3D modelling of a Laser Welding Cell for movie presentation
- Making of the movie

Henri Hansson MR05
Abstract
This report describes a Bachelor thesis work in which a robotised laser welding cell has been modelled and simulated for the purpose of making a presentation movie. The report shows that the work has been concentrated on making the movie from the modelling phase through the recording of the movie and ending up with the editing of the final presentation movie.

A pre-study was made prior the Bachelor thesis work. In the pre-study a literature study was conducted about measurement and calibration of a welding cell. Measurement of almost all equipment in the entire cell was also conducted in the pre-study. The main result of this pre-study is a thorough investigation of what objects and functions that needs to be modelled in order to explain the functions in the specific laser welding cell.

The purpose for this Bachelor thesis work is to give an efficient and alternative way to present a laser welding cell that resides in Production Technology Centre (PTC) at Innovatum, Trollhättan Sweden. The movie can be used outside PTC or if the laser welding cell is occupied with work, since it is not allowed to be inside the cell when in progress.

The result of this work is a nearly 12 minute long presentation movie which shows all predefined elements of the cell together with a real welding sequence with metal deposition (MD).
Preface

This report is the result of a 15 point Bachelor thesis work at University West. The report aims foremost to those that have an interest for moviemaking from a 3D model. Included in this report is also a 7.5 point pre-study that was conducted prior the Bachelor thesis work. The pre-study aims foremost to those that have a bit of knowledge about calibration and measurement of a robotic welding cell. The pre-study and the Bachelor thesis work have been performed during first and second quarter of 2008 at Production Technology Centre at Innovatum, Trollhättan Sweden.

I would like to thank the following people for their devotion for this project: Anna-Karin Christiansson and Mattias Ottosson for their incredible involvement, support and ideas. For the support of drawings and some models on the equipment in the laser welding cell: Mats Hansson, Volvo Aero Corporation, and for the final extra addition of MD-movie to the presentation movie: Per Thorin, Volvo Aero Corporation.

I also want to take this opportunity to thank my mother and friends for their support during these years of my Mechatronic engineering studies.

Henri Hansson
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<table>
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>.CO</td>
<td>File extension that the software Robcad can read</td>
</tr>
<tr>
<td>.COJT</td>
<td>File extension that the software Process Simulate can read</td>
</tr>
<tr>
<td>AVI</td>
<td>Audio Video Interleave – Most common used movie format on personal computers</td>
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<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>DH</td>
<td>Denavit-Hartenberg – Used to determine the position of the robot</td>
</tr>
<tr>
<td>eBOP</td>
<td>Electronic Bill of Process – Act as a central repository of information that enables different users to work with the same project.</td>
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<tr>
<td>End effector</td>
<td>A device or a tool connected to the robots hand</td>
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<tr>
<td>GPL</td>
<td>General Public License</td>
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<tr>
<td>NTSC</td>
<td>National Television Systems Committee – TV system in America</td>
</tr>
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<td>NX</td>
<td>Siemens PLM Software – 3D CAD software</td>
</tr>
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<td>OLP</td>
<td>Off-line programming</td>
</tr>
<tr>
<td>PAL</td>
<td>Phase Alternating Line – TV system in Europe</td>
</tr>
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<td>PD</td>
<td>Siemens PLM Software – Process Designer</td>
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<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
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<td>PLM</td>
<td>Product Lifecycle Management</td>
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<td>PMI</td>
<td>Product Manufacturing Information</td>
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<tr>
<td>PPI</td>
<td>Pixel Per Inch – Measurement for pixels in images</td>
</tr>
<tr>
<td>PS</td>
<td>Siemens PLM Software – Process Simulate</td>
</tr>
<tr>
<td>PTC</td>
<td>Production Technology Centre at Innovatum Trollhättan, Sweden</td>
</tr>
<tr>
<td>SOP</td>
<td>Sequence of operation</td>
</tr>
<tr>
<td>TCPF</td>
<td>Tool Centre Point Frame</td>
</tr>
<tr>
<td>Tessellation</td>
<td>Process of subdividing a surface into smaller shapes</td>
</tr>
<tr>
<td>VAC</td>
<td>Volvo Aero Corporation, Trollhättan Sweden</td>
</tr>
<tr>
<td>VRML</td>
<td>Virtual Reality Modelling Language</td>
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1 Introduction

This report presents a work for Bachelor degree, where a modelling and simulation of a laser welding cell has taken place, for the purpose to make a presentation movie from a 3D model. Prior the Bachelor thesis work there has been a pre-study conducted that involved a literature study, determining of objects to include in the movie and measurements of the cell environment including partly measurements of objects. This report presents the approach taken for making a presentation movie and what equipment and software that has been used in the making of the movie. The report also presents what objects and what functions there are in the specific cell, what software that has been used in the modelling and simulation parts. This report also reflects on the general purpose for measurement and calibration of a robotic cell.

1.1 Bachelor thesis background

The background for this Bachelor thesis work is to give the opportunity to have an alternative way to present a specific laser welding cell. This laser welding cell resides within Production Technology Centre (PTC) at Innovatum area in Trollhättan, Sweden (www.ptc.hv.se).

The purpose for a presentation movie of a laser welding cell is e.g. to be able to present the specific laser welding cell when the laser is in progress and hence no one is allowed within the cell area or when e.g a presentation is conducted outside the PTC.

Prior to this Bachelor thesis the approach has been do physically go to the specific cell and present it or to show a specific object within the cell. Sometimes the laser welding cell is occupied with work by University West or any other company that has rented the cell for their purpose. At these times a presentation of the inside of the cell is impossible as it is strictly forbidden to appear inside the cell environment when the laser is in progress. If a presentation of the specific laser welding cell has been conducted outside the PTC, e.g at the University West, a general introduction of the cell and the purpose for it has been presented orally. The specific laser welding cell is used in research projects at PTC, and there is need for efficient means of explanation what these projects really are about.

1.2 Purpose and goal

The purpose for this Bachelor thesis work is to present methods for making a presentation movie of a specific laser welding cell that resides within PTC at Innovatum area in Trollhättan, Sweden. The goal is to present a movie made out of a 3D model of the laser welding cell. This Bachelor thesis work is made in cooperation
with a student colleague Daniel Mattsson whose main contribution has been on modelling the cell within Process Designer and Process Simulate softwares.

1.3 Limitation

Limitation has been done regarding both models and movie. Prior the modelling and simulation stage a part time goal had to be fulfilled in order to be sure that a movie could be made:

- Small movie made from Process Simulate, simulating a robot movement.

The models to be created have been put on a list of object specification that has a priority attached to it of 1 to 3.

- Priority 1 objects will be modelled first.

- Priority 2 and 3 objects will be modelled if all priority 1 objects have been modelled, imported into Process Designer and a movie has been produced.

Objects will be modelled in the software NX and imported to the simulation software Tecnomatix: Process Designer (PD) and Process Simulate (PS). Following the list of object specification is the list of function specification. The list of function specification is regarding kinematics on certain objects. It also has a priority attached to it of 1 to 3.

- Priority 1 functions will have the kinematics attached first.

- Priority 2 and 3 functions will have the kinematics attached to it if all priority 1 functions have been made with kinematics and a movie has been produced.

The measurement details on models can vary depending on significance. This includes all objects on the list of object specification and all models surrounding the cell such as beams, walls, floor and roof. Also, the level of detail does not need to be so high.

Regarding the presentation movie there is no demand for a certain file extension and no demand has been put on how large the files need to be. Initially there was a wish that the final movie had an audio stream, but there were no demand for this.

1.4 Method

Prior the Bachelor thesis work there has been a pre-study conducted in which a literature study was made about calibration and measurement of a weld cell. A decision was made together with those that are involved with using the cell on which objects that should be included in the specification of the cell. Also included are a measurement of nearly all objects and the major part of the cell structure. The measurement have been made with a folding rule, since for the purpose of making a presentation movie there has not been a need for a more precise measurement.
First there was a need to become familiar with the software Process Designer (PD) and Process Simulate (PS), by guiding through the interface, menus and options available.

As a part time goal a small movie was made in order to present that indeed a movie could be made from models in Process Simulate. After the movie had been made the modelling started of the object of specification, specific placement of equipment and specific functions such as kinematics on door and gate that initially were not. To get the model of the cell structure to be as similar to the real cell, a walk around has been made in the modelling phase.

Collecting of information regarding software for capturing of movie, editing of movie and in which format the movie should be presented has been conducted parallel with the modelling phase.

