STEP-NC

Final Report

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1 Project Overview

The main achievement of the project was to develop a data interface for the process chain between computer aided design (CAD) and the manufacturing of the developed product on a computerised numerically controlled machine tool (CNC). A study had shown that savings in the creation of a CNC program up to 50% might be possible by:

- Improved data flow between CAD and shop floor allowing bi-directional data flow
- Avoiding post processors
- Machine independent data allowing flexible re-scheduling.

Such a new data model for the interfacing was developed, implemented, tested and standardised.

Basis for the interface was the geometry data created in a CAD system which was enriched with technology data and the sequence of the work of the machine tool. Figure 1.

As specification for the data format the Product Data Management Standards ISO 10303 AP203, AP214 and AP224 were chosen. These standards are used for the exchange of information in automobile and aircraft industries, the major users of CNC machines.

For the realisation partners of every step of the process chain between CAD and CNC machine tool have been involved:

- Computer aided design: Dassault
- Computer aided manufacturing: Dassault, Openmind, CADCAMation
- Computerized Numerical Control: Agie, OSAI, SIEMENS AG

Figure 1: Structure of the new data model
It was taken care that both possibilities of programming, programming in a job preparation and shop floor programming were involved.

The developed and tested data models were fixed in an ISO standard ISO DIS 14649. The first technology milling is now under distribution as FDIS.

2 Project Objectives

Main objective for the project was the development of the data model for the interface of the CNC for the technologies:

- Milling
- Turning
- Contouring
- EDM

The technology grinding was excluded because a first study showed that a lot of manual interactions hamper the automatic flow and that the process dependency of the data is very high.

The developed interface for the other technologies should be tested by prototype implementations at the CAM and at the CNC level.

The prototypes should be tested and validated at real machines with suitable workpieces. After the validation the data model should be fixed in an international standard.

3 Methodology

Basis for the project work was the activity “Product Data Management” of the automotive and aircraft industry. First hints for a solution of the modelling could be found in the “Optimal” project, in studies of DaimlerChrysler and in the standardisation work of the working group7 of ISO TC184 SC1. Therefore the following steps for the proceeding in every technology were chosen:

- Collection of demands of suppliers and users
- Elaboration of the data model
- Elaboration of a scenario and test workpieces for the realisation
- Implementation of demonstrators
- Test and evaluation of the process chain

Due to the most relevant information the first scenario developed was the scenario for milling (2.5D) and drilling. There the know how elaborated was the most mature one and the demands had been collected during the start period of the project.
The data model covers the whole applications of milling (2,5 and 3D). Figure 2.

The machining features describe what the machine shall do and the workingsteps with the operations describe how the features should be manufactured.

Figure 2: Part of the schema of the data model

The description of the data model was done with the language “EXPRESS” which was developed for this kind of work. The benefit of this language is that it can be used directly for parsers or other kinds of computing.

During the realisation of the prototypes a lot of clarifications were necessary because everything was under construction and everything could include misinterpretations. Therefore it was very helpful to use a common parser developed from WZL because so the data base used was identically. Due to the test results a bigger rework of the data model was necessary. At the end the solution found had also a big impact to the AP standards of ISO 10303 , especially AP224. It was found that there are existing gaps in the feature definition which must be closed by a common harmonisation of the standards. It cannot be avoided that this changes will have also influence to the developed data model.

This actions demonstrate that it is absolutely necessary to realise test implementations for such a kind of modern standards. Creating only theoretical data models will never fit the needs of the applications of the users especially if they are as complex as in our case.

So scenarios for the realisation were drafted. The scenario configurations show the data flow and the description of the work which should be done by the partners. Included were also test work pieces for the validation of the process chain.
For the first implementation of the controller a human interface for manipulating and testing the data model was necessary to be developed. For getting the first experience with this new interface a rapid prototyping was done in VisualBasic. The prototype was presented to the partners and alternatives were discussed. The second prototype in c++ was based on the experience made. By that way the development time could be shortened because some iteration loops could be saved. For the implementation of the features a stepwise development was realised. So it was possible to test the first features very early and the partial functionality was increased from release to release. For the first scenario 23 releases were necessary to reach the functionality needed for the machine tests.

