration and optimisation of production systems / smart products.

The envisaged SAFIRE infrastructure is targeted to be provided as an add-on for an existing production system, or next generation smart factory operating system, allowing production systems to be transformed to include capabilities for dynamic real-time reconfiguration and optimisation. Key-elements of the new environment, such as the SAFIRE ontology, which will be developed as part of the situation model used by the situation determinations services, have been identified as opportunities standardisation aspects.

In order to assure that the methods and tools to be developed meet the needs of European manufacturers, the project is driven by three industrial manufacturing scenarios within globally distributed enterprises, that are partners in the consortium, and who will validate the technologies in multiple manufacturing and product settings. The SAFIRE project will carry out research and development and industrial validations through September 2019.

2. SAFIRE SOLUTION

In this section the different elements that constitute the SAFIRE solution are outlined first at a high conceptual level, and then giving detailed information on the structure and the components to be developed.

2.1 SAFIRE CONCEPTUAL ARCHITECTURE

The advanced analytics and reconfiguration capabilities for optimising production and product performance that SAFIRE will provide will be based on mastering big data challenges associated with manufacturing (sensor and process data), enterprise data and smart product data to provide advanced analytics that allow manufacturers to address production system behaviour forecasting, and to establish optimisation methods that are integrated in the design and product chain. The SAFIRE solution has the aim to:

1) reconfigure reactive and predictive production systems, and smart products;
2) reconfigure in a flexible way and during run-time production rather than pre-planned at production planning time; and
3) reconfigure in real-time decisions for optimisation of performance and real-time production and product functions.

The SAFIRE concept encompasses various actors and complex software/hardware systems and is driven by different manufacturing scenarios and real challenges encountered by European manufacturers today. These different scenarios have been aggregated into a general scenario that represents the many interests and desired improvements manufacturers would like addressed both for improving production, as well as for the smart products that are produced.

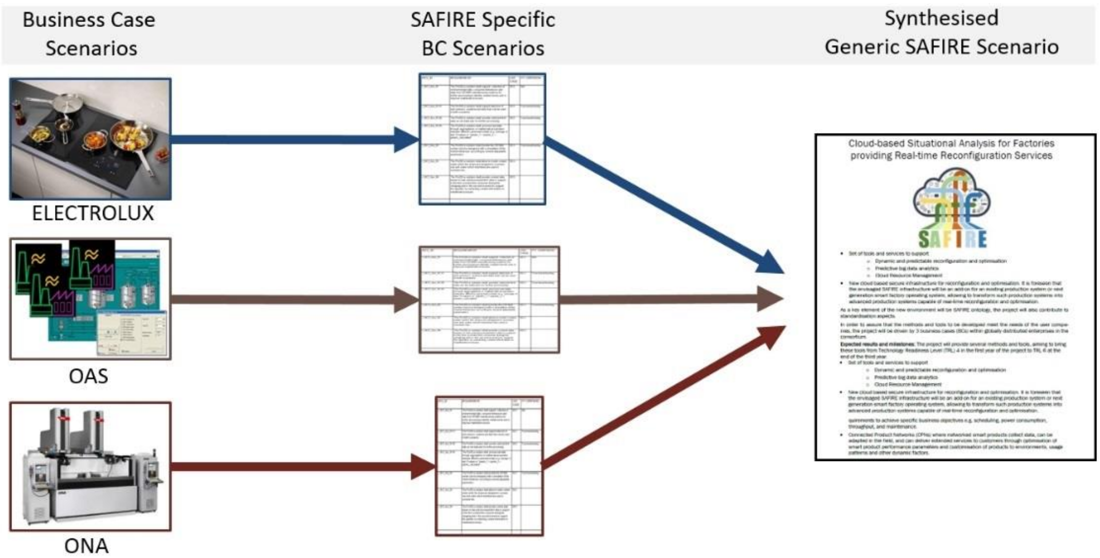

Figure 1: Methodology followed for the extraction of the generalised scenario

Three industrial manufacturing organisations, Electrolux, OAS, and ONA, from different parts of Europe that participate to the project, described scenarios based on their industrial needs, but also representative of many other manufacturers in their respective sectors. A methodology was followed to establish a more generalised manufacturing scenario, starting with the careful examination of the information provided by each of the industrial partners and the specific concerns within each of their manufacturing organisations.

The aggregation of the specific manufacturing scenarios into a more generalised scenario drove the creation of the conceptual architecture for the SAFIRE solution. Figure 2 shows at conceptual level the main blocks of the SAFIRE architecture that address these challenges.