1.5 Computer hardware and software

The result of a movie made from a 3D model can differ when using different computer systems and software versions. Meaning that, a computer system with a strong CPU and a good graphic card that is mainly used for 3D graphic is better to use than a home computer that is mainly used as an all round media computer. The computer hardware that has been used for modelling, simulation and for recording the movie has been provided by the University West. For the editing of the final presentation movie another system has been used, a personal home computer. The specification for these computer systems are as follows:

Spec. for computer provided by UW
- Windows XP Professional
- Version 2002 Service Pack 2
- Dell Computer
- Intel® Core™ 2 DUO CPU E4600 at 2.40GHz
- 1.96 GB RAM
- Graphic: ATI Radeon HD 2400 PRO, 256 MB

Spec. for personal home computer
- Windows XP Media Center Edition
- Version 2002 Service Pack 2
- Packard Bell Computer
- Intel® Pentium® 4 3.20GHz
- 2.00 GB RAM
- Graphic: ATI Radeon X700 SE, 512 MB

The reason why two systems have been used is because that when editing of the movie clips took place the computer provided by UW was slowing down the process and started to crash a lot. There can be a lot of reasons why the computer provided by UW started to slow down and crash. It can be hardware, software or user related problems that caused it. But to search for the solution at this time in the Bachelor
thesis work was time consuming, so the decision was made to bring all movie clips to the personal home computer system for the editing process to be completed.

Computer software used in the Bachelor thesis work is as follows:

- Modelling part NX 5.0 (Student license through University West)
- Simulation part Tecnomatix 8.1.1: Process Designer and Process Simulate (Student license through the University West)
- Movie recording CamStudio 2.00 (Free open source software)
- Editing of movie DivX Author 1.5.2.180 (Personal Purchased License)

For the transition images in the final movie the Microsoft Paint tool was used. This tool exists within Microsoft Windows operating system. For the images added to the end credits in the final movie the command “print screen” has been used and edited in Microsoft Paint.

For an overview of the software used in the Bachelor thesis work, see Appendix A.

1.6 Laser welding cell

The laser welding cell that the presentation movie is built on is the RLMwD-cell at PTC. RLMwD is an abbreviation for Robotised Laser Metal-wire Deposition and is a research project financed by VINNOVA MERA-programme [22]. The RLMwD-cell is more commonly known as the RMS-cell which is a Swedish abbreviation for Robotised Metal Building by Melting Wire. In the RMS-cell laser welding techniques is used to build components by use of melting metal-wire.

For a more detailed description of the RMS-cell, see Appendix B.

2 Literature study

The literature study has been conducted as a pre-study before the Bachelor thesis work and has been about calibration and measurement of a weld cell. The database search tool that is available on the library homepage at University West has been used. A few good sources have been found and the most important and interesting ones have been chosen. Main concentration has been on the abstract of the articles, and if there has been something really interesting the search has gone deeper into the article.

The subject calibration is wide and a lot of articles about different methods have been found. In basic terms a calibration is easily explained but when reading about all these methods it suddenly becomes really hard to actually explain in an easy way. Somewhere in all the searches it became somewhat unclear what calibration really was or why a measurement was actually needed. But as the literature study continued all the pieces came closer and in the end it all fell in place.

The results of this study are presented in their context below.
2.1 Introduction to the Literature study

The position accuracy of a robot is in general determined by the two terms accuracy in the absolute position and repeatability [1]. In the industry, robots are highly repeatable but not very accurate. Since most industrial applications have been programmed through the teach pendant to produce a number of points and these in turn have been replayed for repeatability - hence accuracy was not needed. In other areas the need for accuracy in advanced applications is more present, e.g. in robotic surgery where accuracy plays an important role [2, 3].

When operating the robot manually there is no need for any measurement of the workcell or the workobject. The operator has visual information of all equipment in the workcell and hence is aware of any collision that may occur. For a robotic application to be automatically manoeuvred or simulated through a simulation software there has to be some sort of measurement and calibration of the workcell. A computer generated simulation needs a computer model of the robot and the environment it is standing in. For the robot program to work properly the computer model needs to be calibrated relative the physical hardware [4].

For a computer model to be made there are two vital things to consider, simulation software and a complete measurement of the workcell. For the latter there are several different methods that can be used, both automatically and manually performed. To do a manual measurement of a workcell a folding rule can be used but this method is not very accurate and should only be used when accuracy is not needed. Another example is with a laser measurement tool that also is manually performed but has better accuracy and precision. For automatic measure a robot tracker system can be used that provides absolute measurement positions and is based on principle of triangulation [5]. The measurement can be used for any position in space that is needed. Whichever method that is used it must give good and solid measurements that can be used when modelling the workcell.

Off-line programming (OLP) is a term used when speaking of simulation software. In an OLP-software a model of the workcell and its equipment can be modelled in 3D-environment and simulated. When a simulation has been finished and is correct according to what type of work it is set out to do, a robot program can be generated from the simulation.

2.2 Measurement

A robot is, among other things, built up with a base, one or more links, joints and axes and its hand. Hand is the end of the robot arm, where the end effector is attached. The base, hand and each of its joints have their own coordinate system. Each coordinate system has its own orientation and position. If as an example, one would want the hand to reach a given point in space, there would be an infinite
number of directions from which we could approach this point and still be able to reach the desired position. All these configurations will place the hand at the desired position, but they each would have different orientations and different positions when they have reached the target [9].

When a robot is developed, manufactured and assembled at the robot manufacturer’s workshop, it will get absolute measurements for the entire robot. Meaning it will get, within the set tolerance, exact geometric parameters from the base coordinate system to the first joint coordinate system, from first joint coordinate system to the second joint coordinate system and so on to the end effector coordinate system. It is in a nominal state, see Figure 1 that shows a silhouette of a robot only for visual purpose (the X- and Y- axes indicated are different for the different coordinate systems).

When the robot is put into motion of some kind, see Figure 2, it is required that the position and orientation of the end effector, according to the base coordinate system (most often the Robot system), is recalculated to be able to know where the end effector is in space in the base system. One method for doing this is to make a kinematics model of the entire robot [6, 7].

A kinematic model of a robot has geometric values, parameters, which characterize its physical configuration at any point. The forward and inverse solutions of this model are used to control the robots motion. For the robot accuracy to be improved, one need to determine the parameters of the robots true geometric values as precisely as possible. One way to estimate these values is by measuring the robots Cartesian errors.
at several points in the workspace and then deduce from these measurements the required corrections for the geometric parameters [8].

The principal cause for error in the position of the end effector is due to the inaccuracy of the parameters used to compute the position. The determination of the robot position is usually done using forward kinematics with Denavit-Hartenberg (DH) parameters for each link of the robot [2]. With a complete set of DH parameters the numerical inverse kinematics can be computed in order to find the end effectors position in the base Cartesian coordinate system.

In the end, robot accuracy depends on the accuracy of the DH parameters. Some of the variations come from the manufacturing process, mainly due to inaccuracy in machining. Other variations come from the assembly of the robot, where the precision of the position for the links and joints is not exactly repeated [2]. Also varying work load affect the position accuracy.

### 2.2.1 Measurement of the RMS-cell

The purpose for measuring and modelling a workcell is mainly to avoid any collision that may occur. In the RMS-cell the objects that can cause a collision are attached to the robot. This is because the path of the robot is not in a wide range of locations, it is narrow inside a chamber. The laser tool is then sealed around the chamber with a plastic surrounding this in order to maintain the shielding gas within the chamber, see Figure 3 which shows the laser tool and the sealing.

![Figure 3 Picture that show the laser tool within the chamber, protected by the sealing.](image-url)
The objects that are attached to the robot are the cables which come from several different directions depending on what the specific cable are for. These cables are attached to the robot in something that is called the cable package, see Figure 4 for a picture on the cables behind the robot and see Figure 5 for a picture on the robot cable package.

Figure 4 Picture shows where some of the cables that are attached to the robot reside from.

Figure 5 Picture shows the cable package that is directly attached to the robot.

When a measurement is complete, the measurement data can be added in a computer model of the cell in order for a simulation to take place. Initial measurement of the RMS-cell has been conducted with the help of a folding rule. The method with a folding rule is not very accurate, in fact it is only with centimetre precision and it is actually really hard to measure pipes along the wall, or odd geometric objects such as
emergency buttons. For an example on objects that can be difficult to measure see Figure 6.

![Figure 6 Picture on some of the odd geometric objects in the RMS-cell](image)

Figure 6 Picture on some of the odd geometric objects in the RMS-cell

However, a few simple 2D-drawings were made out of the data from the measurements, for two examples see Appendix C.

A laser measurement tool was presented late in the project and it could be used for a more precise measurement of the walls and some of the bigger objects in the cell. Also, 3D-scanning equipment was presented. With a scanning with this device of the RMS-cell it would be in the millimetre precision area and with a lot of details of the equipment in the cell. It would present a wide range of opportunities and would be a great help with a later modelling of the RMS-cell. For the purpose of making a movie presentation of the RMS-cell, there were not a need for a more precise measurement so for this Bachelor thesis work the laser measurement tool and the 3D scanning...
equipment has not been used. Some other objects in the RMS-cell such as accessories for robot and manipulator have not been measured because it already exist models for them. These objects are the chamber and lasertool that have been obtained from Mats Hansson at Volvo Aero Corporation (VAC), also the ABB Drive module and Control module have been obtained through the ABB homepage.