During the tests the geometry data were imported into the CAM systems. After a feature recognition the necessary sequence of the workinsteps, the tooling and the technology data were added. By simulation at the CAM system the functionality of the program was tested. The positive result was transmitted to the CNC where a test with the real tool set of the machine was done. Necessary changes due to setup or technological data could be performed directly at the control. After a positive simulation the workpieces were cut.

This principle was followed in general in all scenarios. A overview of scenarios shows the following list:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Technology</th>
<th>CAM system</th>
<th>Control /Machine</th>
<th>Workpiece</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>Milling and Drilling 2.5 D</td>
<td>Dassault</td>
<td>Siemens 840D/ Hermle, Chiron</td>
<td>DC– workpiece, Volvo Vamos, Complex pocket</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>3D</td>
<td>Openmind</td>
<td>Selca/Franci</td>
<td>Franci workpiece</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Contouring wood</td>
<td>CMS</td>
<td>OSAI/CMS</td>
<td>Kitchen door, Clock housing</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>Wire EDM</td>
<td>Agie (EPFL)</td>
<td>Agie/Agie</td>
<td>Die plate with watch contour</td>
</tr>
</tbody>
</table>

For the technology turning no scenario was realised. Due to the first schedule this technology was planned to be elaborated from US partners but the shifted start of the US project made it necessary to take over the modelling work. The model itself is developed and introduced into the standardisation.

The tests on the machine tool and the cutting of workpieces has been very sumptuous. The reason for the time consuming machine test is the setup of the whole machine tool, the preparation of the fixtures, the tooling, the preparation of the rawpieces and the maintenance of the machine. Therefore the tests were done mostly on a simulation based on the standard CNC enhanced with the new software. So very early and with not much time consuming simulations new software from the CAM partners could be evaluated. Feed back with hints for different interpretations took not very much time.

The tests and the results were documented by videos and photos which are collected on a demo CD.
4 Project Achievements

During the project the data models for milling, drilling, turning, contouring and EDM could be realised. The functionality of the new interface was proved in 4 scenarios which realised the process chain for the respective technology. The validation was done by creation of programs for the new interface and the manufacturing of test parts on machines equipped with controls which were developed in this project. The goals of the project could be reached in every aspect.

In detail the following prototypes were developed and validated:
AGIE: Frontend STEP-CNC for EDM together with CADCAMation and EPFL
CADCAMation: CAM – station for EDM
CMS: Prototype machine with STEP-NC for wood glass and stone, application contouring.
Dassault: CAM – station for milling and drilling with 2,5 d movements
Openmind: CAM – station for milling and drilling with 2,5 d movements, interface to Vamos
OSAI: STEP-CNC for wood, glass and stone
Siemens: STEP-CNC for milling and drilling with 2,5 d movements

Test group:
DaimlerChrysler: Milling and drilling at Hermle and Chiron machines
Franci: Milling and contouring with frontend solution and legathy code
Progetti: Milling and contouring with frontend solution and legathy code
Volvo: Milling and drilling at Hermle and Chiron machines, interface to Vamos
Wyss: EDM applications

Institutes:
EIG i-tech: Software tools for EDM
EPFL: Software for EDM, AGIE frontend
ISW Stuttgart: Development of turning model
WZL Aachen: Elaboration of milling and drilling model, development of milling applications

Consulting:
AMT: Standardisation ISO TC184 SC1 WG7 and SC4

The new data models were tested for compatibility with the standards ISO 10303 AP224 and were integrated in a new ISO standard DIS 14649. The first part for milling and drilling got a positive vote and the publication is initialised. The voting of the other parts will be done as a next step.
4.1 Results of testing of the machining scenarios

Due to the early preparations of the data model, the first realisation was started for milling. So the other scenarios were built after the first machining test with a milling machine.