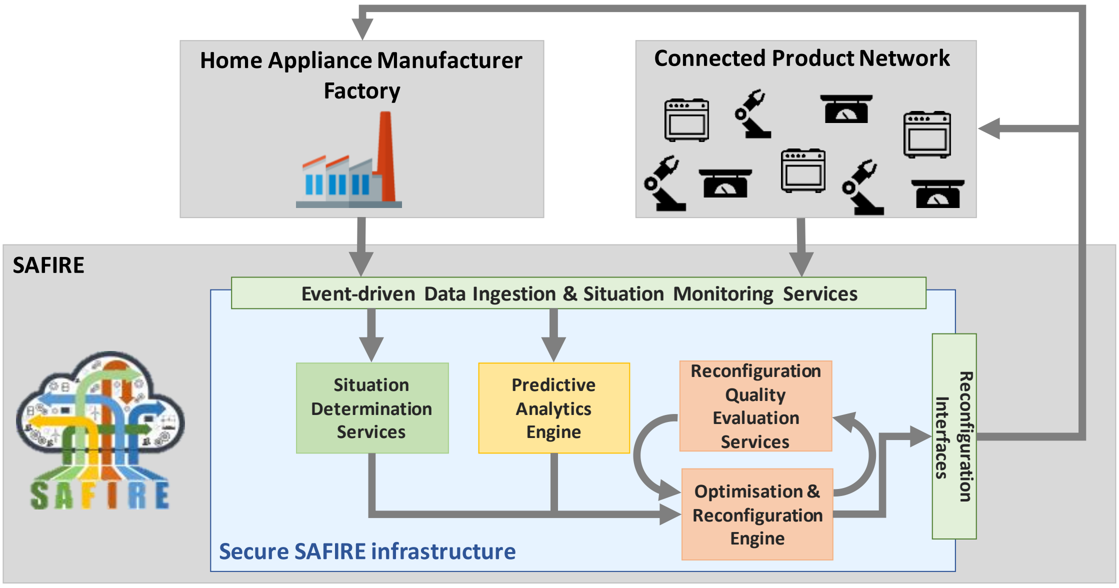

Figure 2: SAFIRE Conceptual Architecture

A quick synopsis of the SAFIRE conceptual architecture shown in Figure 2 would be the following:

> *In a secured infrastructure, a Big Data Platform which contains different components separately managed by a cloud resource management system. The Big Data Platform includes a Predictive Analytics Engine that analyses big amounts of data coming from production systems and smart products through the Monitoring Interface, using different kinds of algorithms and multiple information sources.*
>
> *Results of the Predictive Analytics Engine are used by a Reconfiguration and Optimisation Engine, which generates optimised configurations for production systems and smart products. The Configuration Quality Evaluation evaluates the quality of old and more optimised configurations, based on the feedback loop. The Reconfiguration and Optimisation Engine uses the Reconfiguration Interfaces to upload optimised configurations to connected production systems and smart products.*

The following sections provide more details of the SAFIRE architecture and the capabilities of each of its elements.

2.2 SAFIRE DETAILED ARCHITECTURE

Moving from a conceptual view to a more detailed view of the SAFIRE architecture (see Figure 3) the SAFIRE solution is divided into three main blocks:

- **SAFIRE framework** combines different technologies that are processing data
- **Event-driven Data Collection**, **Situation Monitoring Services** & **Reconfiguration Interfaces** for unified access to connected objects, such as legacy systems and deployed products, for event-based monitoring and reconfiguration
- I**nformation handling resources** for securely sharing information and knowledge between the SAFIRE framework modules, the connected objects, and the needed data modules as configurations, or models, which are handled through a SAFIRE Data Access Layer for storing different kinds of information

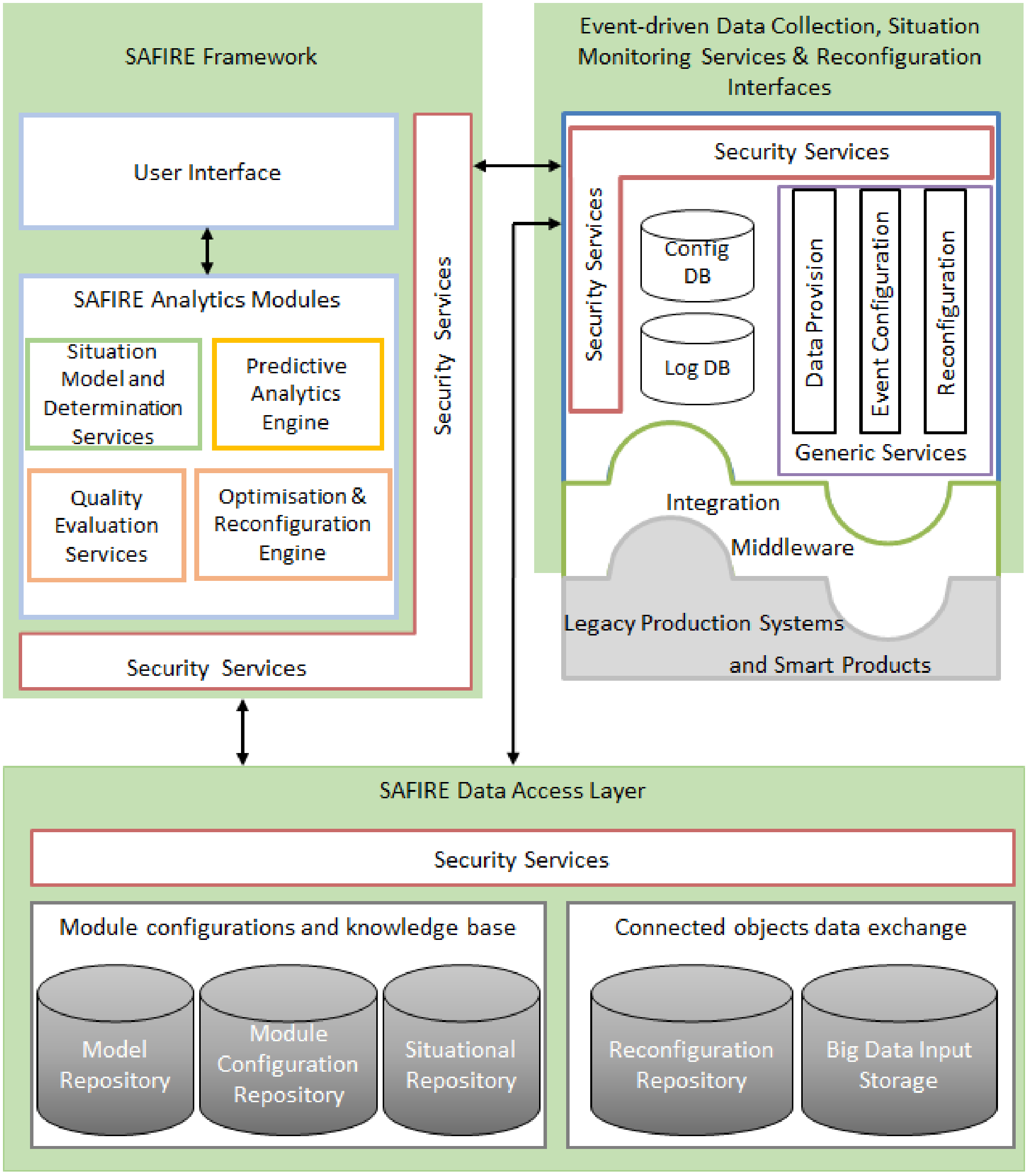

Figure 3: SAFIRE Architecture

All three blocks of the SAFIRE architecture are interacting within a secured cloud infrastructure realised through a security-policy description language and engine that enforces system wide policies for security, privacy and trust.