2.3 Calibration

Calibration of a robot is a process of accuracy enhancement of robot built to a high level of mechanical repeatability. For a robot calibration task some steps include kinematic modelling, identification, compensation and position measurement [9]. The complexity of a calibration procedure varies widely. Some procedures for robot calibration use a generalized error matrix to reduce the positioning error of the system [10], others involve a 3D computer vision system as a position sensor in order to perform robot calibration [1], a three level procedure is presented in [11]. These are only a few examples of the wide area of procedures that exist.

It is important to differentiate between robot accuracy and robot repeatability. Repeatability of a robot is the precision with which its end effector reaches a desired position under repeated commands of the same set of joint angles. A high repeatability is of great importance for several robot applications such as pick and place, spray painting and welding [3]. A measurement for repeatability is in the range of $\pm 0.1 \text{mm}$. Accuracy of a robot is a measure of how well the robot can achieve the position by itself and its end effector at a desired Cartesian position in the workspace [1]. A measurement of accuracy is in the range of $\pm 5 \sim 10 \text{mm}$.

When a robot is programmed on-line, the user moves the robot via the teach pendant to the desired position. No actual calibration or measurement will be needed of the workcell at this point. However, to be able to program an industrial robot using off-line programming software and simulation, the use of a computer model of the robot and its workcell is needed. This model needs to be calibrated against the real hardware in the cell, this means that a measure of absolute position of the robot and other strategic positions within the cell is required, otherwise the resulting robot program and motion will not work as it is intended to [4, 5, 12].

2.4 List of object specification and functions

A list of objects to include in the model of the RMS-cell has been made in cooperation with Mattias Ottoosson. A priority was attached to each object because the time is limited and it is a lot of equipment in the cell. A complete list of object specification can be found in Appendix D.

A list of functions to model involves all motion that are needed for the presentation, e.g. the door to the programmable logic controller (PLC) cabinet that is a really
interesting cabinet for some projects within PTC. In this cabinet a master device for an industrial fieldbus called PROFIBUS [13] resides. This fieldbus could be described as a complete bus topology with rules for communication between one master and several slaves. With kinematic motion attached between cabinet and the cabinet door, the door can be opened and the PROFIBUS master device can be presented. A complete list of the functions can be found in Appendix E.

2.5 Off-line Programming and 3D CAD Software

The intended Computer Aided Design (CAD) software to use for the Off-line programming part in the RMS project is Process Simulate which is rather new software from the same manufacturer as RobCad, Siemens Product Lifecycle Management (PLM) software. Siemens PLM Software product Tecnomatix has a wide range of segments and within one of these, Assembly Planning, the software Process Simulate (PS) can be found. Process Simulate is a 3D environment simulation software that involve different segments of the manufacturing process. With Process Simulate an entire workcell can be built with features such as 3D simulations, static and dynamic collision detection, sequence of operations (SOP), assembly and robot path planning, kinematics and much more [14].

To design the cell there is a tool within the same segment as Process Simulate, named Process Designer (PD). This tool allows for evaluation of alternatives in the manufacturing, resource coordination, estimation of cost and cycle time, optimization of throughput such as bottlenecks and resource utilization, creation of assembly-line layouts and much more [14]. This tool can also be used for modelling all the equipment needed in the cell. However to be able to model in more detail and with more flexibility the 3D CAD software NX (from the same manufacturer) has been chosen. NX is a very powerful and flexible software and offers a wide range of solutions such as design for component, assembly, sheet metal, human modelling and many other areas. For the equipment that will be modelled in the RMS-cell, the NX design application tool Modelling will be used. It is a feature based parametric design tool which means e.g. that changes can easily be applied to the model afterwards. It is however not only limited to parametric solid modelling, it also includes a complete system for defining wireframe, surface and solid geometry [15].

2.5.1 Communication between NX, PD and PS

To be able to communicate between the two software NX and PD a file conversion had to be made. This file conversion was made in NX to JT format, and later translated through an import into the project in PD. As the cell was starting to build up within PD and PS a lot of the objects were translated through an import directly into the cell in PS. The data format JT can hold as little as only facet data or be a lot richer and hold associations to the original CAD information, the product structure, assemblies, geometry, attributes, metadata or Product Manufacturing Information
(PMI). It is a high performance and compact persistence archive format for graphic data. It also supports multiple tessellation and level of detail generation [16].

2.5.2 Existing models
All ABB models have been downloaded from the homepage of ABB Sweden, with authorization from ABB Sweden. This includes ABB 4400 robot as a parasolid for the making of the cable package, an ABB 4400 Robot as a Robcad model to be able to have the kinematics of the robot. In Process Designer this Robcad model that has the extension .CO has been upgraded to have the extension .COJT, which is the correct file extension for a model within Process Designer and Process Simulate. ABB manipulator has been downloaded as a parasolid and imported into NX where a file conversion to the JT format has been made. All the kinematics for the manipulator has then been made in PS (See Appendix A for an overview on these steps). The chamber that is attached to the manipulator and the laser tool with the cone attached to it has been provided by an employee from VAC, Mats Hansson.

3 Study for best suited moviemaking software
Parallel to the Bachelor thesis work there has been a small study to collect information regarding software for making a movie from a 3D model and which software to use when editing the movie. There are usually a lot of settings to learn about before the actual recording or editing can be done. Therefore a simple tool that can produce something without actually going deeper into the parameters settings has been of main interest. The search for information has been conducted both through books about the subject and general Internet searches.

The result of this study is presented in its context below.

3.1 Choice of Moviemaking software
In order to make the presentation movie, software for capturing what was happening on the screen had to be found. By a simple search on the Internet for a movie making software that can capture the result on screen shows that there are many manufacturers and equally many software that can be used for movie making, both free and those that cost money. Since this has been a Bachelor thesis work, a solution for free software has been the aim.

In the software Process Simulate there are such tools that can capture what is happening on the screen and output it to an audio video interleave (avi) file. Avi file format is the most common format for audio- and video data on computers [17]. There are a number of different codec to choose from and each and every one has different settings that can be applied for the purpose of getting what one wants from the actual movie. When the tool within PS for moviemaking was used, an experience in lag occurred. Lag is some sort of time displacement that makes the model appear as
if it was jerking around on the screen even though a near smooth rotation was applied. Even though the lag appeared when making the movie, the movie file was not showing a trace of lag other than the obvious lag. Obvious lag is e.g. hardware related as in too large models being recorded and graphic card has troubles rendering the information, or user related as in not a smooth movement of the model. The experience in lag became a problem as it was not clear what was actually recorded until after a movie was done and it could be played back in a media player.

Due to time limit and the extensive settings that had to be learned in order to understand what was actually being captured from the screen due to the lag present when recording, a decision was made that an external on-screen-capturing tool would be of better use for the movie that was to be made. Main reason for choosing external software was that no lag occurred while recording the model, as small tests had shown.

### 3.1.1 CamStudio

When the searches for a free on screen capturing software were conducted on the Internet, the top choice was a software called CamStudio. CamStudio that is a free open source streaming video software is released under the General Public License (GPL), this means that the software is free to use for any private and or commercial usage. For a detailed view of GPL, go to [http://www.gnu.org/licenses/gpl.txt](http://www.gnu.org/licenses/gpl.txt). The choice for this software was made easy as recommendation to use it also came from Mattias Ottosson, employee at UW working at PTC. Also, in comparison to the software within PS, CamStudio felt like the best choice for making the presentation movie, as it is very easy to use and produces a lot less lag from the screen recording as some tests showed.

### 3.2 Settings for movie

There are several different settings that can be applied before doing an actual on screen recording. All depends on what actually are being captured, what quality the movie need and what format that is desired. All settings that have been applied for the recording of the presentation movie have been tested numerous times before finally deciding what to use. A short description of the settings used for the movie is presented in the context below.

#### 3.2.1 Compression

To compress the media file, a codec need to be used. A codec is software that is used to compress or decompress a media file, such as a movie. The creator of the movie use a codec to compress the movie file, this is done because a compressed file takes up a lot less storage space then a non compressed file [17]. An example is if one takes a 640 by 480 pixel full screen image. The total amount of pixels that this image will
have is 307200 and each pixel will need 3 bytes of data storage to contain all information of colour and brightness. Therefore one frame of video needs 921600 bytes of data storage and at a frame rate of 25 frames per second, one second of video would need more than 23 megabytes of data storage and one minute of video needs over 1,3 gigabytes [18].

