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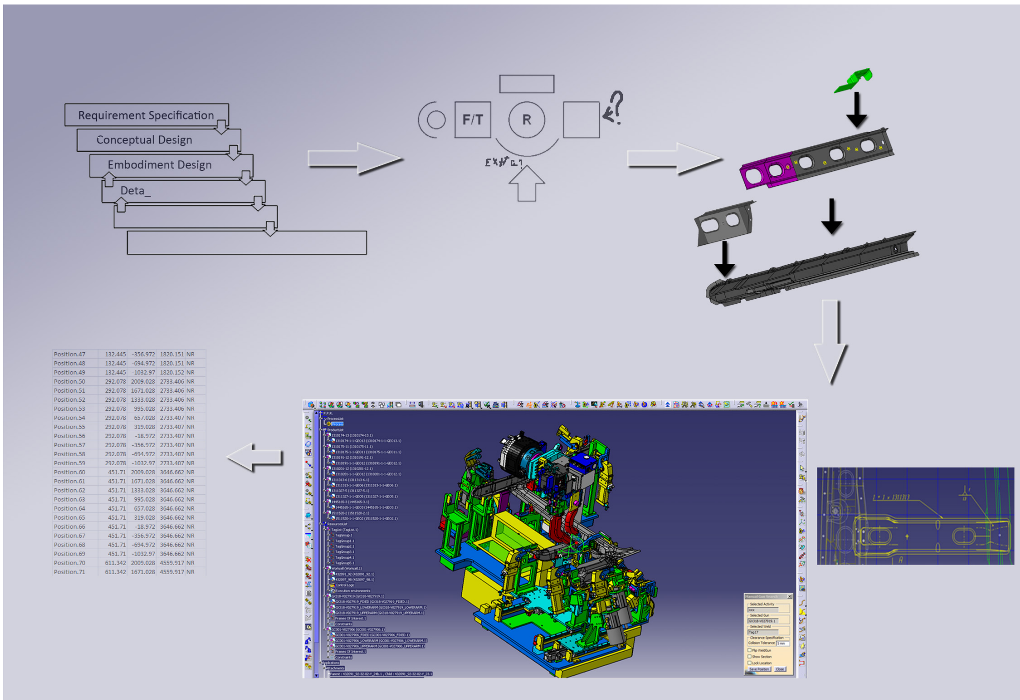

Virtual Preparation of Advanced Production Systems

A Case Study for Body-in-White Industrial Applications

Master of Science Thesis in Production Engineering

EMIL ÅKESSON
Department of Signals and Systems
Division of Automatic Control, Automation and Mechatronics
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2010
Report No. EX096/2010

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Cover: The Cover shows some parts of the tools used in the project as they are being used.

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Göteborg, Sweden, Tuesday 14 December 2010

Abstract

The planning and preparation of production lines have gotten increasingly more advanced in recent times, this is largely due to the heavy influx of virtual manufacturing software getting increasingly more popular. Through simulation and verification of virtual models these programs can help to identify problems and designflaws in any production system or process available. In order to properly use these software it is important to assess that proper methods are used during project planning, data gathering and other parts of project work in order to produce a minimum of wasted time and other undesirables.
This thesis aims to provide a comprehensive analysis of how to best approach a project involving virtual manufacturing. This is achieved by using the experience from a project involving the building of a virtual workcell, based on a real workcell from the Scania© factory in Oskarshamn, from the early production preparation phase to simulating the final result using the software Delmia©. There will also be a detailed explanation of how to utilize the specific Delmia tools utilized during the project. Discussions of a number of suggestions of tools for planning, executing and valuating the project and a final summary of the upsides and downsides of each method will also be performed.

Keywords: Delmia, Virtual manufacturing, Digital factory, VINNOVA, Scania

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Chapter 1

Introduction

Virtual manufacturing programs are decisive tools for a modern industry, their simulation capabilities makes their use a key step in operative production planning processes and allows for greater top level to factory floor planning. They provide means of identifying and analyzing factory plant problems before they are discovered and thereby gives invaluable product life cycle data and solutions. However the present systems of software carries several disadvantages for the user in addition to requiring a substantial investment, these extra expenses includes such things as the fees for licenses and the time it takes to create familiarity with the products.

The disadvantages originates from the wide ranges of activities associated with virtual preparation, in the past these tasks where performed in a number of different programs and by different people depending on what development stage the creation was. This type of system invariably leads to loss of information through poor communication, software incompatibility and manual errors. In order to improve the quality of PLM a new type of system need to be tested according to a predefined set of instructions. The FFI research program has been initiated by the Vinnova branch in order to provide a framework upon which todays automotive industries can base their decisions and increase their figures in responsiveness, knowledge and competitiveness while at the same time preparing for modern environmental concerns. The FFI program is conducted by Vinnova in co-operation with local research institutes and universities as well as leading automotive companies based in Sweden, its focus areas include manufacturing system and manufacturing processes. This project involves cooperation between SCANIA and Dassault systèmes and will involve creating a product specification for an automatic production system and implementing the virtual manufacturing line using the Dassault systèmes PLM software Delmia. It will also aim to provide a better understanding of the Digital factory concept, in particular how the use of virtual simulation and modeling affect the use of information and data gathering.

