



**ComVantage**

**284928**

***Collaborative Manufacturing Network  
for Competitive Advantage***

**Publishable Summary  
2<sup>nd</sup> Periodic Report**



## 1 PUBLISHABLE SUMMARY

*ComVantage* addresses a *Collaborating Manufacturing Network for Competitive Advantage*. It is envisioned to be an interorganisational collaboration space turning today's organisation-centric manufacturing approach into a product-centric one. Manufacturers will benefit from a flexible, efficient platform that helps them to operate as one virtual factory and thus gain competitive advantages in their markets.

Based on best practises of Web 2.0 technologies the collaboration space will be an extension to existing business and engineering software. It will allow the involved stakeholders, according to their rights, to share, administrate and monitor focused information throughout a product's life cycle in a decentralised manner. The close collaboration on the business to business and business to consumer levels will foster existing trends such as Open Innovation or Crowdsourcing.

The framework of the virtual factory will encompass a secure access control that is founded on dynamic workflow models and flexible user roles accounting for large enterprises, SMEs and for end-customers. It will enable temporary and decentralised access management for ad-hoc collaboration between geographically distributed experts.

To adhere to changing working situations, to efficient communication, and to rich interaction technologies, *ComVantage* will focus on mobile devices. Intuitive and trustful mobile apps shall support users in fast decision making and problem solving. Information from different sources across the organisations will be provided and maintained via 'Linked Data'. The integration of sensor data allows for products to be members of the collaboration space.

A continuous evaluation of the ICT and business model considering use cases throughout the project will verify the added-value of *ComVantage* for the European industry. The utilisation of existing technologies, a close user approach, and an incremental project set-up will provide sound concepts ready for fast production. Thus implementing *ComVantage* will increase lean communication, agile and highly efficient production processes, cost control and a low carbon footprint.



Figure 1: The collaboration space of *ComVantage*

The *ComVantage* objectives are addressed in three major phases which reflect the reporting periods:

- M01-M12: development of Mockup Prototypes based on initial requirements analysis and basic RTD concepts
- M13-M24: development of Enhanced Prototypes based on evaluation results on Mockup Prototypes as well as refined RTD concepts and functional implementations
- M25-M36: development of Final Prototypes based on further evaluations and refinements as well as providing best practise guidelines for the collaboration set-up

The project execution follows an incremental approach to adapt to actual requirements and trends.

## **Results Achieved in the First Year (M01-M12)**

In the first year of the *ComVantage* project the focus was on defining initial requirements and basic concepts regarding research and technological development which will be incorporated in the Mockup Prototypes due in M14.

### **COMVANTAGE ARCHITECTURE**

Based on a comprehensive requirements analysis among all project partners an initial architecture was drafted. This architecture represents an integrated state of all the various technology concepts such as business process model, a secure information model, data integration via Linked Data, and an orchestration concept for mobile apps. The architecture envisions an infrastructure of distributed domains that are hosted individually by each collaboration partner. Centralised functionality is reduced to a minimum and is used for configuration purposes of generic components only. The core concept of the architecture is about integrating data sources of arbitrary technology and data schema. This is realised by developing a data integration layer that works with RDF and Linked Data principles.

### **COMVANTAGE BUSINESS PROCESS MODELS**

Based on a metamodelling framework developed by University of Vienna, the first version of the *ComVantage* modelling method has been specified. It aims to support the design and analysis of product-centric, process-driven supply chains, with processes mapped on IT support systems featuring the *ComVantage* specificities - mobile user interfaces and Linked Data informational resources. The modelling method covers a modelling language, a modelling procedure and a set of mechanism specifications to be implemented in a modelling tool, in later stages of the project. The specification of the method's first generic iteration covers multiple layers of detail, from high level business models, logistical scope and process map, to the operational level of business processes mapped on various resource types (human, apps, information), and down the technical level of mobile app user interaction flows.

### **COMVANTAGE SECURITY MODEL**

As a result of an extensive research of the existing access control and trust models and of the different needs of each application area, a first draft of a suitable security method and architecture has been defined to enable secure and trusted collaboration for enterprises sharing their information by means of Linked Data. The approach extends well established multi domain access control practices to incorporate specific capabilities to deal with private-public web of data leveraged by Linked Data technology. The *ComVantage* access control model is designed based on a multi-tiered security approach dealing with web and data access control needs for effective enterprise collaboration. *ComVantage* access control model is aligned with the principles of dynamic and de-centralised collaboration and ensures that Linked Data information remains private to authorised members.