Another advantage for compression is that a file can easily be transferred across the Internet more quickly and smoothly, as it is easier to transfer a small amount of data than a large amount. When the movie is played in for instance Windows Media Player, the player uses a codec to decompress the movie. An encoder and a decoder are two components that a codec can consist of. While the encoder compresses the file during creation, the decoder decompresses the file so it can be played in a media player [17].

Which codec to use, depends on the type of material being compressed and the capabilities of the computer system for which it is designed. Since each codec takes advantage of different properties in order to achieve compression, the type of material being compressed significantly effects both how much compression can be applied and how well the codec will reproduce the original [18]

### 3.2.2 Frame

A frame is a single video image, each video frame consists of two half frames called fields. Video images are made up of half the scans of a full image. All TV systems, National Television Standards Committee (NTSC) and Phase Alternating Line (PAL), use fields to avoid flickering images. Images consisting of either odd or even lines are called fields [19]. It could be explained as a series of images that make up an animation, clip of video or movie film [18].

Countries that have an electrical infrastructure based on 60Hz uses NTSC TV system, use 30 frames per second (fps) (60 fields). Countries that have an electrical infrastructure of 50Hz use PAL TV system and 25 fps (50 fields) [20].

#### 3.2.2.1 Key frames

Key frames are complete, stand alone frames of digital video without any reference to any other frame [18]. These are selected within a timeline for beginning or ending an action or effect, or where sound start to fade in or out [19].

#### 3.2.2.2 Frame rate

Frame rate is the speed in which image moves before the camera gate (film) or image gate (video). For an example on the settings that have been used in creating the presentation movie with the software CamStudio, see Figure 7.
In addition to the video options there can also be some configurations made for the codec that is being used. For the codec that can be seen in Figure 7 there are additional configuration settings. For an example for the codec used in the presentation movie, see Figure 8, where the number 0.75 (out of 1 in total) means time limited quality relation. It is a default value since it actually did not show any difference in the movie produced when changing the value.
Figure 7 and Figure 8 show the video options that have been made for the presentation movie, in addition to this a pre defined region for the on screen window has been set to 800x600 (width x height). The main reason for the pre defined region is due to that the resolution of the screen had been set to 1024x768 and the main graphic window for the Process Simulate environment was a bit larger than 800x600, leaving a few centimetres on both sides for any needed movement of the cursor. For instance if an optional background colour wanted to be set and in order to do so a small pop up window would appear inside the recording frame if the resolution had been set larger than 800x600. Also, as the amount of pixels would increase significantly if the resolution had been set to higher and by that all movie files would be getting very large.

Microsoft Video 1 Compressor only stores the data in 16 bit colour depth, although after a few tests this codec showed more sharpness in the image than a codec with 24 bit colour depth. Therefore the choice of Microsoft Video 1 Compressor was final.

### 3.3 Investigation of editing software

When recording a movie on screen, many things can happen that would make the movie only partly useful. For instance, while recording it may look very good but when a playback of the recording is being done things such as failure in capturing right objects or something may appear in the screen that should not have been captured. So to be able to extract the part that is of good use, editing software is needed where the video frames can be extracted and the right set of frame can be cut out to produce a streaming video.

There are a lot of companies that offer different kind of editing software with different features. Which one to choose depends on several things as it did with the choice of moviemaking software. Editing software is computer software that produces a streaming video of several small movies. A few editing software have been tested, and these are AVS Video Editor, Avid Express, Ulead Toolbox 2.0 and DivX Author.

For the AVS Video Editor software a trial version was tested and because it was a trial version it had a water mark on the movie produced. In order to get rid of the water mark, a full version of the software had to be purchased. At a cost of $ 39.95 the decision was made to look for cheaper software. Along with the book “Avid Made Easy – Video editing with free DV and the Avid Express Family” by Jamie Fowler, that was a loan from the University West library, came a DVD containing a limited version of the Avid Express software. This however, was complex software with a lot of settings that could be made and a lot of features that had to be learned in order to produce a movie. It felt as it was too advanced for the purpose to create a presentation movie. Decision was made to look for something simpler. Ulead Toolbox 2.0 is such software that was a lot simpler in its settings and features. And after a few tries it felt
like it was really good software to actually make the presentation movie with. However, the cost for this software was similar to the cost of the AVS Video Editor software and to be able to fully use the software a full version had to be purchased so the idea was discarded once more. DivX Author was the next software and the final software that was tested before a decision was made on which one to actually use to edit the presentation movie. DivX Author is a simple but yet powerful editing software. Although it got a lot of settings for the video part to be learned in order to fully use the software, it can also just be set to default and still get a really amazing result. It felt in general good to use and the price was half of the above three software. It also had the feature that a DivX certified player such as a standalone DivX DVD player, could play back a file created with the DivX Author. This gave an alternative option for the movie to be presented if such option would be of use.

3.3.1 DivX Author

So the final decision fell on DivX Author. With this software all movies were given the file extension .divx. DivX is a digital media format that compresses video to a fraction of its original size for efficient storage on a hard drive and for easy sharing across the Internet [21].

3.4 Settings for editing software DivX Author

The settings for DivX Author are extensive and nearly all had to be set to default as it was time consuming to actually learn about and test all the different settings that could be adjusted. From experience and knowledge there has been some settings made anyway. Short descriptions on the settings that have been used are presented in the context below.

3.4.1 Movie options

For the movie options that concern the main movie and how it will be made, most settings have been set to default values. However there are some options that have been changed to match the movie produced. These are frame rate, bit rate and in advanced options; performance and psycho visual enhancement. See Figure 9 for the video options in DivX Author.
Frame rate has been set to 25 fps, because of the PAL TV system and if the option for the future is to play the movie on a DivX certified DVD player.

Bit rate has been set to 3000 kb/s, which is the maximum bandwidth allowed for the movie produced. The downside of setting the bit rate to a very high value is that the output size of the movie increases but the picture quality will improve.

The option “size” has been left to default value. This was a small mistake as all recordings made were with a defined region of 800x600. This means that all recordings have been reduced in resolution from 800x600 to 640x480. It is generally not a good idea to resize a movie. If changes are made so that the original size will be larger it will usually degrade the quality of the movie. However, resizing from a bigger size to a smaller will make the pixels smaller and this will not give too much quality setbacks, as the pixel in the resized movie will have more pixels per inch (PPI) [19].

For the advanced settings window see Figure 10.
Performance has been set to insane quality for all individual movies made, based on a recommendation in DivX Author Help. For the final movie it has been set to balanced quality. An insane quality setting will encode at a very slow speed but will give the highest quality picture. For final movie it will encode at a normal speed and will give a balanced quality picture.

Psycho visual enhancement has been set to masking. This ability will use spatial block analysis reducing artifacts and is recommended in DivX Author to use for animated videos.

These are the video settings that have been used for all movies that were edited in DivX Author. If knowledge about all options available had been obtained, the outcome of the final movie might have been different in quality. However for the purpose of this presentation movie the quality that has been obtained is satisfactory.

3.4.2 Audio options

If audio is to be attached to the final presentation movie, the movie had to be done first and after that the audio could be included. In the editing window for the movie file that was to be included with sound there is a menu option at the top left corner called “Properties”. In this window there are settings for the audio. See Figure 11 for an image on the properties window.
Figure 11 Properties for the main presentation movie where audio can be included.

Just beneath the small image in Figure 11 the source name of the movie file is displayed. Beneath that the audio stream mode is displayed. In this example; Audio stream 1 only, has been chosen. This means that the movie contains one audio stream defined by Audio 1 but if the settings for the movie require a second audio stream, data from Audio 1 is duplicated to Audio 2 to keep the movie uniform. And the file name on the sound chosen can be seen under the “Audio input 1” option. The format for this music file is showed below the file name.

After the above options have been set, that is required for the audio, the second thing to do is to open the settings for the movie. In the same window as Figure 9 there are menu options at the top, one of which is named audio settings. See Figure 12 for a image on the audio settings available.
As the option for the audio stream has been set to “Audio stream 1 only”, the default value on the audio stream number in Figure 12 is set to “Automatic (Audio 1 only)”. The settings for “Audio 1” are automatically visible from the music file previously chosen in Figure 11.

These are the basic steps to take when audio is included in the movie.

4 Realization

The realization of this Bachelor thesis work has been divided into three major parts. First part has been about a small introduction to the software Process Designer (PD) and Process Simulate (PS) in order to create a working project and to be able to maintain it throughout the movie making process. Second part has been about modelling all object of specification and implementing them into the project created in PD and PS. The third part has been about movie making, including editing the movie into a finished presentation movie.
Between part one and part two there was a small part time goal. This part time goal was to show if a movie could be made from a simulation in PS.

Parallel to making and maintaining a project with models there has been final measurements of the remaining unmeasured objects in the RMS-cell. Parallel to making the movie of the RMS-cell there has been a search for the best suited software for recording and editing of the movie.

