# 1. Executive Summary

The present document is the final version of the INT_MANUS activity and management report. It presents the activities of the Consortium during the whole duration of the project: from the beginning of October 2005 until the end of September 2008.

The project has developed three prototypes: advanced maintenance, customized production, and error reporting, diagnosis and self-healing. The two latter prototypes have been integrated, tested and evaluated in the industrial environment at CRF and FIDIA respectively.

The targeted technical objectives of the Consortium have been satisfied. The project generated 16 major results in 6 technical workpackages: 12 software modules and 4 techniques. The results have been described in 53 technical deliverables and published in 15 papers in refereed journals and conference proceedings. All the deliverables, that should have been delivered, were delivered.

The consumption of resources of personnel is correct, although some changes have been introduced to the initial project plan. The project effort is measured in terms of person power. Consumed person-month values per partner and per work package are provided for each reporting period. The changes to the initial project plan concerned only the person power and did not change the total budget of the project. The changes allowed partners to concentrate on the most important tasks and to organize the work in the most appropriate way.

# 2. Project objectives and major achievements during the reporting period

## 2.1 General Overview of INT-MANUS

The objective of the INT-MANUS project is to develop a new technology, the Smart-Connected-Control Platform (SCCP) for manufacturing enterprises. This platform will allow controlling the production plant of the future in a revolutionary way. With help of a distributed learning agent platform, innovative mechatronics approaches, and ubiquitous augmented and virtual reality technology the project will implement a research prototype for a manufacturing plant capable of advanced proactive maintenance, customized production, and error diagnosis support. The Smart-Connected-Control Platform seamlessly integrates human personnel and manufacturing machines in the production process.

The INT-MANUS project addresses several problems of today?s manufacturing at the same time. The SCC Platform to be developed is self-organized, self-healing, dynamically extensible and open. Innovative mechatronics provides valuable sensor data to the SCC Platform for diagnostic purposes. Intelligent robots deliver goods in a manufacturing plant in a flexible way on routes that are determined just in time by the SCCP. Human operators will be seamlessly integrated in the maintenance and diagnose process. With help of ubiquitous augmented reality systems an operator can interact with the system on site and provide information that cannot be extracted by machine sensors. Maintenance and repair crews as well as supervisors will have additional information through handheld computers to overlay complex data with real parts and machines during the production process. Finally customers will be able to customize a product prior to production process. The design of specific products will happen in a virtual environment. The resulting specifications will be evaluated and implemented by the SCCP just in time.

The system?s innovative functionality will be demonstrated in three research prototypes:

- In the first phase of the project a basic version of the SCCP will be implemented. A limited set of new sensors will be attached to the machines and the software needed to process this data will be developed. Advanced numerical controls and robots will be attached to the platform as well as handheld computers and other wearable devices. The first research prototype will demonstrate an advanced maintenance scenario on a specially developed test-bed. A maintenance crew will perform its task, supported by the robots and information from the newly integrated sensors visualized on handheld computers on site.
- The second phase of the project will focus on advanced control of robots and machines. Improvements in every module connected to the SCCP as well as the core itself and introduction of the virtual reality system will lead to a research prototype demonstrating a scenario on customized production. In this scenario a customer will design a product in the virtual environment and the SCCP will supervise its production in the manufacturing plant of the future.
- In the third project phase further refinements on all modules and the core itself will allow dealing with error reporting and diagnosis in a learning system. In this phase of the project the scenario to be implemented will deal with collected error data from many machines together and its evaluation for diagnosis purposes. Operators on site will use their advanced visualization technology and the SCCP to diagnose problems in the production plant and react by flexibly reprogramming the production process.
- The final research prototype will show the fully deployed INT-MANUS system with a complete SCCP and all three scenarios. The main project deliverables will be a fully functional SCCP that can be applied to virtually any type of production plant.

The project drives highly innovative research in the areas of:

Knowledge-based agent systems for control of a complex distributed system
Semantic models

Robotics and movement control
Mechatronics and numerical control
Visualization of complex data using small screens (handheld computers)
Human computer interaction in augmented and virtual reality

The technical work has been structured in 7 work packages. There is also one work package for the management activities. Leader appears in brackets:

WP1: Project management (FhG-IAIS)
WP2: Smart-Connected-Control infrastructure and integration (CIM-EXP)
WP3: Semantic processing and knowledge management (FhG-IAO)
WP4: Human computer interfaces (FhG-IAIS)
WP5: Sensors and data collection (FATRONIK)
WP6: Actuators and machine control (Robosoft)
WP7: Requirement analysis and prototype evaluation (FIDIA)
WP8: Dissemination and exploitation (FhG-IAIS)

Three major milestones have been established to assess periodically the progress of the project. The next table summarizes them.