Implementing digital manufacturing and simulation solutions into a company requires a substantial investment of time and money, Therefore it is important to assess the capabilities of the software before going further with it. In order to research the usability of the Dassault Systèmes PLM software Delmia it will first be tested in a project where it will be used to model a new automated working cell based on a production zone in a factory operated by the Scania AB company in Oskarshamn. There will be very few restrictions in the project, meaning the project workers will have the full capability to decide the structure of the project plan as well as what resources to use, construct and replace and where their placement should be. With the data gotten from the results of the project not only should it be possible to assess the product's usefulness but the information gathered about the way to structure and execute this kind of project should also make it easier for persons to perform similar projects in the future.

Objectives

The main objectives in this project are:

- Provide information about how the use of Digital factory affects the various stages of a project built up from the ground up, more precisely, how does it affect such things as planning, data gathering and project structure, furthermore how can this be improved in future projects.

- To prepare an automated production systems in a virtual environment using Delmia, while optimizing the cycle time to improve capacity, guaranteeing the reachability and preventing collisions. Success will be judged on achieving these results in the desired time frame.

- Provide the means of distributing this knowledge to other people within the Scania company through written text and discussions.

Limitations

The project will not address the following issues:

- No attempts will be made at implementing the model made into a real world environment nor will the model necessarily comply with real world environment restrictions and standards.
- The scope of the project will be limited to one single layout solution rather than going through several variations it

1.1 Report layout

This report aims to give the reader a full scale investigation paper on how to perform a project involving the automation of a production work cell using Dassault Systèmes' Delmia program. The background is the first written part provided, here various organizations and programs relevant to this project are described. After that is the literature review, its purpose is to provide the theoretical background of the technical and managerial tools discussed in further chapters. The report will then discuss the methodology, where a set of planning and preparing methods will be laid out before going deeper into the intricacies that a project dealing with virtual preparation will provide, a case study will be used a foundation for the framework of this text. Necessary information and data collection strategies are analyzed in order to provide a final result for the project. The report ends with the next chapter where conclusions are made from the project results and ideas of further research in this subject are presented.

The report requires that the reader has some knowledge about simulating in a 3D environment though not necessarily with Delmia, the language of the report is constructed in such a way to give the reader knowledge about how Delmia functions and the optimal way of performing set tasks.

Chapter 2

Background information

2.1 Digital factory

Manufacturers have created the phrase digital factory to designate a network of digital models, methodologies, and applications used to integrate the planning and design of manufacturing facilities with the manufacturing process itself. Several large companies such as General Motors and Toyota have made significant progress toward realizing this vision. Using specific types of factories solutions, they have designed and constructed facilities with fewer delays and cost overruns and achieved a faster start of production than was possible using previous methods.

The digital factory concept today focuses on an integrated planning process that includes product design, process planning, and planning of the manufacturing operation. Integration shortens the time and delay between these steps and unites the different planning groups. It offers dedicated tools and makes accurate and up-to-date information available to all of the project team members right at the beginning of the planning phase and throughout operations until the facility is renewed.

2.2 FFI Research Project

FFI (Fordonsstrategisk Forskning och Innovation) is a research program originating from the collaboration between VINNOVA and the automotive industry to research and innovate the development of sustainable production and manufacturing. Its main focus areas include production of automotive vehicles, production lines and vehicle components. The goal of the program is to improve the standards of modern Swedish vehicle manufacturing in order to make it more competitive, effective and innovative, it also focuses on environmental sustainability and ecological management, the program is scheduled to have reached its full potential by 2015. As a part of this program this project is in accordance to everything it stands for.[1]

2.3 Scania AB and Scania Oskarshamn

Scania AB is a leading Swedish based manufacturer of heavy trucks, buses and marine engines. They are currently active in over 100 countries and employs over 35 000 people, of these 2400 is working in the research and development section, most of which are based in Sweden. There are also sales offices in Poland, Czech republic, USA and China while the production is conducted in South America and Europe. Scania's design philosophy is based on their modular approach to vehicle design which allows for greater customizability while at the same time keeping production and spare part costs low.[2]

Their factory in Oskarshamn primarily builds the chassis of Scania's trucks, it has approximately 2000 employees. The factory is divided into four parts, the pressing workshop is where the initial sheet metal is formed into their final shapes, in the coach workshop these parts are conjoined into a framework through welding or otherwise. The painting area is one of the most modern in world and provides excellent finish coating for the chassi, it is followed by the assembly where the final parts are added as well as the interior. Oskarshamn itself is a small town located north of Kalmar on the Swedish east coast, the Scania factory is one of the main employers of the town and as such provides great benefits to the town.[3]

2.4 Dassault Systèmes and software

The Dassault Systèmes company is a world spanning distributor of 3D and PLM software, their specialty is to provide software that digitally defines and simulates products. This provides greater planning of the industrial processes and allows the user to study the entire life cycle of products from concept to maintenance to recycling. Their portfolio include such products as Catia, Solidworks, Enovia and Delmia.