4.1 Part time goal

Before the Bachelor thesis work began a limitation was set that a small part time goal was to be fulfilled before any continued work could go on. This part time goal was set to be showed a week into the Bachelor thesis. Included in the part time goal was to make a small movie of a robot simulating a movement, this movie was to be made from the software PS with an external recording software.

The frame and floor of the RMS-cell and the construction that the robot is standing on were modelled in the software NX and imported into Process Designer as JT files, (see more in section 2.5.1). From ABB Sweden homepage the models of the ABB 4400 robot, one ABB manipulator, ABB Drive module and ABB Control system unit were downloaded. The ABB 4400 robot was downloaded as a Robcad file and imported to the cell, the reason why the robot was downloaded this way is because it included the links and kinematics of the robot. The ABB manipulator model was downloaded as a parasolid file and was imported into NX and later exported as a JT file. The reason for a parasolid download of the manipulator is because there was no motions to be attached to the manipulator in the part time goal. The laser tool model, which was provided by Mats Hansson at VAC, was attached to the ABB 4400 robot. For an image on how the placement was done see Figure 13.
A small path was then created in Process Simulate in order to show the movement of the robot. Out of this a very small movie with external recording software, CamStudio, was made. When the part time goal had been approved the rest of the object of specification with priority one attached to it has been modelled in the software NX. Along side the modelling phase all models were imported into PD and PS for the creation of the entire RMS-cell.

4.2 Simulation software

A small introduction for the simulation software Process Designer and Process Simulate was initiated early in the Bachelor thesis work for the purpose to be able to maintain a project. The configuration used was to have two computers running the project with the purpose for both individuals involved in the Bachelor thesis work to learn little bit about the simulation software. These computers were not connected to any database or each other, so the two projects were maintained individually. That meant that when ever a NX-model was ready and had been converted to JT-format, it was imported to both projects on both computers. Eventually, both responsible for the Bachelor thesis work got more familiar with the software and models were imported both into PD and PS. New versions of old models from the list of object specification were imported and the result from this was that one project was more up to date than the other. Solution was to keep only one computer working with the project.

The software PD and PS includes a lot of features that have not been a part of the making of the presentation of the RMS-cell (for a few examples of features see Off-line Programming and 3D CAD Software in section 2.5). The features that have been used are importing and exporting of JT format, exporting of Electronic Bill of
Process (eBOP) project and the use of human models. For more features used, see report of Daniel Mattsson.

A short description will be presented in the context below.

4.2.1 Import of JT format

When importing an object that is a JT file into PD and PS there are a few options to be made for the object to be associated as something within PD and PS, as a structure. For all objects imported from JT format into PD and PS, which were not a device such as a manipulator or a robot, has been set to be associated with a process. One object that has not been on any priority list, is the welding part that is made in PD and associated as a part. The ABB 4400 robot has been set to be associated as a robot and the ABB manipulator is associated as a device. Second option that had to be made was whether or not the object is a tool, robot, device or a general part named PMToolPart. All other objects on the priority list, have been set to be associated as a general part.

A small problem occurred when importing the laser tool as it should have been chosen as a gun but that the tool is an arc welding tool and that the version of the Process Designer that this Bachelor thesis worked with did not support arc welding feature. The workaround on this small problem was to import the laser tool as a general part, PMToolPart and then move the tool centre point frame (TCPF) to the right location in order to have the possibility to visualize movement with a path without having the tool going too deep into the fixture that was placed on the manipulator.

4.2.2 Export of eBOP project

To be able to open the project made, on a different computer the project has to be exported as an eBOP project. The file extension needs to be .ppj and the library folder used in the project needs to have the same path as on the original computer in order for it to work on a different system.

4.2.3 Human models

Human models are the only objects in the cell that have not been modelled. These exist within the PS library and have been brought in through PS. These two models are standing next to the desk with keyboards and screens; see Figure 14 for an image on these two models.
The reason why they are standing is because the kinematics for the human models had a license that was not included in the student license of the software PS at University West. If a license had been available a second viewing option would have been present, to allow the viewer or the movie in this case to get a view through the human models eyes.

4.3 Modelling phase

After the part time goal movie had been approved it was time for the list of object specification to be modelled (In Appendix D). The list contained a total of 38 objects that had a priority one attached to it, out of these 38 objects there were 6 objects that were models that already existed, these were; ABB Drive module and Control module, ABB Robot, ABB Manipulator, Laser welding chamber and Laser tool with cone. All ABB models have been downloaded from ABB homepage with authorization from ABB Sweden. Laser welding chamber and Laser tool with cone has been received from Mats Hansson, employee at VAC in Trollhättan, Sweden.

The rest of the objects on the list were to be modelled in the software NX (see the flowchart in Appendix A). For all large objects such as cabinets and Fibre laser unit a pre measure was made prior the modelling. For not so large objects such as pressure valves for argon gas package as an example, no actual measuring was made but with help of pictures taken from a digital camera as the source of visualization, the design of the particular object were made easier. Picture from digital camera in Figure 15 and the model made from the picture in Figure 16 shows an example of this.
All models have been made with as much detail as possible so that the object in the movie can be recognized from the real cell. Some models are not according to the real model in terms of exact design, as e.g. can be seen in Figure 15 and Figure 16.

4.3.1 Cell structure

The floor and the frame of the cell structure had already been built up for the part time goal movie. To create the entire cell structure, this model was continued on in order to have a pre made model before implementing the models into PD. The cell structure includes floor, beams, walls, roof and door. For an image on the initial cell structure see Figure 17.
This assembly of the cell structure was also used to match some models that were not exactly measured so that when implementing them into PD or PS it would be easy to place the object right from the start. An example on this is the cable holder that runs around the cell parallel to the floor. As the cell was not precisely measured it was really hard to make an easy model of the cable holder which could easily be changed if it was needed or if it is needed in the future. Therefore it was really helpful to have a pre made cell structure where a pre assembly could be made and adjustments to the model could easily be achieved. Picture of real model in Figure 18 and image of the NX model in Figure 19.
One of the purposes for the cable holder to be modelled is to show where the purple cable runs in the cell. The purple cable is the cable that “talks” to the equipment in the cell. All of these purple cables come from the Profibus that resides within the PLC cabinet. One purple cable comes from the Fibre laser unit outside the cell across the roof and through one of the air ventilation holes in the roof. For an overview image of the purple cable running across the roof, see Figure 20.
4.3.2 Modelling methods

The basic method that has been used is to start the modelling with a sketch and additional datum planes where needed. A sketch is similar to a 2D drawing as it works with only two axes, X- and Y axes. The third axes, Z, comes into the model when an extrusion of the sketch is done. An extrusion will make the sketch into a solid. Other features that have been used are subtraction and unite. Subtraction is used to take away unneeded material and unite is used when two solids will become one.

For the visualisation of the objects, a texture was used. Textures consist of an image applied on to a solid in the purpose to give the visualization of the object a more natural look. For instance a brick wall, instead of having a wall only with a red colour on it, a texture will visualize the actual bricks in the wall. For the models that were imported into PD there are no textures. This is because the data format JT does not support textures in the models. So therefore, all objects have been attached with colour instead to visualize the actual colours that are in the real model.

In the upgrade notes for the next version of the planning simulation (Tecnomatix 8.2), there is a notification that the new display engine will be able to provide JT files with texture that has been defined in CAD software [23].
4.3.3 Cable package on robot

When more advanced features had to be modelled, such as the cable package on the robot, a bit different method was used in order to get the cable package as precisely placed on the robot as possible. The whole robot was downloaded as a parasolid from ABB’s homepage and imported into NX as a whole model. By attaching the sketches to the upper part of the robot and by that using the robot geometry in the creation of the cable package made the cable package a lot easier to make. See Figure 21 for a view of an early model of the cable package, presented in NX sketch. The image shows a wireframe of the upper part of the robot where the sketches were attached.

![Figure 21 Early view of the making of the cable package on the ABB robot.](image)

In the real cable package a lot more are attached to it than that was modelled. The most important part of it is the big black box on the top, which is the wire feeder for the metal wire that feeds the laser tool with the wire. The black box can be seen in Figure 22 which shows a picture taken with a digital camera. In Figure 23, an image taken from the software JT2GO on the final model of the cable package, also show the black box on top.
To get the metal wire up to the black box on top of the cable package there is a round black box on the side of the robot which contains the metal wire. This round black box can be seen in Figure 24.

In the final presentation movie the model of the cable package and the model of the round black box will follow the movement that the robot is assigned to do. The black pipe that acts as a rubber tube in the real world, withholds everything that is attached with the laser tool such as metal wire and electrical wires to the laser tool. Figure 25 shows another side of the robot with the black pipe, this image has no laser tool attached.
4.3.4 Modelling of the wall surrounding the cell

All walls that are attached to the actual cell were modelled as single solids to provide easy models for future adjustments. For all walls except the brick wall there is a small list on the lower part of the wall and a metal cover that is reaching half way up. In earlier models these walls were modelled according to what actually was in the cell. The upper part of the wall in the cell has some kind of small structure built into the wall that repeatedly comes back with 200 millimetres in between. See Figure 26, where a small black arrow points on one of these lines.