This security approach will be able to protect all data sets in the collaboration network. *ComVantage* provides sufficient granularity to present specific data sets to each of the collaboration networks and tasks set up by the enterprises in their trusted collaboration circle. Thereby, helping to ward off threats and eliminate vulnerabilities while proving compliance and maximising the efficiency of the operations.

### LINKED DATA INTEGRATION

We have performed a thorough state-of-the-art analysis regarding existing ontologies and tools that can be employed in the *ComVantage* prototypes as well as regarding ontology development and publishing methods. Based on this, we have developed an ontology for the Customer-oriented Production application area and initialised the development process for the other areas. This ontology, which captures terms describing the goods offered as well as the customer-related information, was installed on a Linked Data server and published internally.

Moreover, we have semantically lifted the existing database for the application area Customer-oriented Production and integrated it with this ontology, thus completing the central part of the first Mockup Prototype. This prototype was aligned with the *ComVantage* architecture as well as with the approach of intuitive and trustful mobile collaboration.

### INTUITIVE AND TRUSTFUL MOBILE COLLABORATION

The area of mobile collaboration addressed four challenges within the first year: One challenge addressed the specification of a concise and pragmatic framework for a User Centered Design. This framework defines all relevant terms, conceptualisations and principles, and provides a sophisticated design and evaluation methodology. It specifies the expected results and their lifecycles across all phases of the project. An analysis of the application areas to design appropriate evaluation scenarios, and the basic choice of an evaluation methodology in coordination with the general progress of the project has been provided.

Moreover, an overview of initial concepts for flexible UI presentation frameworks, data structures and dynamic workflow models was created. These frameworks, data structures and workflow models relate to the UI framework and basic principles of User Centered Design process and are aligned with the requirements analyses and scenario specifications provided by the application partners. First Mockup Prototypes that incorporate these results were designed for exemplary scenarios within each application area covered by the *ComVantage* project.

Furthermore, the conceptual design of the user interface modelling and generation framework for *ComVantage* was developed. A comprehensive review of the current scientific literature on running and completed research projects in the field of model-driven software development was carried out. Through an Analytic Hierarchy Process and an assessment of the programming expertise of the *ComVantage* partners with implementation tasks it has been decided to use native development technologies for the mobile apps. The user interface modelling and generation framework will allow the development of mobile apps for the *ComVantage* project. This approach has been verified for a maintenance scenario in an industrial facility. The scenario proves the feasibility of the orchestration approach.

Also first generalised visualisation and workflow patterns were identified and conceptualised. The final patterns and guidelines will be available in the third year of *ComVantage*.

### SCENARIOS AND USE CASE DEFINITION IN THE APPLICATION AREAS

#### ▪ PLANT ENGINEERING AND COMMISSIONING

Plant Engineering and Commissioning is the first out of three work packages that elaborates on a specific application area and implements the concepts and methods developed in the technical work packages. The objective is to save money and time during commissioning activities with the implementation of tools that help designers in cycle time validation, data elaboration and sharing information.

Main results are the definition of scenarios and requirements, the analysis of tools and technical approaches to improve commissioning efficiency, data workflow management, ontology development for the automotive commissioning domain and the evaluation of the secure information model. Based on these results, a Mockup Prototype was developed.

- **CUSTOMER-ORIENTED PRODUCTION**

Customer-oriented Production is the second out of three application oriented scenarios that implements the concepts and methods developed in the technical work packages. The objective of this scenario is to refine the establishment of the *ComVantage* prototype for a mobile infrastructure to ease collaboration and communication between customers and production stakeholders in order to have a transparent supply chain that provides the possibility for late changes. A further objective of this scenario is to enhance the competitiveness of SMEs by allowing better communication in between the different suppliers involved within a design and production process.

Main results are the definition of personas, scenarios and requirements with respect to the business model, first adaptations and refinements of the generic concepts (secure information model, Linked Data integration concept, mobile collaboration framework). Based on these results, a Mockup Prototype has been developed.

- **MOBILE MAINTENANCE**

Mobile Maintenance is the third out of three application oriented work packages that adapt and evaluate the concepts and methods developed in the technical work packages. It aims to illustrate the improvement of asset management and mobile maintenance by combining mobile collaboration and sensor data integration.

Main results are the definition of scenarios and requirements, ontology development for the Mobile Maintenance application area, implementation of live access to middleware data and the execution of test case scripts directly on the machine to get self-diagnosis results. Furthermore, a Mockup Prototype was developed to showcase the mobile maintenance workflows.