4.1.1 Scenario 1 for milling and drilling

Figure 3 shows the specification of scenario 1.

<table>
<thead>
<tr>
<th>Application: Milling, Drilling, 2.5D + 3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAMOS</td>
</tr>
<tr>
<td>CATIA V5</td>
</tr>
<tr>
<td>Open Mind</td>
</tr>
<tr>
<td>NC Machine</td>
</tr>
<tr>
<td>Siemens</td>
</tr>
<tr>
<td>Open Mind</td>
</tr>
<tr>
<td>CATIA</td>
</tr>
<tr>
<td>STEP-NC Interpreter</td>
</tr>
<tr>
<td>Siemens 840D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Partner</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens</td>
<td>build prototype nc controller based on 840D</td>
</tr>
<tr>
<td>DaimlerChrysler</td>
<td>user test and validation, 2.5D machining</td>
</tr>
<tr>
<td>Dassault</td>
<td>StepNC Output for CATIA V5 Manufacturing for 2.5D</td>
</tr>
<tr>
<td>OpenMind</td>
<td>StepNC Output for 3D NC programming environment</td>
</tr>
<tr>
<td>Volvo</td>
<td>user test and validation, 3D machining</td>
</tr>
</tbody>
</table>

Figure 3: Scenario 1 for milling application

To test different program sources, two input data streams from VAMOS and from CATIA were chosen. The design of the test parts was done by DaimlerChrysler and Volvo. The data were used from Dassault and Openmind CAM stations where the features were identified and added with the necessary technological information like feed, spindle speed and the kind of operation. The CAM-stations of Openmind and Dassault are shown in figure 4 and 5.
Figure 4: CAM – Station Dassault based on CATIA V

Figure 5 CAM – Station Openmind
The output of the CAM stations was the new interface code as developed in the project and fixed in the new standard ISO DIS 14649.

Figure 6 shows one of the test machines used for the validation. The Hermle machine was equipped with automatic tool changer so that all the technological surrounding could be tested.

![Figure 6: Hermle Test machine with STEP-CNC](image)

To show that the code is independent from the machine tool there were also tests with a Chiron machine and a Maho machine. So it was demonstrated that no postprocessor is necessary. One difficulty was the supply of the machines with the tools according to the programs. The setup work for the cutting of a work piece pointed out how necessary a standard is needed for the tool description. It was arranged that the standardisation group responsible for tools got all the information for their work. In the meantime the missing tool description was incorporated into ISO DIS 14649.

Figure 7 and 8 show the results of the machine tests. In addition to this work pieces tests of pocketing and different sequences of machining operations were done. The functionality of the scenario realised allowed to cut every feature but sometimes restrictions were found which reduced the free selection of the technological possibilities.
Figure 7: Test workpiece data imported from Vamos

Figure 8: Test work piece with the most important features
4.1.2 **Scenario for freeform** surfaces Progetti / Franci

The scenario demonstrated the work with the new interface together with the legathy code of the controls used at Franci. The tasks for the scenario are shown in figure 9 and 10.

A part designed by Franci was programmed by Openmind. The selected geometries for the tests can be seen in figure 11. Main goal was the cutting of the freeform part. The Openmind code was compiled by a prototype postprocessor into the legathy code.

<table>
<thead>
<tr>
<th>Task No</th>
<th>Task Description</th>
<th>Leading Partner</th>
<th>Involved Partner</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Generation of prismatic and free-form 3D parts Programming</td>
<td>Franci</td>
<td>Progetti</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Openmind</td>
</tr>
<tr>
<td>2</td>
<td>Test of user interface</td>
<td>Franci Progetti</td>
<td>Franci Progetti Derendinger</td>
</tr>
<tr>
<td>3</td>
<td>Test of milling path</td>
<td>Franci</td>
<td>Franci Progetti Derendinger</td>
</tr>
</tbody>
</table>

![Diagram](image)