2.2.1 SAFIRE Framework Layer

The SAFIRE Framework Layer includes the following components:

Security Services are configured and deployed by a Security, Privacy, and Trust (SPT) Framework that enables the identification of security requirements, prioritisation of security objectives and selection of technologies for the implementation of SPT Runtime services. The security services build an overall solution providing security, privacy and trust for the production and product data and authentication and verification services to ensure the integrity of optimised configurations.

Situation Model and Determination Services analyse correlations between production and products including situational information. These services dynamically monitor and identify situations based on process information from various sensors, products and databases. Analysis results are used for further analytics in the Predictive Analytics Engine and by the Reconfiguration Quality Evaluation Services to adapt configurations to specific situations.

Predictive Analytics Engine will provide support for real-time big data analytics based on the Lambda+ architecture which offers data aggregation, filtering, mapping, storage, processing etc., in a near real-time context. Moreover, the platform will be capable of using machine learning algorithms to the ingested data in order to extract valuable knowledge. This component will be deployed in a distributed fashion, in order to provide tolerance to failures and enabling continuous operation despite hardware or software crashes.

Optimisation & Reconfiguration Engine provides reactive and predictive optimisation of production asset and product configurations within real-time constraints based on analysis results from the Situation Model and Determination Services and the Predictive Analytics Engine. The engine uses search and related techniques to calculate new configurations which meet system metrics (e.g. real-time constraints, communications bandwidths and latencies, power dissipation, maintenance cycles). It also generates new scenarios for the models to evaluate. These scenarios will be based upon the current system state, or on some close variation (e.g. predicting the likely future states of the system which can be based upon historic data). Optimised and evaluated reconfigurations will be sent to connected production assets and products using the event-driven data collection, situation monitoring services & reconfiguration interfaces.

Reconfiguration Quality Evaluation Services are evaluating optimisation metrics related to each production or product scenario, and provide respective data collection strategies and configuration quality evaluation methods.

User Interface block provides the graphical user interface or programming interface for client applications to access the SAFIRE modules.

2.2.2 SAFIRE Data Access Layer

The SAFIRE Data Access Layer includes **Security Services**, data repositories for configurations and knowledge related to modules, and the following repositories for the data exchange with connected objects (e.g. production/factory assets and connected smart products):

- **Model Repository** stores situation models (schemes) of production systems and intelligent products, their current state and environment, as well as optimisation metrics/performance characteristics, and situational constraints. Such models will be used by the Situation Model and Determination Services.

- **Situational Repository** stores extracted situations (data) calculated by Situation Model and Determination Services.
- **Module Configuration Repository** stores configurations of SAFIRE analytics modules. Any information which is necessary for a manufacturing scenario-specific execution of these modules will be stored in this repository.

The block "**Connected Object Data Exchange**" contains two repositories for the data exchange between SAFIRE analytics modules and connected objects.

- **Reconfiguration Repository** stores reconfiguration calculated by the Optimisation & Reconfiguration Engine to be provided for an evaluation by the Reconfiguration Quality Evaluation Services or for a reconfiguration by connected factory assets or smart products.
- **Big Data Input Storage** stores data coming from connected factory assets or smart products. These pre-processed (filtered, aggregated) data are used by Situation Model and Determination Services and the Predictive Analytics Engine.

2.2.3 Data Collection, Situation Monitoring & Reconfiguration Interfaces Layer

This layer is a shell for connected objects, which includes Security Services, Generic Services for data provision, event configuration and reconfiguration, repositories to store configurations and log data, and an integration middleware to integrate e.g. legacy productions systems or smart products.

The **Generic Services** define the necessary functionality to access the connected object including:

- **Data Provision Service** is a monitoring service which provides monitored, collected, filtered, aggregated and pre-processed data of integrated legacy production systems and smart products. Such data is sensor data but also manufacturing scenario depended meta data. This service provides a generic web-service based data acquisition interface to provide all needed data for the data analysis in the SAFIRE analytics modules.
- **Event Configuration Service** enables the configuration of publish and subscribe features. Data transport in modern unified cross-level and cross-domain communication infrastructures increases the data amount in networks. One technique to reduce the overhead in such infrastructures is an event-based communication. This generic service provides event-based communication features including publish and subscribe functionalities to provide event-based monitored, collected, filtered, aggregated or pre-processed data.
- **Reconfiguration Service** enables the configuration provision and reconfiguration of the connected object. Normally SAFIRE connected production systems or smart products have a specific manufacturing scenario dependent configuration defining their behaviour in run-time. This generic service enables a unified provision of currently running configurations and provides also a unified access to reconfigure the connected production system/smart product.

The shell will also include two repositories to store data:

- **Configuration Database** stores the current configuration of the connected object. It is a unified embedded storage for the object internal provision and replacement of the configuration which defines the run-time behaviour of the object.
- **Log Database** stores configured events/data (temporary) needed by SAFIRE analytics modules. It is a unified temporary storage needed e.g. to enable data pre-processing, data aggregation or data package/bundle creation.

The integration middleware defines a layer between the connected object itself and the generic SAFIRE Event-driven Data Collection, Situation Monitoring Services & Reconfiguration Interfaces. This middleware has to be implemented for specific needs of a manufacturing scenario to integrate specific production systems and smart products.