The Delmia program is of central importance to this project and is one of Dassault Systèmes main brands. Other programs related to the project includes Catia, which provides the ability to create models which can easily be adapted in Delmia. This program will be used when creating products that there are no models of presently or when some products need to be modified, it will also be integral in some future planning of the project. The Enovia program, a tool that allows multi-discipline sharing in a single group, will be discussed and evaluated but will not be actually used.

2.4.1 Delmia V5R19

Among companies in today's modern industry virtual processes is steadily achieving more importance, the result is that new expectations on the use of integrating and manufacturing with modern production planning. Higher efficiency, greater accuracy and up to day information are some of the results which can be achieved by using digital manufacturing. The Delmia program created by Dassault Systèmes gives the designer the ability to plan for the creation of manufacturing floor by providing the designer with the tools to plan, create and monitor all stages in its creation without having to pay heavy investments.

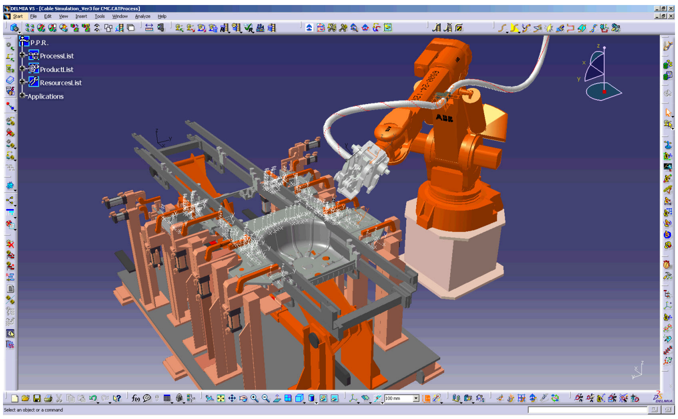


Figure 2.1: *The Delmia graphic interface*

Unlike other software which provides similar services, the Delmia program does not need to divide its functions between several programs as it already posses all the necessary functions that might arise. This means that there is no loss of information or any sort of contact discrepancies as data is passed on. Delmia is an important tool in product life cycle management and by using it to model and simulate the product and production line a company can plan more efficiently and thereby increase the product quality while streamlining the manufacturing of the process.[4] The V5R19 denotes the version and release of Delmia used in this report, for more info on differences between this version and previous versions consult the Delmia V5R19 fact sheet.[5]

Chapter 3

Theoretical framework

In order to assess the framework of the project it is important to first gather information regarding the various resources and structures to set. This will enhance the basis of the report and help to define a set theoretical rules of which to obey in the simulated environment as well as create a plan which will make identifying further steps easier.

3.1 Project Planning

3.1.1 Assembly sequence theory

A product might be made of a large number of complex subassemblies containing from dozens to hundreds of parts. They join to each other at relatively few places. The liaison diagram is a relatively simple tool which allows the designer to visually demonstrate the relationships between certain parts. Mechanical assemblies have for a long time been the staple of manufacturing but research on their composition began only recently, typical products with only a handful of parts may have thousands of assembly sequences, the Liaison diagram have become the canonical network representation of an assembly and other repeating networks. [6]

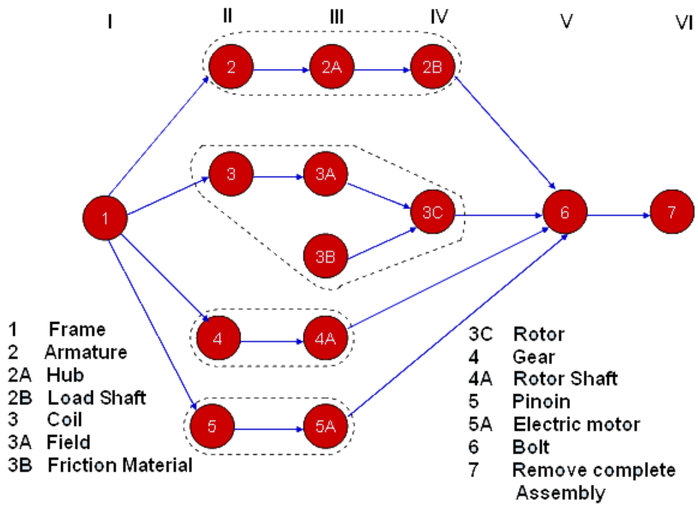


Figure 3.1: *Example of Liaison diagram showing an electric clutch assembly*

3.2 Manufacturing processes

3.2.1 Welding equipment and data

Welding is one of the most common and cheaper types of metal joining techniques. Though there are many types of welding only the spot welding technique will be discussed here due to its usability in the field of robotics and automation. Spot welding functions by creating an electric current through two electrodes into the sheets of material positioned between these electrodes, this generates such heat that it makes the material melt into a slag joining it with the overlapping sheet. The technique is especially effective on carbon steel due to its high electrical resistivity and low thermal conductivity when compared to the copper tips used as electrodes. However there may arise problems with materials that have lower resistivity than copper such as aluminium, these materials will require a higher level of current which may damage the electrodes. The advantages of this type of welding is its high performance speed as well as low thermal distortion, the method is also highly compatible with robot movements making it ideal for this type of process. [7]