#### **EVALUATION OF ICT AND BUSINESS MODEL**

In the context of evaluation of ICT and business model, the first year of the project has focused on the development of the theoretical and conceptual foundations upon which the contribution of the project would be evaluated. The first stage involved the construction of an evaluation roadmap to guide the evaluation process throughout the project. Then, a comprehensive review and analysis of the relevant literature was performed, resulting in the formulation of an evaluation framework that would serve as the conceptual foundation for all future evaluation activities. In general, the framework identifies three collaborative capabilities that are expected to be enhanced by the project (supplier-related, internal, and customer-related) and six organisational dimensions on which these collaborative capabilities are expected to make an impact (cost, efficiency, quality, flexibility, innovation, and sustainability). The third stage involved the development of a comprehensive set of metrics through which the specific impacts of the project could be evaluated. To achieve these objectives, we also performed in-depth analyses of the various project scenarios and used interviews and questionnaires to collect preliminary data from key stakeholders in each application area. The resulting evaluation framework and metric set will be used to evaluate the effects of *ComVantage* on the implementing organisation.

#### **STANDARDISATION, EXPLOITATION, AND DISSEMINATION**

In the area of standardisation, dissemination, exploitation, and cluster activities the focus was on presenting and discussing the overall idea and first concepts which provided the basis for further collaborations.

- **STANDARDISATION**

The consortium spent their efforts to introduce the preliminary results of the *ComVantage* project to the relevant standardisation bodies: Task Force GMA FA 5.16 “Middleware in Automation”, DKE Standardisation Task Force UK 921.1 “Begriffe der Leittechnik” (mirror to the IEC/TC65 “Industrial-process measurement and control”); “IEC 60050 - International Electrotechnical Vocabulary, Part

352: Industrial IT”; DKE/K 931 “Systemaspekte” (mirror to the IEC/SC 65E “Devices and integration in enterprise systems”; OMI workshop on “Modelling Methods in Motion”.

▪ **EXPLOITATION**

In the area of exploitation internal activities by the partners have been started which are yet in a too early stage to present official statements. The first specific output is the identification of the cooperation domain on modelling by UNIVIE and BOC-IB. Furthermore, a first *ComVantage* prototype was presented at the SAP internal Developer Kickoff Meeting (DKOM).

▪ **DISSEMINATION**

In the area of dissemination several channels have been engaged for communicating the *ComVantage* idea and first results: *ComVantage* project web site ([www.comvantage.eu](http://www.comvantage.eu)), including the availability of public deliverables; Set-up of social media channels including a communication strategy being aligned with FInES / ENSEMBLE; Dissemination material such as project leaflet and EFFRA brochure; Participation at conferences; Publication of scientific and journal articles; Internal collaboration wiki.

▪ **CLUSTER ACTIVITIES**

The idea and first concepts of *ComVantage* have been discussed within the FInES Cluster as well as towards other national and international projects: Participation in FInES Cluster meetings and workshops; Contributions to FInES Task Forces (Business Values, Scenarios, and Models; Interrelation between FInES Research and Standards & Standardisation; FInES Research Roadmap; Manufacture and Industry); Lead of FInES Task Force SMEs in the Future Industry; Discussion of concepts and identification of synergies with other EU and national projects; Participation in the MEP 2020 Master Plan Survey.

## Results Achieved in the Second Year (M13-M24)

In the second year the *ComVantage* project focussed on refining the initial concepts and verifying the technical feasibility in line with the development of Enhanced Prototypes in each of the three application areas.

### COMVANTAGE ARCHITECTURE

Based on a continuously performed requirements engineering and a first architecture draft from the first year, a final architecture including a conceptual and technical integration of development and research results regarding business process modelling, mobile application orchestration, user authentication, user authorisation, data federation, as well as data integration was documented. Moreover, the development of the Domain Access Server (DAS) as central component of the *ComVantage* architecture for integration of Linked Data adapters, access control components and mobile apps was realised. The DAS serves as basis for all data integration and data federation tasks for the Enhanced Prototypes, integrates required authentication and authorisation components and offers a single point of access for client applications.

### COMVANTAGE BUSINESS PROCESS MODELS

The *ComVantage* modelling method that was drafted in the first year of the project was refined with respect to specific requirements of the application partners and on the basis of concrete findings during the adaptation of the modelling method within each of the *ComVantage* application areas. Based on the enhanced *ComVantage* modelling method, the development of a modelling prototype through the Open Model Initiative (OMI) was realised. The modelling prototype and the *ComVantage* modelling method was used to create specific business processes as basis for the Enhanced Prototypes within each of the application areas.