3. SAFIRE WORKFLOW

The SAFIRE solution is composed by different services which either act as a proxy serving data to other services, or are being used to process the data and ensure their secure flow within the SAFIRE solution. In order to understand the system operation in detail, it is important to describe the workflow that occurs in the different phases (i.e. configuration and execution phases), as well as the workflow within each of the module services. The interaction between the different phases is shown in the generalised scenario in **Error! Reference source not found.**.

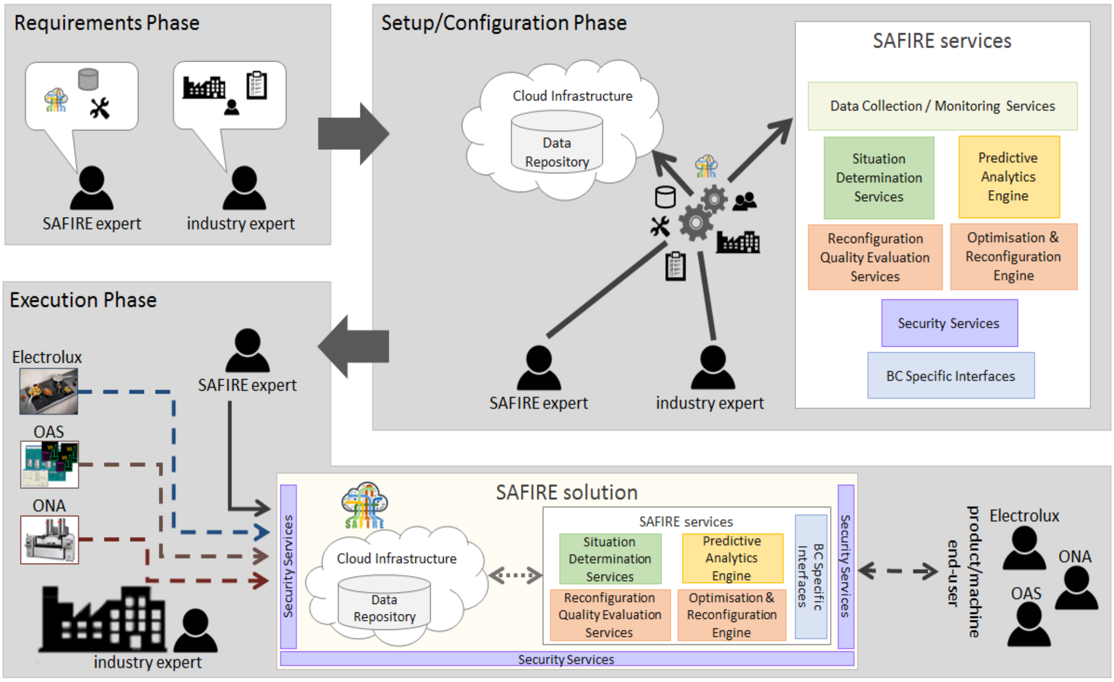

Figure 4: Generalised Scenario addressing manufacturing challenges

Figure 5 shows an example of a sequence of steps that can be followed for the configuration of the SAFIRE solution during the Setup/Configuration phase. Since the configuration of the different services does not depend on one another, the sequence of the steps may be different depending on the individual preferences of the specific manufacturing application scenario.

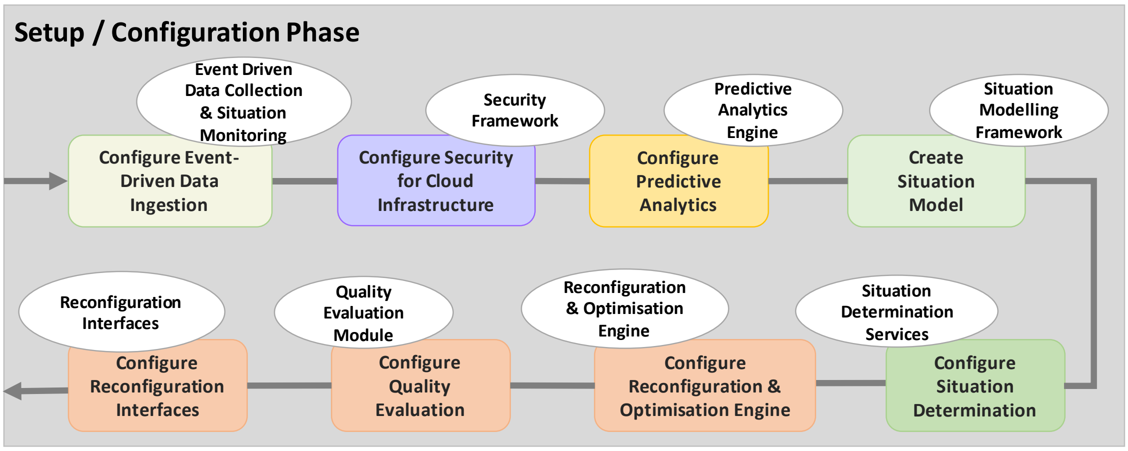

Figure 5: Workflow of Setup/Configuration Phase

The steps that are typically taken in the Setup/Configuration phase are the following:

- **Event Driven Data Collection & Situation Monitoring:** The first step entails data gathering from the different Internet of Things (IoT) protocols. The data will be ingested using an horizontally scalable framework that will enable its normalisation and routing to different channels of the SAFIRE publish / subscribe messaging system called Kafka in order to allow further processing.

- **Security Framework:** A security framework provides a complete and coherent approach to system security based on establishing system level principles and utilising secure-by-design techniques. It is distinguished from the results obtained from an unprincipled assembly of a patchwork of security products that may leave gaps in coverage of threats or policies. It is conceived to cover a broad range of circumstances and the complexities and diversities that occur in practice. From an analytical standpoint, the security framework provides generality and completeness. From an implementation standpoint, the security framework provides tools, methods, and pre-packaged adaptable security components that ease implementation, integration, and security evaluation.