3.2.2 Robotics

An industrial robot is defined as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axis(ISO[1]), due to its flexibility it can be used in a number of ways in assembly. A robot can be outfitted with a variety of end effectors, these are tools placed on the tip of the robots arm that allows the robot to perform more varied tasks by switching the tools according to need. Tools include grippers with mechanical and hydraulic mechanics as well as spot welding guns, spray painting guns and rotating spindles. There are a great deal of advantages in using a robot in certain conditions instead of ordinary manual labor, the robot offers a greater repeatability and accuracy making it useful in monotonous tasks. Robots are also a good choice for tasks that would put a human in an hazardous environment or when dealing with products that would be difficult to handle because of their heavy weight. Because of the robots adaptability, especially for welding operations, and its compabilities with a lot of software it would be an ideal tool when creating an automated production cell in a simulated environment. [8]

3.2.3 Programmable Logic Controller

A programmable logic controller (PLC) is an industrial control device used in industries specifically for controlling mechanical devices by means of storing instructions and responding with these when receiving feedback from a number of sensors and actuating parts. The PLC is basically a computer comprised of a CPU, containing its processor and its memory, as well as a system power supply and a Input/Output system. The I/O system receives and sends signals to the specific machine the PLC controls and its auxiliaries, this is often done by a boolean logic design where all the actuators in the interface have two states. [9]

3.2.4 Fixture design

The fixture is the device that fixes the different parts that are to be assembled to their respective positions by performing such functions as supporting, guiding, graduating and more. Fixtures contain a number of components such clamps, vises, chucks or other mechanical devices to hold parts with, a number of sliders to change the structure of the fixture in case there are several variations to the product and sensors. Dedicated fixtures are used for specific unchanging part while modular fixtures can be used when there is need of rapid reconfiguration of production targets making them popular during the world wars when products were constantly changing. The fixture is usually set up to a PLC machine which controls in what order and at what time its devices are to move.[10]

The movable parts of a fixture is commonly operated by a pneumatic system, that is a system of pipelines, control valves, actuators and auxiliary devices which transport compressed air to allow for mechanical movement. The system is dependent on the pressure that it manages to build up in the valves making the pressure drop between generation and consumption of compressed air one of the main considerations when designing the system, especially the width of pipes have to be taken into consideration. Due to its relatively low price and the ease of which to implement it has made pneumatics a popular choice when mechanizing and automating old tasks. [11]

Sensors are usually mounted on a fixture, they are simple tools which detects obstacles in its way and interacts through the use of I/O signals with a PLC. By doing this they can be used to investigate if the product has been set up in the right way or if any safety parameters are being overridden.

Chapter 4

Methodology

As was established previously the purpose of this report is to provide a framework for working with the program Delmia. In order to do this we must ask the question, what are the greatest problems that a newly trained operator of Delmia might come into contact with? This question has several implicit functions, meaning that there is no single answer for every type of problems but rather that most situations will have to be assessed from the operators previous experience as well as complementary documentation and standardized tools. In the text that follows an example of how a project dealing with Delmia dealing with a specific situation should be performed, it will also at times mention alternate methods to operate with and discuss problems that may arise during development in order to give a more complete view of what to expect.

4.1 Requirements Specification

4.1.1 First steps

As the project starts it is assumed that the following equipment is at the readers disposal or is accessible in some way: a licensed version of the DELMIA software, models of all the different items in the intended workcell, data concerning the different items based on their real world performance. In the specific case presented in this report the subject of the project is to reconstruct a workcell from the Scania factory in Oskarshamn. The models that were provided in the case were simple static models with no sets of behaviors implemented yet meaning the data had to be collected from other sources.

It is important to get a good understanding of how the whole work-cell functions from the very start of the project, any documentations regarding the functions and limits of the different systems should be read thoroughly.

4.1.2 Delmia system interaction

Delmia is a sizable program, without prior knowledge it is easy to get lost amongst all the different functions it provides. Therefore it would be wise to first read about its functions and try some practice scenarios before doing any serious work. Unfortunately there is very little documentation to be found about the specifics of Delmia operations, no detailed books or online documents exists as of yet. Fortunately Delmia comes prepackaged with a comprehensive help document which details the various functions of the software tough its structure can be difficult to comprehend for novices. This document will be the primary reference in subsequent part of the report when dealing with Delmia. It is recommended that a beginner tries to read up on the different parts of in the documentation before attempting to implement any functions. The parts that are to be focused on in this report includes some tools from Factory Layout & Robotics and most of the functions in Delmia Automation.

4.1.3 Project planning

As you start getting more familiar with the program and the tools you possess you should be able to assess the amount of work that you may encounter during the project. At this stage you should focus on preparing the project plan of the project, make sure to include a process plan and detail all necessary schedules.