This small structure caused a bit of a problem when rotating the model in PD and PS. It was showing small glitches of lights where the structure were attached. See Figure 27 for an image taken from NX where the lines can be seen.
It became such a huge design flaw that a remake of the wall was needed. So in the final part, these small structures in the wall are not implemented.

When the cell had all its walls in place and the structure outside the cell were in place another small mistake was discovered. The walls were made as solids and the structure outside of the actual cell was also made partly as solids. When rotating the model in PD or PS the very same small dots of light appeared in between the models. So the outside structure had to be remade in order to minimize the dot of lights in between the solids. The reason why the walls that are surrounding the cell still has small dots of lights is because of the movie making and that the need to blank a certain wall to be able to record from a special angle and for that there need to be one wall per side and not a complete solid surrounding the cell. See Figure 28 that shows an image taken from inside the cell from the presentation movie. The small dots between upper and lower part of the walls can be seen where the black arrows are pointing.
4.3.5 Difference between real cell and 3D model

A lot of differences can be seen in the 3D model in comparison with the real RMS-cell. Example of this is the gate where the difference lies in the shape of the gate while it is moving. The real gate is divided into small pieces and is folded a bit while going up and are straightening out when going down. When making the 3D model of the gate it was easier to make it as a flat and stiff gate that just go up and go down. But for this to be possible, the beam that acts as a holder to the gate had to be lowered 400 millimetres in the 3D model. Otherwise the gate would have gone through the roof when opening it. Another difference that can be seen in the 3D model is that the brick wall is only visualized with dark red colour, this due to that texture in PD and PS can not be visualized, see discussion in section 4.3.2.

4.4 Making of the presentation movie

Before the actual recording of the movie a manuscript of some kind is needed. See Appendix F for a vision that was drawn up and approved by Mattias Ottosson, employee of University West working at PTC.

In order to make the movie all the settings that had been tested before the actual recording, where used. With the external on screen recording software CamStudio (see section 3.1.1), more than 80 recordings where made, each recording being from 10 seconds up to approximately 6 minutes long. All these recordings took up about 20 gigabytes of storage space. The vision of the movie that had been previously drawn up was followed but a problem occurred. To be able to zoom in on an object in order to get a close look at it, much of the cells environment had to be blanked out, made invisible, in order to get a smooth but yet relatively fast motion while zooming. This in itself was not a problem when a zoom was made on a single object, but when the idea that one would stand in the middle of the cell and rotate around to look at everything inside the cell the problem occurred with too slow rotation. When looking
at the playback on such recording it felt as it would take ages to look around the cell. To solve this small problem, recordings were made from above the cell at a distance, giving a kind of perspective view of the cell.

All the rotations and pans have been done by hand with a little help from the software PS where a setting for “Continuous Viewing” could be adjusted in options. Also the quality of the level of details that were to be shown in the cell could be set in the option window. See Figure 29 for the options window in Process Simulate.

Figure 29 shows the setting that was made for in general all movie clips that were recorded. But even though the “Continuous Viewing” had been set to slow, all movie clips that have been recorded experienced some sort of lag. Depending on what was recorded. When panning and rotating the cell during a recording, the graphic card had to calculate a lot of information and that is what is causing the most lag in the movie. When e.g. the robot was moving along its path, the graphic card had only the robot and its movement to calculate as the entire RMS-cell was not moving. This is the main explanation for the lag that is visible in the presentation movie.
4.4.1 DivX Author

With DivX Author the actual movie making started. It was here that the movie came to life with all the recordings made previously and with the vision in mind and to try to follow it as much as possible. A lot of movies had actually been made before getting close to a final movie and a couple of problems occurred during the work that made the process time consuming. When a project in DivX Author is started it must finish at the same computer, meaning that project file, raw format movies and images can not be moved from one computer to another. This due to that the software will not recognize the raw format as it did when the project started. As the build up of the movie continued and the amount of media started to build up extensively the computer provided by the school started to slow down and eventually crash from time to time. This however was solved by switching the computer at school to the computer at home, but since all materials had to be moved all projects were lost and the presentation movie had to be built up again.

The main presentation movie was made in three parts:

- Part one – Intro sequence, both outside and inside the cell and finally some of the main objects including PLC cabinet and the electric cabinet attached to the manipulator.

- Part two – Robot sequence showing the small path that had been created and the opening of the door and gate.

- Part three – Intro sequence run backward, transitions for cooperation partners, people and company that were given a special gratitude and the end screen that showed who had made the presentation movie.

**Part one** that included the intro sequence was made out of images taken from the screen of a build up of the cell, in total there were twenty images in the intro sequence. This was made to show how much that actually was modelled and it was followed by a sequence where the entire cell was rotating. For the first image in the intro sequence see Figure 30 and for the last image see Figure 31.

![Figure 30 First image in the intro sequence](image1)
![Figure 31 Last image in the intro sequence](image2)
On the priority list of the functions in the cell, the opening of the PLC cabinet and a look inside had a priority one attached to it. Since texture was not possible in PS a small walk around had to be made in order to actually have this sequence in the final movie. This was done by taking a image of the final screen where the PLC cabinet was open and in Microsoft Paint cut and paste so that the picture from within the PLC cabinet could be shown, that had been taken previously with a digital camera. To end the sequence a movie clip was brought in to show how the PLC cabinet closed the door. See Figure 32 for an image of the PLC cabinet in an open state and see Figure 33 to see what is inside the PLC cabinet.

![Figure 32 PLC Cabinet in open state](image)

![Figure 33 PLC cabinet with the inside](image)

**Part two** included a small path that was created to visualize how it could look when the robot was in motion. The actual path that was created is very different from the real path that the robot is making when laser welding. But it is for a visualization purpose only and was made so that even if a sequence of frames was taken from a distance the actual movement of the robot and the laser tool still could be seen very clearly.

**Part three** included the very first sequence with the intro build up, but this time it was running backwards as if the cell was about to pack and go home. It also includes a sequence of three images where gratitude towards special people and companies that
have been giving their help, cooperation partners for the RMS-cell and a final image where the names of the moviemaker appear.

The reason why the main movie were created with three parts are because if any sequence had to be changed it would be easier to just change one or two parts instead of making a complete new movie.

Close to the end of the movie making, an alternate sequence was presented. A live feed of the actual real welding, metal deposition (MD), was obtained from Per Thorin at VAC. Still saving the first made movie, but adding this sequence to the part two segment and made a second complete presentation movie with the addition of a MD weld in the middle of the robot sequence.

Near the very end of the Bachelor thesis work, when the movie had been finished, a request came from one of the companies that had provided material for the movie. The request was about the last three images and that the images did not really show the right information regarding the RMS-cell and company information. The end of the presentation movie, part three, had to be changed a bit. Instead of three images showing gratitude towards companies helping with material, the end of the movie will show some information regarding what project RMS is and where to get more information about it. It will also show an image for each company that have provided with material for the movie. The last two images have just been altered to fit in to the new ending of the movie. In total there are now seven images in the final sequence of the movie. To view these images, see Appendix G.

4.4.1.1 Transition in between movie clips
Between each and every one of the movie clips in the three parts there have been transitions added. Transitions are pictures that have been made to fit in between the clips. These transitions have been made in Microsoft Paint and by saving single frames in DivX Author as an image. After each movie clip, a transition of the last frame of that particular movie clip has been saved and added with an effect attached so it would appear as if that movie clip was shrinking into the screen and finally leaving a black screen. After that picture next transition was added as a black screen with white text, made in Microsoft Paint, giving an idea on what next sequence would be about. See Figure 34 for an example on a black screen with white text explaining what the next sequence will be about.
4.4.1.2 Addition of audio

To make the presentation movie a bit more fun to see and to give the opportunity for a non oral presentation the addition of audio could be done. For the movie that was presented at the Bachelor thesis presentation, audio was included, but for main presentation movie no audio has been included. The main reason has to do with
3D modelling of a laser welding cell for movie presentation – Making of the movie

Copyrights. And to find music that had no copyrights and that was long enough seemed rather hard and time consuming to do.

4.4.2 Alternative presentations of the work

For the presentation of the movie a computer is needed that has the right codec installed and a media player that can play back the presentation movie. One such media player is Media Player Classic that is a freeware player which means it is free to use by anyone.