### COMVANTAGE SECURITY MODEL

The Secure Information Model drafted in year one was further refined and enhanced, especially with respect to the cross-domain characteristic of the *ComVantage* collaboration scenarios. Innovative concepts



and technologies have been provided that enable a decentralised administration of data access in a flexible way, taking into account the existence of both traditional data and Linked Data within a virtual factory. In line with this concept, a cross-domain authentication and authorisation framework was developed based on a multi-tiered access control concept for graph-based data (RDF) leveraging a SPARQL interface. The authorisation service features a complete tool chain including a Policy Decision Point (PDP), a Policy Administration Point (PAP), a Policy Enforcement Point (PEP) and a Policy Information Point (PIP).

#### **LINKED DATA INTEGRATION**

Based on the initial findings from ontology engineering and Linked Data generation in the first year, the semantic data modelling activities have been continued. First, the analysis of existing ontologies and vocabularies has been continued and the potential for reuse and application in various application areas of the manufacturing domain has been evaluated. Ontology drafts from the first year have been enhanced based on specific business requirements (e.g. specific characteristics of commissioning, production, maintenance and sales processes). Existing Linked Data adapters have been analysed and adapted for the use within the *ComVantage* application areas in order to make legacy data available for collaboration scenarios (e.g. adapters for relational databases and spreadsheets). Additionally, a prototypical Linked Data adapter for specific manufacturing middleware solutions like Gamma has been implemented to allow real-time access on individual sensor values and to manage on-device diagnostic tools. Additionally, a middleware adapter for OPC-UA solutions has been designed. In order to fully leverage the advantages offered by the existing and open Linked Data ecosystem, a proposal of a *ComVantage* tool chain to author, curate, map and link Linked Data in an interorganisational context was published.

#### **INTUITIVE AND TRUSTFUL MOBILE COLLABORATION**

The Mockup Prototypes of the first year have been evaluated with respect to a preliminary version of the collection of questionnaires, protocols and measures that will make up the *ComVantage* usability & trust metrics toolkit. Furthermore, enhanced presentation and workflow models have been developed according to continuous requirements analyses and refinements with respect to evaluation results of mockups. Based on the generic concepts of the *ComVantage* UI modelling and generation framework from the first year, a working prototype of the Industrial App Framework (IAF) has been developed and gradually refined as basis for the Enhanced Prototypes in year 2. Additionally, a set of generic Apps as templates for domain-specific app development has been provided in cooperation with the *ComVantage* application partners. Utilising the IAF and the Generic Apps, the development and orchestration of mobile apps with respect to specific business processes is significantly facilitated.

#### **SCENARIOS AND USE CASE DEFINITION IN THE APPLICATION AREAS**

The feasibility of generic research and development results within the *ComVantage* project is verified within three application areas that are:

- **PLANT ENGINEERING AND COMMISSIONING**
- **CUSTOMER-ORIENTED PRODUCTION**
- **MOBILE MAINTENANCE**

The results of the comprehensive requirements analysis and scenario definition from the first year have been gradually refined with respect to selected focus scenarios that are the basis for the scope of the Enhanced Prototypes. With respect to Plant Engineering and Commissioning, the cycle-time validation scenario has been further developed to improve the station performance on automotive production lines. With respect to Customer-oriented Production, the order management, stock management and KPI management scenarios have been further developed to improve resource utilisation and order distribution in a collaborative micro-company production network. With respect to Mobile Maintenance, the predictive maintenance and the repair scenario have been further developed to improve the remote preparation of on-site maintenance operations leveraging the sensing capabilities of active machines.

Moreover, improved technical concepts have been adapted to the context of each application area. First, the refined secure information model has been adapted with respect to the creation of specific user roles and access control policies. Second, refined Linked Data concepts with respect to improved data models (ontologies) and improved Linked Data adapters have been adapted, taking into account the application area specific business requirements and constraints. Third, the refined mobile collaboration concept for business process-driven orchestration and template-based development of application-context-specific mobile apps has been adapted. The results of technology adaptation have been used for developing Enhanced Prototypes in all three application areas.

#### **EVALUATION OF ICT AND BUSINESS MODEL**

After the development of the theoretical and conceptual foundation for the evaluation of ICT and business model in the first year of the project, the activities in the second year were aimed at providing the empirical foundation using process simulations and subjective data analyses. Process simulations examined the effects of organisational and inter-organisational collaboration capabilities facilitated by the *ComVantage* platform within the three application areas, including the definition of a representative organisation for each application area, development of as-is models, formulation of new *ComVantage*-based process capabilities, and comparative analyses based on simulation runs. Subjective data analyses examined the effects of *ComVantage* technologies and capabilities on various operational dimensions based on the evaluation framework developed in the first year, including the development of an instrument for a web-based survey, pre-test and pilot test of this instrument, and administration of the survey to collect subjective data from around 300 managers in various industries across Europe. These activities will continue in the third year of the project along with objective data analysis to provide the empirical foundation needed to understand the organisational impacts of *ComVantage*-based capabilities.