The process of planning assembly engineering incorporates the activities of gathering and organizing customer requirements and system specifications, making explicit representations of them, and making sure that they are valid and accounted for during the course of the design lifecycle of the product. The representation should account for providing a system which provides early identification of conflicting ambiguous and redundant requirements thereby providing a safe foundation of the project. The figure 4.1 show an example of an assembly cell specification, it is the same representation used in the specific project of this report.

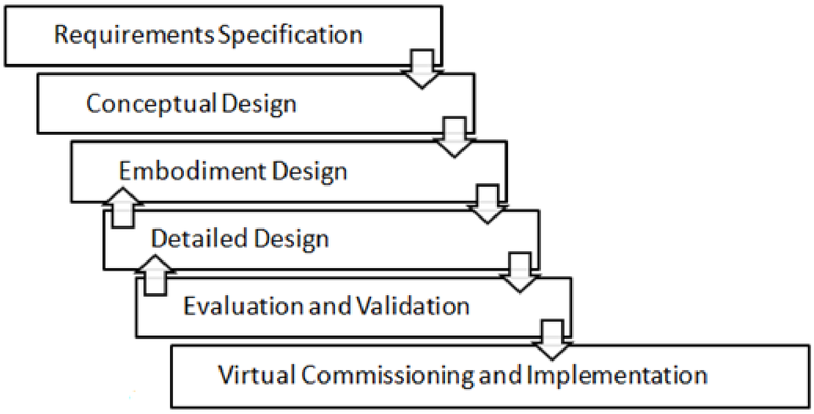


Figure 4.1: *Project process model*

The different stages of the Project process model play a certain role in the project, an arrow leading back to a previous stage means that the stages may be to advanced to perform linearly and may need to be iterated at a later stage.

1. **Project Management**: During the course of the project, the activities will be managed according to its life-cycle. The project will be initiated and planned, it will be executed following the method described and monitored by status reporting and other scheduled activities. At the end, the project will be closed ensuring that the objectives were achieved.

2. **Requirements Specification**: At this stage, the product functional characteristics and the process constraints will be studied in the current station in order to understand the nature of the current operations sequence and therefore the restrictions for defining a new automated sequence. Documentation will be created along this and every other stage of the process.

3. **Conceptual Design**: At this stage, equipment (e.g., robots, tools, fixtures, turntables, etc.) will be selected and/or designed to comply with the requirements specification. Preliminary layout examples will be designed incorporating the chosen equipment. The best alternatives will be selected as conceptual models for several levels of investment.

4. **Embodiment Design**: At this stage, full-scale use of Delmia will begin. It will be assured that there are CAD models for the equipment

selected and/or designed. If necessary the definitive layout will be designed using CAD models of the resources and products in a CAT Product. Delmia's Factory Layout and Robotics module will be used to assemble the station and provide kinematics. From this point, the project process starts to be iterative and it may be possible to come back from later stages to make changes.

5. **Detailed Design**: At this stage, the advantages of using Delmia's data-based system will be seized by designing the interaction of the process/product/resources with the PPR Hub. Device tasks and activities will be defined to plan the process and the system will be optimized according to cycle time using different tools. Control functions for the equipment will be developed and the structure of the data interaction will be analyzed.

6. **Evaluation and Validation**: At this stage, the resulting production system will be simulated and evaluated. Its quality will be assured by collision detection and the result will be validated. As an output, it is expected to provide all information necessary for the implementation of the proposed solution in the actual plant.

7. **Virtual Commissioning**: At this stage, further research will be made to generate solutions for the interaction with the data structures currently in use.

4.1.4 Data processing

In order to progress it is important to properly gather and define data the relevant data, this section will look at what information this project has and how it can be processed.

4.1.4.1 Zone 4b

The manufacturing workcell of zone 4b is dedicated to the assembly of the left door frame of a Scania truck, there are 4 variations of this product named P16, P19, R16 and R19. The workcell include one operator, two welding guns mounted to a traverse above the station, an observation screen, a control panel, a PLC a buffer of parts for the product and two fixtures. The guns are of two different types, one being a C-type and the other being an X-type, this means that the two guns have different cutting design making each one suitable for reaching into specific types geometries with their welding electrodes. The screen allows the operator to observe what variation of the product is supposed to be assembled next, the operator can select this variation with the control panel which is then executed by the PLC. The two fixtures are next to each other, each one belonging to a different station, station 15 for the first fixture and station 25 for the second. Both of them are specially designed to allow the parts to be mounted in a certain way by the operator and both can have a mechanic system based on pneumatics which allows then to control their movable devices. These devices consists of clamps, pins, fasternes and traversing tables. The repositioning are done according to a predetermined order defined in the PLC, this order will change depending on what product variation input is in the control panel.

Once the PLC has started a new product variant the fixture will move its part accordingly, this will allow the operator to place the part into the fixture and then close the clamps of it with the control panel. After each part is secured the operator can use the proper weldgun to weld together the right spots and then open the fixture clamps. The welded parts are then transported to the second fixture where the process is continued in a similar manner until the product is fully assembled.