**Figure 9: Scenario 2**

The prototype postprocessor was built from EPFL based on the parser of WZL. In parallel Progetti built a simple converter of the ISO 14649 file entity “TOOLPATH” generating the geometry information of the machine.
Figure 11: Test workpiece Scenario 2

Freeform (Ball tool dia. 32.00 or 20.00)

Pocket (Flat tool dia. 30.00)

Holes
4.1.3 Scenario 3 for wood and glass cutting

The goals of scenario 3 have been:

- Test and show the validity of the new proposed data interface with the added extension for the technologies wood, glass and stone
- Reproduce significant product parts
- Show the interoperability of a STEP-NC model on other kinds of NC machines or CAD CAM systems.

The realisation of scenario 3 was done from the control builder OSAI and the machine tool builder CMS. The general layout is shown in figure 12. The data needed were generated with a tool from CMS and from Openmind.

![Scenario according demonstration configuration 3](image)

The features for scenario 3 are nearly the same than the milling and drilling features. But the tools, strategy and the technology are different. Therefore an extended data model was developed and tested.
Figure 13 shows the machine tool used for the tests. It is a CNC machine from CMS equipped with a control from OSAI. For the programming there are no standard CAM systems on the market. Every machine tool builder has his own solution. So CMS implemented also the necessary software for the CAM part.

Figure 13: Test machine CMS Zogno/Italy equipped with OSAI control

Figure 14: Test part “kitchen door”
As test part a kitchen door was selected. Figure 14 shows the production and the milling of the contour of the design.

In addition to the first work piece, a more sophisticated workpiece, the body of a clock was tested. Figure 15 shows the cutting of the graduated face.

Figure 15: Cutting the face of a clock
4.1.4 Scenario 4 for EDM

The goals of the test scenario 4 are the following:

- Check the validity of the wire-EDM data model defined in the Work Package 5 of the current project.
- Check the feasibility of a prototype implementation in a CAD/CAM system and in a wire-EDM machine CNC.
- Check the interoperability of a STEP-NC file on different types of machines (Charmilles Technologies and AGIE).

Figure 16: Test scenario 4 principle
Figure 17: Test machine Wire Cut, Charmilles

The test part designed by Wyss for the wire-EDM scenario is a die for watchmakers. The following design features will be cut by wire EDM processing:

- A vertical cylindrical part
- A conical part with a taper of 2 degrees

Figure 18: Test part for wire EDM
The demonstration of the scenario 4 was executed on 12th December 2001 at Charmilles Technologies, EDM machine builder in Meyrin (Geneva, Switzerland).

Figure 19: Test part result

4.2 Results of testing of enhanced CAM functions

The goals of the project concerning CAM function were:

- To define the scope of future CAM and SFP systems and to identify new functions that could be implemented in them.
- To choose two intelligent functions that could be implemented in CAM/SFP and to develop the corresponding algorithms.
- To implement some prototype functions in a CAM system.
- To implement some prototype functions in a SFP system.

In a survey the most interesting functions were collected and rated. The three most needed were selected and realised. These functions are:

- Simulation of cutting paths and collision check (Openmind)
- Read-in module for feed back of modified NC programs (Dassault)
- Data base for program distribution and version management (WZL)
Simulation

For the simulation it was necessary to take the different kinematics of a machine tool into consideration. In the project the normal rectangular kinematics with up to 2 round axes were chosen and can be selected. Figure 20 shows a sample of the collision simulation. The collision is highlighted using a red dotted line. In parallel the “broken tool” icon is shown in the browser window.

Database for program management and feedback of programs

The introduction of STEP standard (ISO10303) has brought a better interface between CAD and CAM systems within the planning department. However, it has not been connected down to the shop floor until now. The new data model, STEP-NC, breaks down the walls between planning department and the shop floor and also inside the shop floor. As the STEP-NC interface is compliant with the STEP standard, which is used by CAD/CAM systems, the bi-directional exchange of information becomes possible.

Among several possible methods described in D3.0 issued in April 2001, implementation of a database was selected as a solution to manage the version information of “project” and revision histories of object instances. The data model and algorithm were designed as described in the following sub-chapters.