- **Predictive Analytics Engine:** The predictive analytics framework is in charge of the storage of the massive amount of information that will be ingested from connected factory assets or smart products to the SAFIRE platform. Apart from that, the predictive analytics engine will provide real-time and batch Big Data analytics enabling a complete solution. Moreover, the Predictive Analytics Engine will provide to other SAFIRE modules product and factory data when required.

- **Situation Modelling Framework:** In this step, the situation model (ontology) of the specific manufacturing scenario should be decided. The situation model should include all the relevant entities that constitute the environment under which the SAFIRE solution will operate (e.g. different actors, infrastructure and relations between different entities). A respective rdf/owl file should be created in order to be used as input for the Situation Determination Services.

- **Situation Determination Services:** In this step, the situation model will be given as an input to the determination services. Additionally, specific configuration will be done with respect to the data sources that the Situation Determination Services will analyse in order to identify the context under which the SAFIRE solution operates.

- **Reconfiguration Interfaces / Quality Evaluation Module / Reconfiguration & Optimisation Engine:** There are various alternative means of specifying optimisation problems with associated trade-offs between ease-of-modelling and expressiveness. However, they all share the essential notions of: input variable, output values and associated constraints together with a means of evaluating the quality of an optimised output. A 'problem specification language' will be provided and the reconfiguration interface will be implemented so as to receive a specification in this form and produce an optimization algorithm configured to the specified problem.

Having completed the Setup/Configuration phase, the SAFIRE solution would then transition to the Execution phase, which is shown in Figure 6.

In the Execution phase, the Event-driven Data Ingestion services accept data from the factory and the connected products and acts as a proxy, serving the data as input to the Situation Determination services and the Predictive Analytics Engine. Processed data from the Situation Determination services and the Predictive Analytics Engine flow into the Optimisation and Reconfiguration services for further processing. The results of this processing are forwarded through the Reconfiguration Interfaces, and from there are fed back to the production system processes or the connected products.

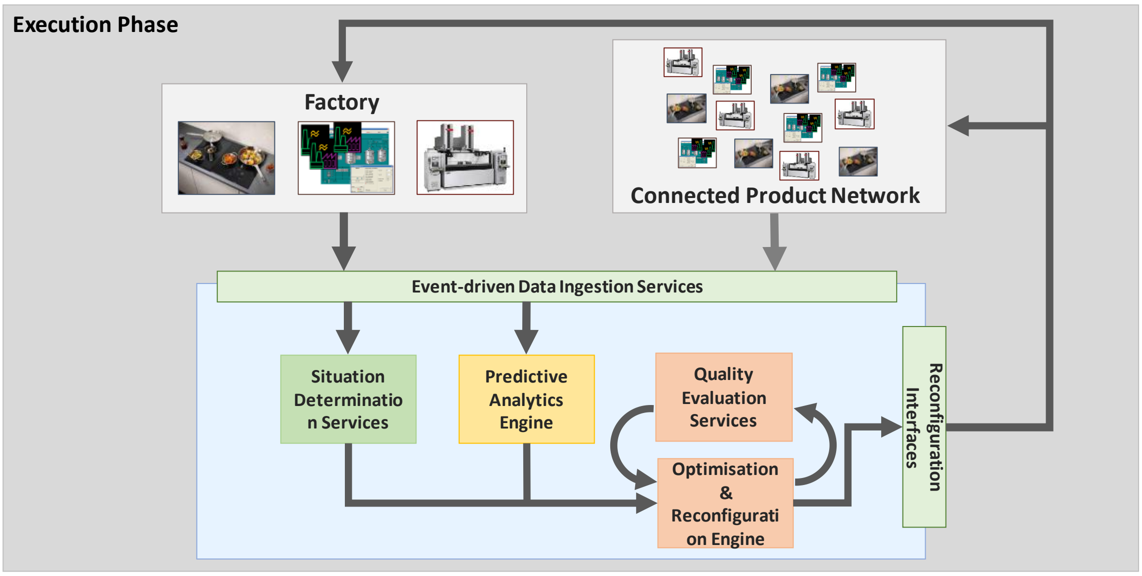

Figure 6: Workflow of Execution phase

For the Predictive Analytics Engine, the workflow can be described in Figure 7. The services start, having as an input, data coming from the Event-driven Ingestion services or from the other modules of the SAFIRE platform. The input data will both be stored in a scalable data lake and processed in real-time using a distributed real-time analytics engine. Moreover, the same engine used for real-time analytics will be used for Big Data batch analytics over the stored data.

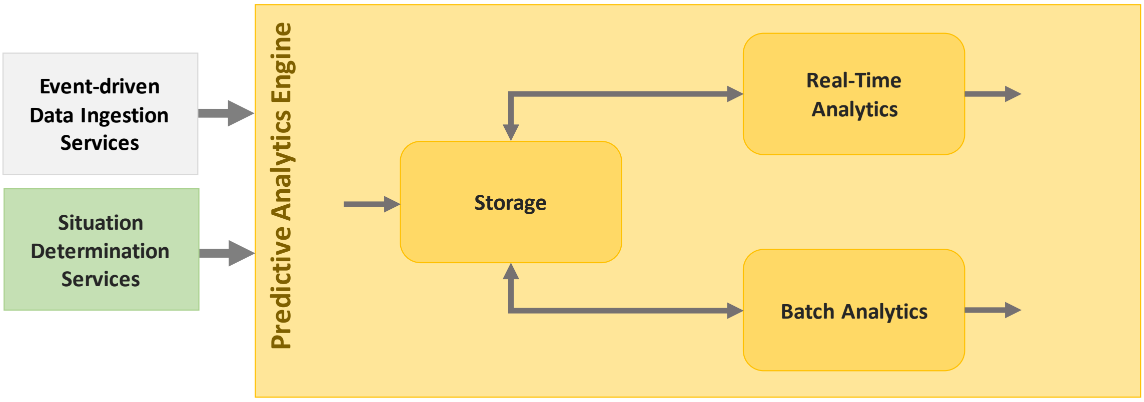

Figure 7: Workflow for the Predictive Analytics Engine

Figure 8 shows the workflow for the Situation Determination services. Those services receive input data both from the Event-driven Data Ingestion services, as well as from the Predictive Analytics Engine. The workflow of this module starts with the reception of the data in the appropriate format, and continues with the analysis where the current situation of operation is identified. Through reasoning techniques, the identified situations are being polished and the results are being forwarded for storage, to be available for the other services.