4.1.4.2 Product assembly sequence

One of the early problems identified in the project was how to decide what how to define the amount of sequences possible in the real world based on the scenario of an automated system. In this case the greatest complication was to define how to decide which order of parts that can be placed without any parts being placed wrongly. Each variation of the door frame consists of 13 original parts, the divisions of these parts into each variation look as follows:

Part#	Rev	Part Name	P16	P19	R16	R19
1310174	13	B-Pillar DOOR STRIKER REINFOR.				
1310175	11	DOOR STRIKER PLATE				
1526159	5	COVER FRONT SIDE MEMBER				
1310191	12	B-PILLAR LH				
1310197	10	C-PILLAR INNER LH				
1310201	12	BODYSIDE LOWER BRACKET LH				
1311357*	16	BRACKET BED SUPPORT*				
1311427	14	COVER B-PILLAR LH				
1311313	6	SIDE MEMBER BELTLINE				
1311327	5	SIDE MEMBER UP LH				
1311331	7	COVER REAR SIDE MEMBER LH				
1447787	4	BRACKET TAB DWG				
1310153	16	SIDE MEMBER UP LH				
1310173	9	BELTLINE SIDE MEMBER				
1311385	7	COVER REAR SIDE MEMBER				
1486520	7	BRACKET LH				
1310151	12	B-PILLAR LH				
1310163	21	C-PILLAR INNER LH				
1310167	12	BODYSIDE LOWER BRACKET LH				
1311417	5	FLOOR SIDE MEMBER OUTER LH				
1511520	2	SIDE MEMBER LH				
1310195	16	FLOOR SIDE MEMBER OU LH				
1310199	12	BODYSIDE SIDE MEMBER LH				
1311325	3	FLOOR SIDE MEMBER OU LH				
1311329	4	SIDE MEBER LH				
1311381	15	COVER B-PILLAR LH				
1501746	7	BRACKET LAMP UPPER BED				
1518113	3	FLOOR MEMEBR SI OU LH				
1798439	4	SIDE MEMBER LH				
1798441	6	COVER PLATE B-PILLAR LH				

Table 4.1: Product part matrix
*This part is already attached to another part when it arrives to the station

However the different parts belonging to different variations can be said to be similar to parts of other variations, often the difference between them consists only of a small variation in measurements. Therefore it can be said that all variations consist of the following types of parts.

Product part ID	Part name
1	BODYSIDE SIDE MEMBER
2	FLOOR SIDE MEMBER LH
3	B-PILLAR DOOR STRIKER REINFORCEMENT
4	BRACKET TAB DWG LH /BRACKET LAMP UPPER BED
5	BODYSIDE LOWER BRACKET LH
6	DOOR STRIKER PLATE
7	B-PILLAR LH
8	SIDE MEMBER UP LH
9	COVER FRONT SIDE MEMBER LH
10	COVER B-PILLAR LH
11	COVER REAR SIDE MEMBER LH
12	C-PILLAR INNER LH
13	BELTLINE SIDE MEMBER

Table 4.2: Part identification

These parts are represented graphically in figure 4.3 using the product P16, the parts of the different variations look slightly different however they should still be recognizable. The other product variations can be viewed in the appendix.