A second alternative to the Media Player Classic is to burn the actual media file onto a CD-ROM and play it in a DivX certified DVD player. A DVD player that is certified for DivX playback will enhance the visualization of the movie and present the movie in a sharper state. However, this will make the upper and the lower part of the movie to appear outside the TV screen since the aspect ratio has been set to 1:1 which means that the movie will be used in a computer display. For this to be an alternative a final editing of the movie has to be done and the aspect ratio must be set to 12:11 for a 4:3 TV ratio in PAL and the size of the picture needs to be set to 720x576. Equally for NTSC TV system, the aspect ratio must be set to 10:11 for a 4:3 TV ratio and the picture size to 720x480 as being recommended in the help assistant in DivX Author.

An alternative to the playback of the presentation movie is to export the entire cell model from within PS to the JT format and then open the entire model in the software JT2GO which is software that will present the entire cell in a 3D environment. Within the JT2GO software, similar commands that also can be found within PS can be used such as zoom in / zoom out and rotation / panning of the entire cell.

A second alternative to the playback of the presentation movie is to export the cell to Virtual Reality Modelling Language (VRML) format. With a plug-in to Internet explorer the cell can be downloadable from anywhere and by anyone with an Internet connection. However, within PD and PS there exist no such tools that can export the cell to a VRML format. This has to be done from NX. Though, a small problem occurred with the particular cell when opening it in NX. By exporting the cell from PS to a JT format and then opening it in NX, it causes the NX software to crash. Rather to search for the cause of the crash, the cell that had been built up in NX was used as a test for exporting to VRML format. This was done successfully, though it did not represent the entire cell due to that the cell built in NX has been used as a tool to match certain objects to the cell in PS.

5 Conclusions

Calibration and measurement of a workcell can be as simple as just explaining it in two sentences. Or complex and totally confusing after reading somewhat 30 articles
that tell about different approaches and views of the same idea or the same problem. Nearly everything that has been read about this subject has left a mark. There are so many factors that need to be considered and of course what one would want and need is an easy way to approach the problem at hand. Due to this a delimitation was made early in the literature study regarding what to study about calibration and measurement techniques.

The basic knowledge that would be needed for finding the best suited software for recording and editing of the movie was not enough when trying to find such software. There is a lot of software that can be used and each has their special settings that have to be learned before any test can be conducted. For recording software, a simple tool was needed and chosen software CamStudio felt as the right to pick. Due to the extensive settings for the editing software chosen DivX Author, delimitation was made that most settings would be default.

Basic knowledge in NX had been freshening up prior to the Bachelor thesis work. This made the modelling phase very smooth. Although it was many objects that were to be modelled, a high level of detail has been maintained throughout the list of object specification.

The offline programming software used, Process Simulate and Process Designer, felt as solid software even though it was an early version used. With good help from teachers and other students the learning process was easy and to maintain a project became acceptable within the time limit.

5.1 Result

With the goals for this Bachelor thesis in mind, the results of this work are as follows:

- Literature studies and studies for best suited moviemaking software

The study shows that calibration and measurement of a robotic welding cell are important in order to get a 3D model and the real model to work together properly. The studies for movie recording software and editing software for the final movie shows that a more thorough investigation of the settings chosen for the software should have had a more aimed concentration. This to avoid downtime e.g. computer system crashes.

- Simulation software – Process Designer and Process Simulate

To be able to maintain a project within the simulation software and to be able to make a movie out of the RMS-cell within the software the result is that enough time was set for this part and a basic knowledge has been achieved. As a perspective on functionality the software worked very well.

- Modelling phase – list of object specification
All objects on the list of object specification that had a priority one and five objects that had a priority two attached to it, have been modelled in the software NX. In addition to models made in NX there was also objects on the list that already had been modelled e.g. robot, manipulator, control module and drive system that were obtained from ABB, and model of the laser tool and chamber that were obtained from VAC. Also a good level of detail has been maintained on all objects that have been modelled for the purpose of recognition.

- Movie making

Large amount of recordings from different views have been made in Process Simulate on the RMS-cell, all with the vision in mind. Through the editing software two different presentation movies have been produced. One in which a metal deposition movie has been implemented as an extra addition to the weld path.

The physical result of this Bachelor thesis work is a DVD containing:

- Presentation movie
- Additional small movies of the RMS-cell
- All NX models and assemblies
- All NX models converted to JT format
- Entire RMS-cell as a eBOP project file for Process Simulate
- Entire RMS-cell as JT format

### 5.2 Recommendation for continued work

To be able to view the movie on any computers, recommendations are to find editing software that can produce a movie with a different format, or to find software in which a conversion can be made to another format than DivX.

In order to have less lag in the presentation movie one recommendation could be to divide the simulation project into smaller projects and attach more kinematics between objects. By doing so, less calculation is needed by the graphic card and therefore also less lag will be produced.

For further use of the 3D model, a calibration between the 3D model and the real RMS-cell is recommended. For this there might have to be a more precise measurement of the objects inside the cell. If so, recommendations are to use a laser measurement system of some kind or a 3D-scanning device. With a laser measurement system the surrounding walls and beams will get a more exact position in the model space and with a 3D-scanning of the cell the detail on the equipment would be increased and the measurement of the equipment would be in the millimetre area.
Reference


3D modelling of a laser welding cell for movie presentation – Making of the movie


A. Flowchart overview of the Bachelor thesis work
B. RMS 2007 Projektkatalog eng

Robotised Metal Building by Melting Wire, RMS, Dnr 2006-00100

The project develops an automatic and flexible method for building metal components directly from a CAD-drawing. The technology is based on robotised laser welding using wire as added material. The energy source is a 6kW fibre laser. The automation is accomplished through an Off-Line-program that creates nominal robot paths using nominal process parameters while a control system uses sensor information for detecting real results and adjusts accordingly on-line so as to fulfil desired performance.

Motivation
Develop an automated laser process for product development, manufacturing and repair direct in metal.

Expected results
Overall: After 3 years be able to build defined geometries in selected materials in a validated automatic process.
Industrial expectations: The automatic process is expected to minimise use of material, increase design and production flexibility, shorten lead times and reduce cost for manufacturing of prototypes and components as well as repair of these. The process is fully automated, uses less energy and gives a higher yield compared to other methods used for building metal directly according to given geometries.
Academic expectations: More scientific knowledge and academic graduation within manufacturing technology through increased knowledge in automation, modelling and control design for a process of high industrial relevance.

Project realization
Pre-studies started during 2005, and the main RMS-project was planned to start April 1 2006, however not approved until at end of June 2006. The RMS-project continues until March 31 2009.

The RMS-project requires a close cooperation between the industry partners and the academy in a number of parallel activities. The pre-studies have emphasized the need of powerful equipment for succeeding to achieve high deposition rates while maintaining good material properties. This is why a new laser (IPG fibre laser of 6kW) and a modern robot with manipulator (ABB with IRC5) will be used in the project. The method is schematically illustrated below.
Process development is performed to assure that the requirements on material integrity and material properties are fulfilled by the RMS-process. During this work a number of sensor data will be stored to facilitate for efficient modelling of static and dynamic behaviour to be used for on-line control algorithms. In parallel to this work Off-Line-programming is developed for the RMS-process and 3D-scanning methods are evaluated.

The system parts like control algorithms, sensors, robot and laser communicate mainly over the Profibus, and the programming environment LabVIEW is used for control and supervision according to the principals in the following figure.

Validation will be performed on components and geometries that are relevant for SAAB Automobile and Volvo Aero respectively. The amount of validation varies due to the requirements from the two companies, and will at least include geometry and material integrity.

**Results and effects so far**

Two pre-studies have been performed within the RMS-project. Their results are mainly

- Promising initial experiments in existing laser equipment by University West at Innovatum
- Proposed industrial solution defining the main project activities
- Identification of needed equipment
- High industrial potential

Further results

- Main activities initiated
- Equipment obtained by and installed at Innovatum
- Good cooperation between industry, suppliers and academy
- Co-location at Innovatum
- A PhD-student employed within the field of automation

**Participating parties and Contact persons**

Innovatum AB, Lillemeet Lindberg, chair of steering group
Volvo Aero, Peter Jonsson, project leader, tel 0520 93833
SAAB Automobile AB, Michael Nordström
Högskolan Väst, Anna-Karin Christiansson
Permanova Lasersystem, Lars-Erik Jansson
Volvo Powertrain through VCE, Jack Samuelsson
UGS Svenska AB, Lars Sveding
COOR Service AB, Jerker Andersson
C. Simple 2D-drawings on the RMS-cell
### D. List of object specification