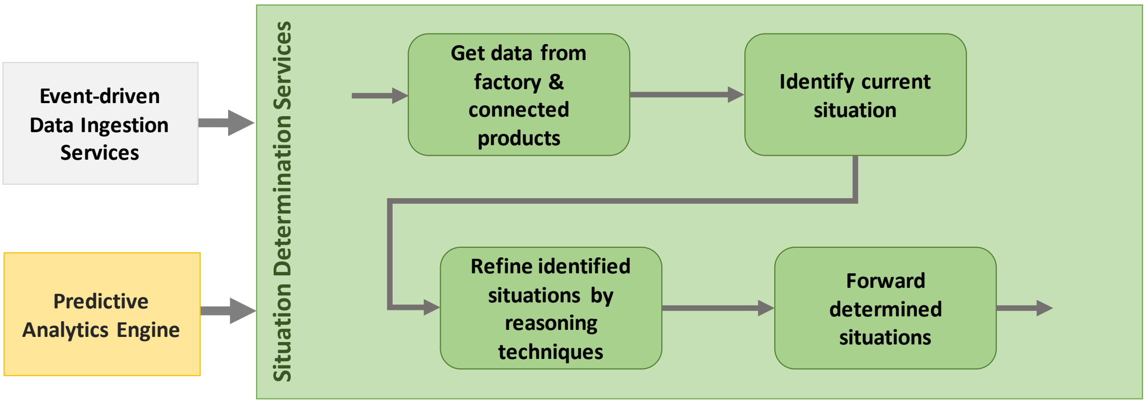

Figure 8: Workflow for the Situation Determination Services

The workflow for the Optimisation and Reconfiguration Engine is shown in Figure 9. This module receives input data from the Event-driven Ingestion services, as well as from the other two services, namely the Predictive Analytics Engine and the Situation Determination services.

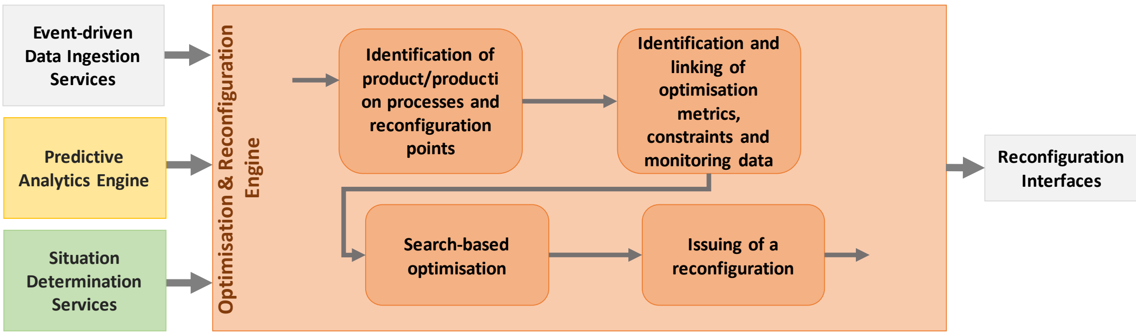

Figure 9: Workflow for the Optimisation & Reconfiguration Engine and Quality Evaluation

As a first step, processes and reconfiguration points are being identified by this module. Given a description of valid configurations and a measure of configuration quality, search-based optimisations seek to find a 'high quality" configuration. The results of this engine are forwarded to the Reconfiguration Interfaces in order to be fed back to the factory or the connected products.

4. GETTING STARTED WITH SAFIRE

4.1 SAFIRE ACTORS

The actors that will typically be involved in exploitation the capabilities of the new SAFIRE technologies fall within the following categories:

- ***SAFIRE Expert*** – personnel with IT expertise involved in the technical design/development/testing of a SAFIRE implementation. Actors in this category have skills in Big Data analysts, situational awareness, reconfiguration/optimisation specialists and security experts. These might be personnel from technology vendor supporting a manufacturer, or it may be in-house personnel of a manufacturer.
- ***Business Expert*** – those that have knowledge on the specific business needs and goals, and could give information on the target group of the company and their needs.
- ***Factory Operator*** – employees of the respective industrial unit that is responsible for operating the software/hardware systems.
- ***Machine Supplier*** – suppliers of the software/hardware infrastructure of the factory.
- ***Product/Machine End-user*** – customers/consumers of the end product of the industry, which is either an individual product or a production machine.

The role of the *SAFIRE Expert* in the solution is to provide expertise and knowledge on the opportunities of the solution to operate in a real industrial environment. This expert has skills concerning the SAFIRE modules (is familiar with the structure and the architecture of the solution and is able to operate it) and is responsible to guide the others on how to configure (or setup), and start and stop the operation of the SAFIRE system. Furthermore, this person has the knowledge to support the operation of the SAFIRE solution, in case either an error occurs, or some adjustment should be done in its operation due to change of configuration needs.

The *Business Expert* is responsible for providing the *SAFIRE Expert* with business-related information ensuring the precise definition of the business-specific requirements, which will lead the SAFIRE solution in covering the goals of the factory and the needs of their customers. More specifically, the *Business Expert* will provide knowledge on the business processes used in the factory, description of the customer target groups and their needs, if necessary, as well as information of what are the visions of the factory for the future.