#### **STANDARDISATION, EXPLOITATION, AND DISSEMINATION**

In the area of standardisation, exploitation, dissemination and cluster activities the focus was on continuing the successful activities from the first year and further contributing to scientific communities with high-quality publications.

Regarding **standardisation**, we continued our involvement in standardisation activities with respect to industrial standards (GMA FA 5.16 “Middleware in Automation” and DKE Standardisation Task Force UK 921.1 “Begriffe der Leittechnik”). Furthermore, *ComVantage* became member of the DEXPI working group (“Data Exchange in the Process Industry”).

Regarding **exploitation**, an enhanced exploitation plan for the *ComVantage* project results based on a modular packaging of required components and a set of agreed licenses was documented.

Regarding **dissemination**, the *ComVantage* architecture, its key concepts and application areas were documented in several scientific publications and in two book chapters (“The Future Internet, Validated Results and New Horizons” and “Revolutionising Enterprise Interoperability through Scientific Foundations”). Furthermore, the *ComVantage* partner Innovalia has assumed the chairmanship of the FInES cluster activities. In line with this responsibility, the *ComVantage* project organised a session with respect to a consolidated vision on Enterprise position towards H2020 research (presented at FoFH2020 conference in Geneva).

### **Potential Impact and Use**

*ComVantage* will trigger a significant impact on improving interorganisational production processes by supporting emerging virtual factories and enterprises. The collaboration of various experts and end-customers regarding specific product-related issues will lead to major enhancements of product design and related services, and such to substantial competitive advantage for the European industry.

In the above spirit, European enterprises will benefit from enhanced know how on product development and product-related services, cost and time reduction by merging geographically distributed expertise, and thus by accelerated innovation processes.



- European citizens will benefit as *ComVantage* will have a positive impact on the European manufacturing competitiveness as well as by being active part of Open Innovation and Crowdsourcing.
- The European market will benefit by introducing advanced ICT technologies that support the networked enterprise concepts.

#### **IMPACT AND USE IN THE FIRST TWO YEARS**

The results of the first project year provide a solid foundation for the upcoming research and technological development activities, thus their potential use and impact outside the consortium is limited.

Yet, the preliminary results on Intuitive and Trustful Mobile Collaboration enable the implementation partners to adapt the generic concepts and to design, implement and evaluate their initial prototypes in accordance with the expected level of functionality and refinement proposed in the *ComVantage* outline. The *ComVantage* User Centered Design framework is publicly available for other projects. The framework is in an applicable state and can be used for evaluation activities in these projects as well. The user interface modelling and generation framework for *ComVantage* already gained some attention from research partners outside the *ComVantage* consortium and thus may have impact on future research projects soon.

Moreover, the evaluation framework and metric set, generated as part of the Evaluation of ICT and Business Model activities, can be straightforwardly generalised to assist in the evaluation of the organisational effects of various technologies in various industrial settings.

During the second year, initial concepts regarding the secure information model, the Linked Data integration concepts and the mobile collaboration concept have been refined and the technical feasibility of these concepts has been verified.

Major improvements regarding the secure information model are the realisation of cross-domain authentication and authorisation as well as a SPARQL rewriter component for controlling access to Linked Data. Moreover, an updated version of the business process modelling workbench based on the latest *ComVantage* modelling method refinements has been released. Regarding the Linked Data integration, the adapter concepts from the first year have been refined and working prototypes have been developed for relational databases as well as for the Gamma middleware solution. An OPC-UA adapter was designed based on the Gamma middleware adapter concept. Regarding the mobile collaboration concept, first releases for the App Orchestration Concept (as part of the Industrial App Framework, IAF) have been provided and Generic App sets for specific application areas have been developed. Results from all generic concepts have been used to develop the Enhanced Prototypes within each application area.

Furthermore, an overall exploitation approach of the *ComVantage* research and development results based on packaging of individual components and agreed licenses has been proposed.

#### **FINAL RESULTS**

The final results address the following goals:

- Higher management efficiency of networked and sustainable business operations
- ICT tools enabling the participation of SMEs in virtual factory environment
- New business models and innovation scenarios for a low carbon economy

#### ***ComVantage* Web Site and Contact Information**

For further information, please, refer to the project's web site [www.comvantage.eu](http://www.comvantage.eu). Specific questions may also be directly addressed per email: [dissemination@comvantage.eu](mailto:dissemination@comvantage.eu).

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