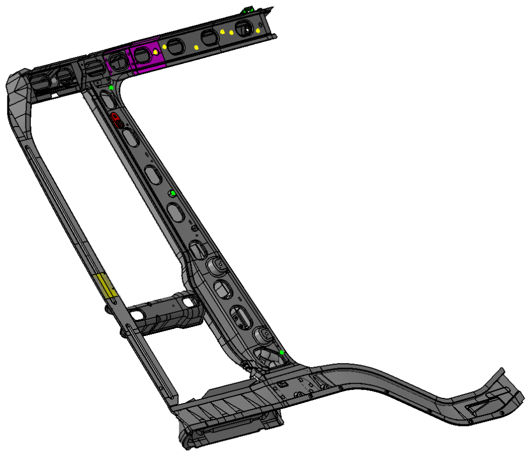


Figure 4.2: *Full product P16*

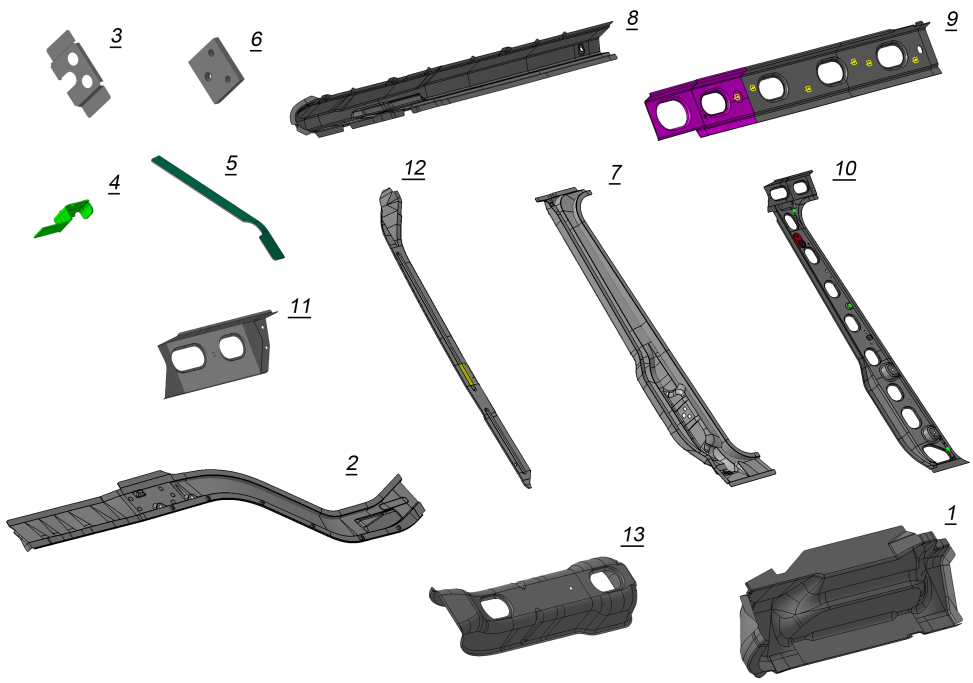


Figure 4.3: *Parts separated from eachother and given the number corresponding to their part (the scale of the parts are not exactly correct relatively to each other)*

Now we know that there are thirteen base parts, at the first of two fixtures 8 of these parts are mounted and conjoined. At the second fixture the large conjoined part is placed and 5 more pieces welded to it. Certain pieces must be mounted before others in order to not interfere with each other. In order to illustrate which pieces go before others we use a simple Liaison diagram, the order of parts is shown in table 4.3 and the Liaison diagram is seen in figure 4.4.