The *Factory Operator* is able to run the legacy systems and is familiar with their results and purpose on the production process. This operator can also provide important feedback on weaknesses identified during the system operation, or make suggestions on necessary interactions missing from the currently used installations. Moreover, the *Factory Operator* is able to give technical information on the products (or machines) produced in the factory.

The *Machine Supplier*, on the other hand, has technical knowledge on the machines/legacy systems used, as for example, what input/output data they can process/produce, or what are the conditions under which they operate most efficiently (e.g. needs in power, storage capacity, connectivity opportunities, etc.).

The *End-user*, either for individual products, or for machines, is the one who will ultimately benefit from the application of the SAFIRE solution. Improving the operation of the factory, or of the products produced, which is the main focus of SAFIRE, might result in more individualised products covering more specific user needs, or even to more quality and, potentially, better price-value balance for the *End-user*.

The *Product/Machine End-user's* role in the SAFIRE solution is to use the products (or machines) and provide feedback on their satisfaction (or performance). By the interaction with the end-product, the *End-user* will produce usage data that can be analysed by the *SAFIRE* technologies and the *Industry Expert* to reveal optimisation and reconfiguration opportunities for productions, as well as recognise any errors or deficiencies for the products.

4.2 SAFIRE DEPLOYMENT

Manufacturers interested in benefiting from the improvements provided by the SAFIRE solution would typically pass through four phases as follows:

4.2.1 Manufacturing scenario phase

In order to configure the SAFIRE solution for a specific manufacturing or product scenario, all actors involved in its operation (*SAFIRE* and *Industry Expert*) should have a common business understanding. The *Industry Expert* explains that the company wishes to use information of the machines used and the products produced, for improving the future design-phases. Additionally, they aim to increase the visibility of the production processes, and products, optimise the overall efficiency of the production processes, and optimise/individualise their products based on the *End-user* behaviour. The *SAFIRE Expert* identify that those goals can be covered by the reconfiguration opportunities the SAFIRE solution can produce.

From the technical point of view, the *Industry Expert* (also here could be the *Machine Supplier* or even an experienced *Factory Operator*) explains that the factory could benefit also from a possible better performance of their production infrastructure, the avoidance of faults, or the saving from maintenance expenses or used resources. The result of this phase is that all actors at this point have a common business understanding.

4.2.2 Requirements phase

In this phase, the *SAFIRE Expert* and the *Industry Expert* plan the deployment of the solution. In order to get a common technical understanding for the processes and the products of the factory, the industry expert sets the focus on the SAFIRE relevant issues, providing details on the processes used, as well as technical details on the machines. The *SAFIRE Expert* analyses the information to understand what are the possibilities for reconfiguration of machines, processes and products, what is the data availability (what data is available and how it can be acquired, e.g. with sensors or from a storage device) that SAFIRE could take advantage of, as well as to define the technical goals of the solution (e.g. improvement of production or product individualisation).

Also during this phase, the *SAFIRE Expert*, together with the *Industry Expert*, should understand and define the data to be used from the SAFIRE solution. More specifically, they have to define exactly the data that is relevant for supporting the business goals, and those that are relevant for SAFIRE (e.g. data types, amount of data, relation to the desired goals). The result of the requirements phase is that all actors have a common technical understanding on the solution and the data to be used, and have all the initial information necessary for the setup/configuration phase.

4.2.3 Setup/Configuration phase

In this phase, the *SAFIRE Expert* and the *Industry Expert* prepare and configure the data collection and reconfiguration interfaces. The *SAFIRE Expert*, responsible for the integration of the solution in the factory legacy systems, configures the security aspects of the cloud infrastructure, as well as the different SAFIRE modules, namely the *Situation Determination Services*, the *Predictive Analytics Engine*, the *Optimisation & Reconfiguration Engine*, and the *Quality Evaluation Module*. As a result, the SAFIRE solution configuration is completed, and the system is ready to operate.

4.2.4 Execution phase

In this phase, the *SAFIRE Expert* together with the *Industry Expert*, deploy the SAFIRE solution. The *SAFIRE Expert* extracts the situation information of the factory environment, and of the produced products (*End-user* feedback), to identify patterns for potential optimisation opportunities of machines and products (through reconfiguration). Observing the operation of the system, the *SAFIRE Expert* identifies specific performance differences (e.g. increased Overall Equipment Efficiency (OEE)), on specific working condition changes (e.g. specific environment temperature, or material used for the processing).

The *Industry Expert*, having the appropriate knowledge to interpret the identified pattern, could use this information to request, for instance, specific configuration for the used machines, or adjust the working conditions to match the machine specifications more accurately. The result of this phase is the expected knowledge produced from the information the SAFIRE solution extracts (new data) and processes, that the *Industry Expert* could use in the future to achieve, already from the design phase, improved machines and products.

5. CONCLUSIONS

This document presented a detailed description of the SAFIRE concept. The different components of the SAFIRE solution have been described, along with details about the workflow of how the SAFIRE solution would be setup, configured and deployed by a manufacturing organisation. The actors involved and how they would participate in a SAFIRE solution deployment have also been described. The early prototypes of the technologies and innovations from the project described in this document are planned to undergo first industrial evaluations in mid-2018, with final technology prototypes being made available to industry in 2019.