<table>
<thead>
<tr>
<th>Priority</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fibre Laser unit (outside)</td>
</tr>
<tr>
<td>1</td>
<td>Emergency button on Fibre laser unit</td>
</tr>
<tr>
<td>1</td>
<td>Door</td>
</tr>
<tr>
<td>1</td>
<td>Gate</td>
</tr>
<tr>
<td>1</td>
<td>Cabinet for resetting the cell and robot. (outside)</td>
</tr>
<tr>
<td>1</td>
<td>Table with computers and screens. (outside)</td>
</tr>
<tr>
<td>1</td>
<td>Emergency button outside of door</td>
</tr>
<tr>
<td>1</td>
<td>Sensor Door</td>
</tr>
<tr>
<td>1</td>
<td>Sensor Gate</td>
</tr>
<tr>
<td>1</td>
<td>ABB Drive system (Model already exists)</td>
</tr>
<tr>
<td>1</td>
<td>ABB Control module (Model already exists)</td>
</tr>
<tr>
<td>1</td>
<td>ABB Robot (Model already exists)</td>
</tr>
<tr>
<td>1</td>
<td>ABB Manipulator (Model already exists)</td>
</tr>
<tr>
<td>1</td>
<td>PLC cabinet + 5 lights on the roof of the cabinet.</td>
</tr>
<tr>
<td>1</td>
<td>Emergency buttons in cell (2)</td>
</tr>
<tr>
<td>1</td>
<td>Permanova cabinet in cell. (Cooling holes on the side not important, but box are)</td>
</tr>
<tr>
<td>1</td>
<td>Floor cabinet next to Permanova cabinet</td>
</tr>
<tr>
<td>1</td>
<td>Laser welding chamber (Model already exists)</td>
</tr>
<tr>
<td>1</td>
<td>Laser tool with cone (Model already exists)</td>
</tr>
<tr>
<td>1</td>
<td>Cable attached to the robot (can be shown as boxes)</td>
</tr>
<tr>
<td>1</td>
<td>Cable from robot that goes partly up in hole in roof and partly down to red box on the floor behind the robot.</td>
</tr>
<tr>
<td>1</td>
<td>Electric cabinet manipulator</td>
</tr>
<tr>
<td>1</td>
<td>Big air outlet + pipe that acts like air outlet near floor.</td>
</tr>
<tr>
<td>1</td>
<td>Power Source. Welding power unit that acts as pre-heater.</td>
</tr>
<tr>
<td>1</td>
<td>Sony camera (point to the chamber)</td>
</tr>
<tr>
<td>1</td>
<td>Cable holder down to floor for Sony camera</td>
</tr>
<tr>
<td>1</td>
<td>Pipes for Argon gas package</td>
</tr>
<tr>
<td>1</td>
<td>Cable holder parallel with floor that partly goes around cell.</td>
</tr>
<tr>
<td>1</td>
<td>1 light pillar behind robot</td>
</tr>
<tr>
<td>1</td>
<td>Manoeuvring panel for manipulator</td>
</tr>
<tr>
<td>1</td>
<td>GARO-box 1-part</td>
</tr>
<tr>
<td>1</td>
<td>GARO-box 3-part</td>
</tr>
<tr>
<td>1</td>
<td>Sheet metal on floor that is covering cables behind robot</td>
</tr>
<tr>
<td>1</td>
<td>Pipes for air pressure outlet on brick wall</td>
</tr>
<tr>
<td></td>
<td>Holes in roof that acts as light traps. Air in above door and PLC. Air out where big air outlet is.</td>
</tr>
<tr>
<td>1</td>
<td>Sony handycam on manipulator</td>
</tr>
<tr>
<td>1</td>
<td>Purple cable that is the cable that “speaks” to everything in the cell</td>
</tr>
<tr>
<td>1</td>
<td>Light trap in roof. Make with a bend on top of roof as visualization.</td>
</tr>
<tr>
<td>2</td>
<td>Electric panel to computers (outside)</td>
</tr>
<tr>
<td>2</td>
<td>Cable holder under table for computers (outside)</td>
</tr>
<tr>
<td>2</td>
<td>Light trap to the left of table with computers. (outside)</td>
</tr>
<tr>
<td>2</td>
<td>Computer screen above door (outside)</td>
</tr>
<tr>
<td>2</td>
<td>Cable holder above PLC, Door and Gate</td>
</tr>
<tr>
<td>2</td>
<td>Cable holder to the right of the PLC cabinet</td>
</tr>
<tr>
<td>2</td>
<td>Air outlet pressure pipes on left wall. (Is not in use anymore)</td>
</tr>
<tr>
<td>2</td>
<td>Fan for floor cabinet</td>
</tr>
<tr>
<td>2</td>
<td>Cable attachment for fibre + other cables. 2 on brick wall</td>
</tr>
<tr>
<td>2</td>
<td>Tubes from robot</td>
</tr>
</tbody>
</table>
2 Light switch
   Cables and holders for cables under pipes on brick wall. (Networking socket not important)
3 Inside PLC cabinet.
3 Inside electric cabinet on manipulator.
3 Electric socket above ABB
3 Electric socket next to Permanova cabinet.
### E. List of functions

<table>
<thead>
<tr>
<th>Priority</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Opening of door</td>
</tr>
<tr>
<td>1</td>
<td>Opening of gate</td>
</tr>
<tr>
<td>1</td>
<td>Opening to show inside of PLC cabinet</td>
</tr>
<tr>
<td>3</td>
<td>Visualization of paths of signals</td>
</tr>
<tr>
<td>3</td>
<td>Simulation of welding path</td>
</tr>
<tr>
<td>3</td>
<td>Reorientation of manipulator</td>
</tr>
<tr>
<td>3</td>
<td>Lights on/off</td>
</tr>
<tr>
<td></td>
<td>Button pushing, example light switches and emergency buttons</td>
</tr>
<tr>
<td>3</td>
<td>Visualization of emergency button</td>
</tr>
<tr>
<td>1,5</td>
<td>Worker at Manoeuvring panel</td>
</tr>
<tr>
<td>3</td>
<td>Visualization of camera</td>
</tr>
<tr>
<td>3</td>
<td>Cables</td>
</tr>
<tr>
<td>3</td>
<td>Thread feeder</td>
</tr>
<tr>
<td>2</td>
<td>Lightpillars</td>
</tr>
</tbody>
</table>
F. Vision of the presentation movie

Small introduction by visualizing the small corridor before the gate that leads into the RMS-cell:

- View of Fibrelaser (with emergency button)
- View of computers and screen
- View of box that resets the cell
- Emergency button

The gate opens. A short brake here for an overview of the entire workcell. Overview visualization around the workcell e.g. to the right:

- Sensors for door and gate (possible zoom-in here)
- Emergency button
- Control and Drive module for ABB-robot
- PLC-cabinet (maybe possibility to open and look inside)
- Movement along wall that has the Permanova computer. View on emergency button and the GARO-box (1 part).
- Closer view of Permanova computer.
- Overview of the cabinet that stands next to the Permanova computer on the floor
- Complete overview of brick wall
- Air outlets (all with priority 1)
- Pipes (Gas package)
- Network connectors
- Cables and cable attachments under network connectors
- 1 light pillar
- Box for reset
- GARO-box (3-part)
- Sony Camera that is point towards the chamber.
- Big air outlet hose

Back up a bit and take an overview around robot and manipulator:

- Robot
- Cables on robot (or boxes that will present these)
- Rubber tube from robot, partly up in a hole in the roof and partly to a red box under the cables near brick wall.
- Manipulator
- Chamber
- Laser tool
- Electric cabinet on manipulator
- Sony Handy cam attached to the manipulator (pointing towards the chamber).

Back out a bit, towards the gate. Get an overview of the entire cell. Zoom-in on the chamber where the laser tool is welding a small path.

Zoom-out and back out of the cell. Gate will close.
G. Final ending of the presentation movie

This has been a presentation of the RLMwD cell at Production Technology Centre, Trollhättan Sweden.

RLMwD that is more commonly known as RMS, is a VINNOVA MERA-programme.

For more information, please visit:

www.ptc.hv.se
www.vinnova.se

[RLMwD - Roboticised Laser Metal wire Deposition]
[RMS - Robustöver Metallbyggnad via Smarkning]
A special thanks to the following two companies that have provided with materials for this presentation movie:

**ABB Sweden**

For providing the following models:

ABB 4400 Robot:  
- Parasolid model  
- RobCad model

ABB IRB750A Manipulator:  
- Parasolid model  
- RobCad model
Volvo Aero Corporation

Mats Hansson  - NX model of the laser tool
              - RobCad model of the chamber

Per Thorin   - Metal Deposition movie

A special thanks to:

Mattias Ottosson at University West
- who made this presentation movie possible.
Cooperation Partners Involved in the RMS-project:

VOLVO AERO
UNIVERSITY WEST
INNOVATUM TEKNIKPAR

PERMANOVA Lasersystem ab

COOK SERVICE MANAGEMENT

SIEMENS PLM COMPONENTS

VOLVO

This movie was created by:

Daniel Mattsson
Henri Hansson

Mechatronic Engineering, MR05
University West, 2008
Trollhättan, Sweden