| Milestone | Description | End of Month |
|---|---|---|
| M1 | Milestone 1: First prototype (in FhG-IAIS). Most of the state-of-art ubiquitous computing technologies will be integrated into this research prototype. It will mainly show the advanced maintenance features of the INT-MANUS system using a specially developed test-bed. | 11 |
| M2 | Milestone 2: Workshop + Second prototype (in CRF). The focus of the workshop is to exchange and present knowledge and experience to the industrial community in the area of intelligent networks for human-machine and machine-machine communication with a special emphasis on manufacturing systems.<br>The second prototype will mainly emphasize the customized production, though it also will show an improved version of the advanced maintenance scenario and a limited set of error reporting and diagnosis abilities. | 23 |
| M3 | Milestone 3: Final research prototype (in FIDIA). The research prototype will include a full INT-MANUS system with a fully implemented Smart-Connected-Control Platform and human-machine and machine-machine communications. | 35 |

Table 1: List of major milestones

## 2.2 Specific objectives of the reporting periods

The first year had the following major objectives:

1. Specify of requirements for the SCCP as a whole and for the first research prototype.
2. Develop first research prototype modules. The focus of the first prototype is Advanced Maintenance.
3. Disseminate the project ideas and analyze the feedback from the society.

The second year had the following major objectives:

1. Specify the requirements for the SCCP and for the second research prototype.
2. Develop and integrate all modules related to the second research prototype. The focus of the second prototype is Customized Production; test environment – CRF test bed. However, the modules developed in the first prototype should have been further improved.
3. Disseminate the project ideas and analyze the feedback from the society.

The third year had the following major objectives:

1. Specify final requirements for the SCCP as well as the requirements for the third (final) research prototype.
2. Develop new modules related for the third prototype, i.e. software modules for evaluation of the residual life of mechanical components through application of a set of tests.
3. Further develop and improve modules related to the first and second research prototypes. Identify methodology testing approaches for all modules.
4. Consider safety and security issues of the INT-MANUS technologies. Identify potential threats and create a list of actions needed to resist them.
5. Integrate, test and evaluate the final prototype at FIDIA test laboratory with active end-user participation.
6. Perform the acceptance study of the INT-MANUS ideas, concepts and technologies.
7. Analyse potential market for the INT-MANUS technologies. Identify activities needed to make products from prototypes and estimate costs of the products.
8. Disseminate the project achievements.

## 2.3 Achievements of the reporting periods

During the first year the Consortium achieved the following objectives (given with references to respective deliverables):

1. The requirements for the SCCP and the first research prototype has been specified (D-7.1.1, D-7.1.2)

2. The modules of first research prototype have been developed, however not yet fully integrated (D-2.1.1, D-2.2.1, D-3.1.1, D-3.2.1, D-4.1.1, D-4.2.1, D-5.1.1, D-6.1.1, D-6.2.1).

3. The test beds for the development and demonstration purposes have been specified (D-7.3.1).

4. A methodology testing approach has been elaborated (D-7.4.1).

5. The project ideas and achievements have been presented to the society (deliverable D-8.1.1 will be issued in November, some information may be also found in the description of the WP8).

During the second year the Consortium achieved the following objectives:

1. The requirements for the SCCP and the second research prototype have been specified (D-2.1.2, D-7.1.3)

2. The modules of second research prototype have been developed, however not yet fully integrated (D-2.2.2, D-3.1.2, D-3.2.2, D-4.1.2, D-4.2.2, D-5.1.2, D-6.1.2, D-6.2.2). Integrated prototype will be described in D-7.7.1 in December 2007.

3. A methodology testing approach has been elaborated (D-7.4.2).

4. The project ideas and achievements have been presented to the society (deliverable D-8.1.2, some information may be also found in the description of WP8).

During the third year the Consortium achieved the following objectives:

1. The requirements for the SCCP and the third research prototype have been specified (D-2.1.4, D-7.1.4)

2. The modules of third research prototype have been developed (D-2.2.3, D-3.1.3, D-3.2.3, D-4.1.3, D-4.2.3, D-5.1.3, D-6.1.3, D-6.2.3).

3. A methodology testing approach has been elaborated (D-7.4.3).

4. Safety and security issues have been considered (D-3.4.1, D-2.3.1).

5. Final prototype has been integrated and evaluated at FIDIA test laboratory. The integrated prototype is described in D-7.9.1.

6. Acceptance study has been performed (D-7.2.1).

7. Potential market for INT-MANUS technologies has been analysed. Activities needed to make products from prototypes have been identified and the costs of potential products have been estimated (combined report D-8.2.1&2&3).

8. The project ideas and achievements have been presented to the society (deliverable D-8.1.3, some information may be also found in the description of WP8).