Thanks to this aspect of the STEP-NC interface, last-minute changes or corrections of the part program can be directly fed back to the planning department, enabling the exchange of knowledge between the planning department and the shop floor.
An object-oriented database (OODB), which both CAD/CAM and CNC can access, has been employed for the management of revision. In this database, all entity instances are handled as separate records. It means that all entity instances defined in the EXPRESS schema of STEP-NC are handled as an object, which can be archived in and retrieved from the object-oriented database.

As illustrated in Figure 21, the STEP-NC OODB was implemented by the use of the POET database. The STEP-NC Parser of WZL is used for the I/O of NC part programs. The mapping between the Parser and the database was coded by the use of the POET C++ library. Simple user interfaces for the development phase are created by the use of MFC library and Java Applet which run on Windows NT 4.0 and Web browser respectively.

![Figure 21 Software environment for prototype implementation](image)

For the demonstration of bi-directional exchange of NC programs, a scenario was established as shown in figure 22. Both Siemens 840D CNC controller and CATIA V5 CAD/CAM system can upload and download the STEP-NC file. The version information and revision history is available from the database management system via user-interface in the intranet.

**From CAD/CAM to NC controller**

Under the work package 2, scenario1, the down stream process of STEP-NC file has been already developed and tested.

The primitive STEP-NC program for an example work piece used for scenario 1 of WP2 was stored into the STEP-NC database. The STEP-NC server registers the NC program along with it's version information and status. Siemens 840D controller queries an NC machining "project" from the database and gets the corresponding STEP-NC program. Hereby the machine operator can easily notice the status of the "project" by checking the version information.
From NC controller to CAD/CAM

The machine operator modifies the STEP-NC file by using the front-end software of Siemens 840D controller. E.g. In a dialog box for drilling operation, for example the cutting depth of drilling is changed to higher value. The STEP-NC database checks the modified NC file and reports on the version information including revised data by the use of the user interface.

Figure 22 Implementation Scenario

Figure 23 illustrates the principle of bi-directional exchange of NC programs in future. Various CAD/CAM/CNC systems in local or external site can be linked to the STEP-NC server where the NC programs are efficiently managed and the distributed knowledge is encapsulated and analysed for reuse.
4.3 Conclusion

The tests demonstrated the usability of the new process chain and endorsed the expected benefits:

- No postprocessor is necessary
- Closed process chain between CAD and CNC
- No geometry programming of the workpiece is necessary
- Upload of program changes and reuse is possible
- Best suited for ecommerce
- The expected values of savings (30%) are realistic

The demonstrated scenarios have been the first step for an introduction of the new process chain into practice.

The next step must be a broader use of prototypes. For this step the solutions have to be improved due to the results of testing. This will increase the acceptance of the market.
For the broad use in plants the prototype solutions must be integrated into the standard products along with smaller improvements. The savings in the new process chain are a challenge to be introduced.

### 4.4 Relations with other relevant projects

The project results brought us into a close collaboration with groups active in this field around the world:

**USA**

In the US one year after the start of our project a project called Supermodel was started. Leader of the project is Prof. Hartwig owner of the company Steptools. We have close contact to him by the standardisation meetings.

Prof. Hartwigs goal is to develop software for STEP-NC and he announced to have a prototype for a lathe end of the year 2001. For the realisation he has chosen a slightly different way. He mapped the new standard in an “Application integrated model” and is going to do his implementations on his toolware. The difference between his solution and our implementations is that he prefers to use a solution based on information technology and we preferred to do the job more technology oriented. The comparison of results when they arise will be fruitful for both.

Integrated into the activities is also a group called OMAC (Open Modular Architecture Controls) in which the most important users from Automotive and aircraft industries are involved. Implementation plans for applications are under discussion for the year 2002.