6. Appendix – Glossary

Terms	Definition within SAFIRE	Notes
Business Expert	Person which is agent for the business concerns within a manufacturing system. One of the main actors in the SAFIRE scenario.	
Connected Products	Products embedding processors, sensors and software enabling connectivity and data exchange with other products, the manufacturer, the user or its environment.	
Context/ Situation	Dey (2001) defines context as "any information that can be used to characterize the situation of an entity." In SAFIRE context is any set of information that can be used to characterize the situation of the product or factory use (e.g. the situation in which a car or a refrigerator is used, or in which a machine is used etc.). Context can be set of information which characterize the situation under which sensor data are obtained (e.g. situation under which the data from temperature sensor in a car is obtained etc.).	http://en.wikipedia.org/wiki/Context_awareness Dey, Anind K. (2001). "Understanding and Using Context". *Personal Ubiquitous Computing* **5** (1): 4–7. doi:10.1007/s007790170019.
Event-driven Data ingestion	Data that are sent or received triggered by something that happens outside the system. These data can be used immediately or stored in a database.	
End-user	User of a product (e.g. user of a car and services around car, user of a refrigerator, user of a machine (operator) etc.)	
Factory Operator	One of the main actors of the SAFIRE scenario who is handling and operating the production machines within a production process.	
Knowledge	"The digital or non-digital application of *information*, either as action or communication". Knowledge is a very important asset in networked enterprises, which includes documents, manuals that carrying all kinds of explicit knowledge, as well as implicit knowledge such as techniques, skills residing in employee's mind.	Coleman, D. and Levine, S. (2008). *Collaboration 2.0 Technology and Best Practices for Successful Collaboration in a Web2.0 World*. Cupertino, CA: Happy About.

Terms	Definition within SAFIRE	Notes
Knowledge base	Technology used to store complex structured and unstructured information used by a computer system in order to support Knowledge Management. It includes relational databases and ontologies.	Atlassian Software: *What is a knowledge base?* https://www.atlassian.com/it-unplugged/knowledge-management/what-is-a-knowledge-base
Machine Supplier	One of the main actors of the SAFIRE scenario who is responsible for providing the production equipment.	
Methodology	Refers to the specific set of procedures, rules and methods distinguishing the SAFIRE solution.	
Metrics	Characterizes the measurable parameters of the production process itself as a whole.	
Ontology	An ontology is a formal specification of a shared conceptualization. In the context of computer and information sciences, an ontology defines a set of representational primitives with which to model a domain of knowledge or discourse. The representational primitives are typically classes (or sets), attributes (or properties), and relationships (or relations among class members).	Tom Gruber, http://www-ksl.stanford.edu/kst/what-is-an-ontology.html, http://tomgruber.org/writing/ontology-definition-2007.htm
Optimisation Metrics	Main term which unfolds two different aspects to be considered within the SAFIRE scenario: Determination of a production system's quality by aggregation and evaluation of machine related data Accomplishment of a solution for the optimisation problem with the objective to get an optimal production process configuration based on the given metrics Since the optimisation problems addressed in SAFIRE are unlikely to be solved towards optimality, *acceptable* solutions have to be found by refering to Benchmarks. (see Benchmark)	
Overall Equipment Effectiveness (OEE)	Measurement for how effectively a manufacturing operation is utilized. The algorithm takes into account the availability and speed of a production machine as well as product output quality in a useful and responsible way.	OEE Foundation. Seiichi Nakajima (1982). *TPM tenkai*. JIPM, Tokyo. http://www.oeefoundation.org/

Terms	Definition within SAFIRE	Notes
Predictive Analytics	“Predictive analytics software applications use variables that can be measured and analysed to predict likely behaviour by individuals, machinery or other entities.”	SearchBusinessAnalytics, key word: *Predictive analytics* http://searchbusinessanalytics.techtarget.com/definition/predictive-analytics
Product	Main output of the production process within a factory.	
Reconfiguration Service	The main service, which controls the variable parameters of a production process in accordance to the optimisation metrics for achieving an optimized production process. (see Optimisation Metrics).	
Repository	Often referred to as “data-warehouse”: A digital storage containing data.	
SAFIRE expert	One of the main roles within the SAFIRE scenario, embodied by a natural person which holds the key expertise in the SAFIRE solution for analysing, configuring and deploying the solution on the factory operator’s systems.	
Scenario	"A scenario is a sequence of steps (a flow) describing an interaction between a user and a system."	Fowler, M. (2003), *UML Distilled: A Brief Guide to the Standard Object Modeling Language*, Addison-Wesley, Boston, MA.
Secure Infrastructure	The SAFIRE solution provides a technical infrastructure which is based in accordance to the SPT requirements. (see Security, Privacy and Trust)	
Security, Privacy and Trust (SPT)	Indicates the three key requirements in the context of trustworthiness distinguishing IT systems that are: resistance against external attacks (Security), full control about how personal information is used in the system (Privacy) and the assurance about keeping all sensible information within a specific context defined by all parties a priori (Trust).	
Service	Software module that delivers a specific functionality. The SAFIRE solution is following the as a Service (*aaS) approach by implementing e.g. the Reconfiguration engine as a Service (RaaS)	

Terms	Definition within SAFIRE	Notes
Situation Determination Service	This service extract context from the raw data provided by the Context Monitoring Services. The extracted information is represented as instances of the selected Context model (Ontologies).	
Situation Determinator	The Context extractor is the software component (core service) responsible for detecting a change of Context, identifying the modified Context, enhancing this by Context reasoning and finally informing the other services with the PES.	
Situational Awareness	Describes the ability of production machines, products and other production related equipment to determine the conditions of its surrounding environment by obtaining and evaluate situational data particularly via sensors.	http://en.wikipedia.org/wiki/Context_awareness Dey, Anind K. (2001). "Understanding and Using Context". *Personal Ubiquitous Computing* **5** (1): 4–7. doi:10.1007/s007790170019.
Situation Monitoring	The Situation Monitoring will observe external systems/devices docked into the Situation Extractor to receive raw monitoring data. This raw monitored data will then be used for further processing and for context identification.	
Situation Repository	The data-warehouse responsible for storing identified contexts.	
User	Natural person which interacts with products, machines and related technical infrastructure (as well as SoPS).	