**Korea**

The Korean government has founded a research centre for the new process chain including STEP-NC. The institute is very active and is collaborating with the university Stuttgart in the modelling for turning. They have elaborated some technological gaps in comparison to the milling technology. The solutions of this gaps may change in some points the modelling of the other technologies. It is necessary to discuss this results deeply with specialists because similar problems are just solved in the milling model.

It is a problem for the Korean developers that they do not have interested and powerful CAM and control manufacturer. So the practical test of the theoretical results is sometimes difficult. It would be helpful to intensify the relation to the institute and to exchange data which may be tested in Germany if there are controls and machines available.

**Japan**

Since summer of this year the government is sponsoring a 7 years program with the title “Digital Master”. Goal of the project is the process chain from CAD to CNC but with first emphasis on CAM activity. Details are not known but it seems to be a goal to get a closer connection between CAM and CNC. The results of the work can be seen in the input to the standardisation in ISO TC184 SC1 and SC4.
Europe

There are a big variety of actions running which spread out the modelling to all other technologies which are not covered now.

Our project is limited to material removal technologies. There we see in the moment our main goal. Later we will also pick up activities in rapid prototyping and measuring. This are work items which will be tackled by standardisation and are to be seen in close relationship to parts manufacturing.

4.5 Implications on Standards

On the activities around the world it can be seen that standardisation is the big platform where the modelling of product and manufacturing data is tackled. We started the first activity in 1995 when we created an international workinggroup and the first standard proposal was distributed in 1997. This first draft was the basis for the STEP-NC project and it should be shown that an implementation of this draft can be done economically.

Short after the first draft of the IMS-project the ISO group “Industrial Automation” draw their attention to the drafted standard. A discussion came up to include it into a new “Application Protocol” of ISO 10303. Due to the close relevance to the technology of the used “Physical Devices” the work was continued in the TC 184 SC1 “Physical Devices”.

The implementation work of the project and the tests showed that some redrafting was necessary to include the necessary CNC functionality.

During this test phase a very intensive discussion began with the US standards bodies. Especially Steptools took a very active part to adopt the drafted standard 14649 to the PDM framework (PDM = Product Data Management) of ISO 10303. They correlated the draft with the elaborated standards ISO 10303 AP 214 and AP 224. By that way gaps could be closed between the PDM standards and the upcoming ISO 14649.

After a fruitful rework of the draft the second DIS version was balloted. Two parts were voted positive and one negative. After the integration of some additional instances the voting was changed in positive and the DIS was accepted.

The new ISO DIS 14649 includes 3 parts:

Part 1: Introduction
Part 10: General features
Part 11: Milling and drilling technology

As further results of the project drafts for part 12 “Turning technology” and part 13 “EDM technology” are introduced into the relevant working group.

In parallel the mapping tables between 14649 and the relevant 10303 standards were elaborated as AP 238.
4.6 Benefits to Society

The project work made it possible that the first industrial realisation of this new data model could be demonstrated in Europe. It was shown that the new data model functions as a bridge between CAD and the CNC at the shop floor. It was shown that the simplifying of the process chain is possible and that additionally benefits like easier setup, no need of postprocessing and easy back propagation is achievable.

It was also seen that for a broader use in high productive applications the features for controlling the processes must be enhanced. A data access to the real time events at the control side must be used for decisions in the process control level. It is up to the European users and applications implementers to use this new data model and to earn the described benefits.

The elaborated know how at the partners side can support the manufacturing industry in applications which are working with machine tools. For the development of manufacturing programs two CAM supplier have demonstrated their solutions. As input data product data was used supplied from CAD systems working with ISO 10303 code.

The CAM output code was used on different machine tools equipped with a control with an integrated new interface. The integration was done based on a well known CNC so that the user had no problems with the general use. The operator never got into touch with this new data model so that the education was reduced to a simple demonstration of the setup.

Concerning the employment the use of the new data model will have no general influence. The not needed post processing saves money and resources, but the new process environment with the challenge of better tooling, automated measuring with feed back of process data compensates this effect. Stronger will be the influence on quality of life because decisions, setup, exchangeability and the degree of automation are on a higher level. The transparency of data and the possible support is better because the data sent to the control has much more content than the used legacy code.

Due to environment and resources the most important fact will be the higher productivity which can be reached. The reason is the automated optimisation and possibility of manipulation of the data. The working sequence of the program, the technology and the tooling can be changed easier at the control by the operator. A missing tool means not to stop the whole process. The action can be cut out or done with an other tool or done with a different technology. This saves energy and natural environment.

The savings calculated for the new process chain will be between 30 to 70 % of the programming, editing and maintenance of the NC programs. In addition the expenditure for post processors and their maintenance will no longer be necessary.

5 Deliverables and References

The major project documentation was done by two kinds of deliverables:

- Project documentation
- Project management
5.1 Project documentation

The first step of the project was a collection of the demands of users and manufacturers towards the new data model. The collected data are described in a first document. After that the specific requirements of the users were put in a specification for the relevant technologies.

For the implementation and test of the demonstrators 4 scenarios were assigned and a schedule for their midterm development was fixed. Parallel to the development of the demonstrators the data model descriptions of every technology developed was sent to ISO TC 184 SC1 WG7 for the integration into the new upcoming standard ISO 14649.

The test of the scenarios, the work pieces produced, results and new ideas for the future work were documented. The scenario1 which was firstly developed could be tested more in detail. The results and the benefits which can be expected by industrial use are put together in a document “Results of usability tests for milling”.

A complete list of the deliverables can be found in Annex I.

5.2 Project Management

The whole project was documented by progress reports which were elaborated every 6 months. The content was:

- Executive Summary
- World-wide “state of the art” update
- Exploitation of results
- Work progress overview
- Clarifications
- Information dissemination activities
- Contractual matters

All documentation of minutes, review results, deliverables and descriptions are archivised on a project internal web page. In addition a public web page www.step-nc.org serves the general information and is base for an user group.

5.3 References to dissemination activities

A list of the dissemination activities can be found in the Annex.
6 Outlook

The reached status with the new interface technology of CAD/CAM/CNC shows the benefits which can be reached. Until now it was very theoretical that there will be an enhancement of the process chain. But now the feasibility is demonstrated and major betterments could be shown.

That means that the new technology is still in phase one. The end users must be confirmed by demonstrating the new process chain. Therefore all the tangible tools necessary have to be working and available. This is still not 100% the case. Especially the tools have to be involved deeper. In this moment only sponsored single implementations have a chance of realisation. For this few applications the prototype realisations with small enhancements will be sufficient.

After the availability of the test results of this applications the interest of using the process chain will grow during phase 2 of exploitation. End users which could test the benefits will get the know how for the implementations and the necessary environment. Realisation plans will be made and the pull after the new technology will grow, small orders will take place. That can start in the years 2002 to 2003.

The next phase, is the hot business phase 3 where users are aware of the benefits and try to share them. For that phase the today’s prototypes have to be enhanced to standard products with high reliability. The work to do should not be underestimated and also the environment for the process must be ready for use.

During the project a lot of information dissemination by paper and by events has been done. To get forward in the exploitation phases future work is necessary and so the partners decided to enter into a new international project together with the other regions which are active in this field.

USA, Korea, Switzerland and the EU have signed a contract with shared activities in that area. In the next 2 years it is scheduled also to develop prototype implementations for the turning, measuring and the rapid prototyping technology. This gap closing technologies for fully automated manufacturing needs also the development of information entities like tolerances which will be used for inspection of the manufactured parts.

In Germany the project partners have installed a link to a machine tool builder group which works for automotive industry. They claimed to have additional enhanced features for a more real time control of the process. This will also a goal for this international IMS project STEP-NC. Kick-off of the project will be early in 2002.
## 7 Annex

### 7.1 Deliverables

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<th>Types of deliverables</th>
<th>Description of the deliverable (Title)</th>
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<th>Work-package reference</th>
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### 7.2 Articles, Conferences, Presentations

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<td>ADITEC WZL Aachen: The machine tool goes STEP</td>
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