1	2	3	4	
5	6	7	8	
9	10	11	12	13

Table 4.3: Product part composition

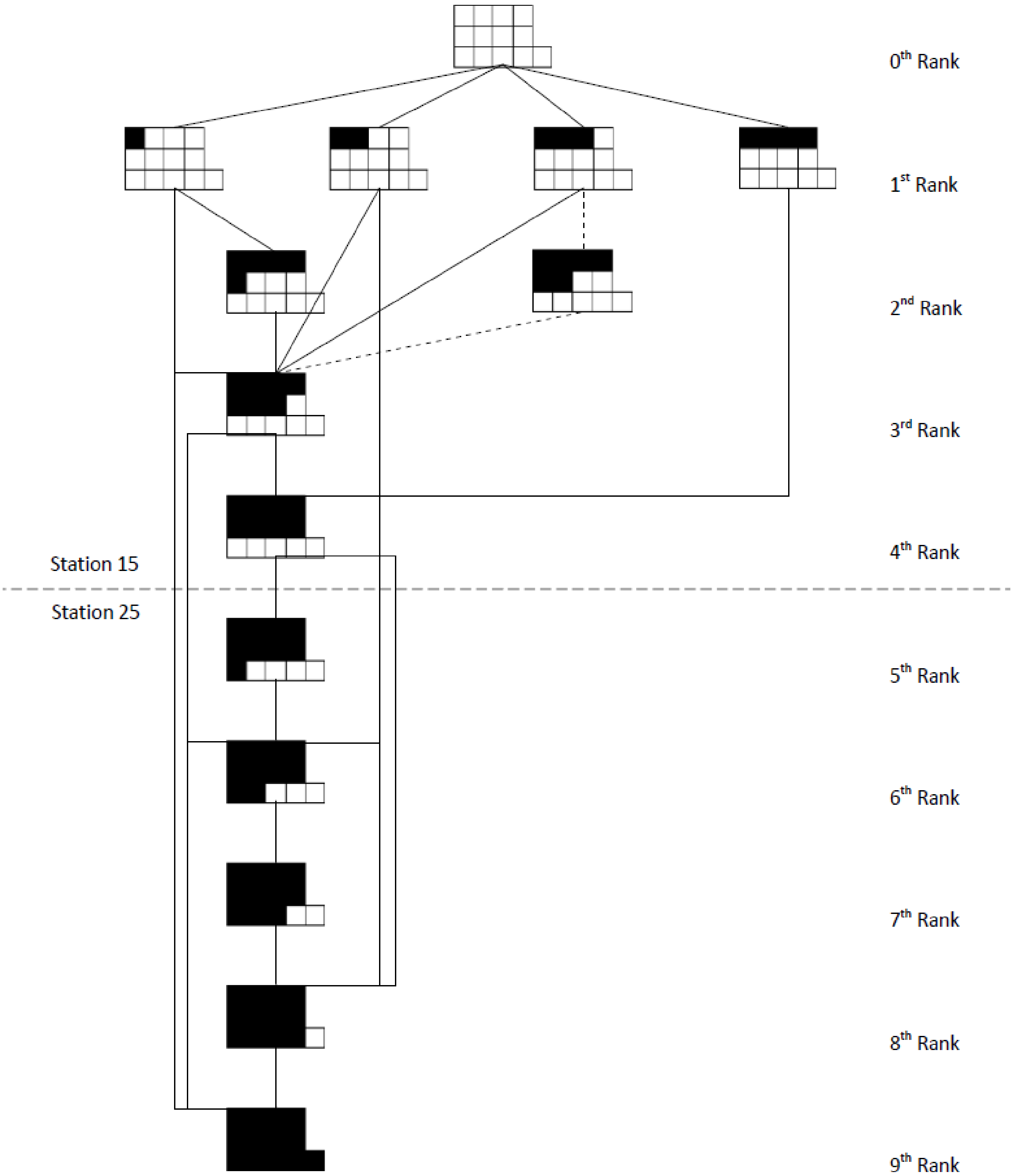


Figure 4.4: *Liaison diagram for the assembly*

4.1.4.3 Mechanism data gathering

A mechanism of a device is one of the earliest parameters to study, it is defined by the axis which it moves in and the part which it moves in relation to, its also important to find out data related to the movement of parts such as their stationary positions, acceleration and speed. Analyzing the model in Delmia will often provide some direction of thought at what parts might be controlled by a mechanism and might even in some cases indicate the different stationary positions by placing the same part in two different positions. As you have gotten more familiar with the different devices and their placement in the model you should investigate alternative resources such as a work instructions of the cell or the PLC configuration which should make identification of movable devices more accessible.

Figure 4.5: *Example of a sheet showing the PLC signals of a specific station for a specific product*

If the model is based on an actual product try to investigate that product in person and document its features with pictures or movies, its especially important at this stage to take into consideration the different positions of movable parts and how they move relative to each other. Finding out correct speed and acceleration can only be done by reading official specifications, however if these variables have relatively negligible impact on cycle time they can be ignored in favor of default configurations.

4.2 Conceptual Design

When dealing with the product specification it is important to consider the impact that different resources and parts contribute. From the table 4.4 we can make some conclusions about the process requirement by looking at how the sequence affected the finished product.

Workcell Elements	Impact on products
Part(s)	Functional
Fixture(s)	Dimensional
Welding guns	Structural
Robot(s)	Cycle time

Table 4.4: *Impact of the automated workcell elements on the product from the operations sequence point of view.*

From table 4.4, it is possible to observe that any radical change on the clamping or welding sequence will affect the quality of the side-frames. For instance, every change done to the clamping sequence should ensure that compliance with tolerances is not affected or changes performed to the welding sequence must ensure that no residual stresses are induced to the work piece. Therefore we can make some assumptions regarding the structure of workcell elements, for example the fixture should not be redesigned because of the inherent performance and the sequence of the part loading should be further examined. All of this will be further examined in the following sections.

4.2.1 Planning Workcell layout

As the station was to be completely automatized the old layout used in the factory was no longer an alternative. By brainstorming a few alternative layouts were constructed.

Figure 4.6a shows a line-shaped layout using an automated gripper very similar to the manual gripper used currently in production carrying the finished product from fixture to fixture , labeled F/T for fixture with turntable, and to the in-feed. Fig 4.6b. shows an alternative T-shaped layout to reduce space and allowing the robot (R) to take the finished product

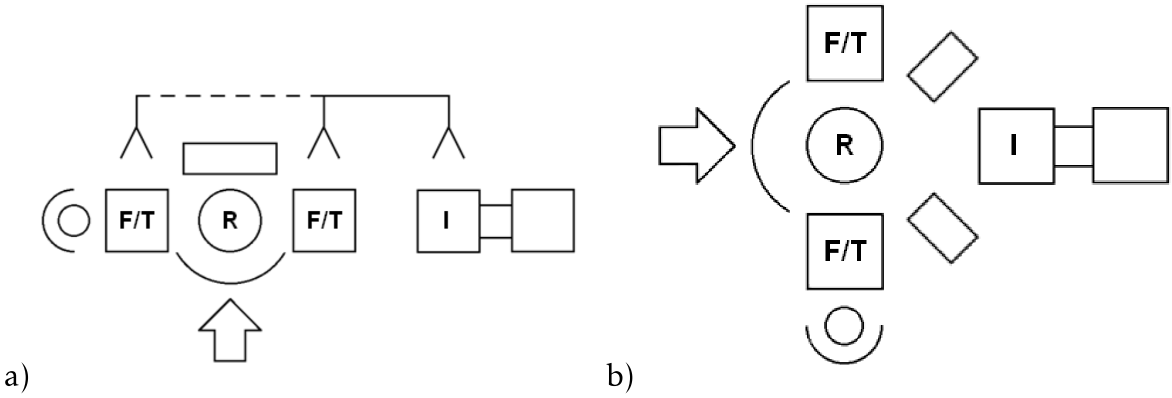


Figure 4.6: *Conceptual model alternatives for a single-robot scenario.*

to the in-feed (I) without the need of the gripper shown at the top of figure 4.6a , however increasing the cycle time because of tool changes. The rectangle areas correspond to the tooling while the arrow and curve indicate the input of parts. In order to improve the cycle time furthermore, a second robot may be placed as shown in Figure 4.7.

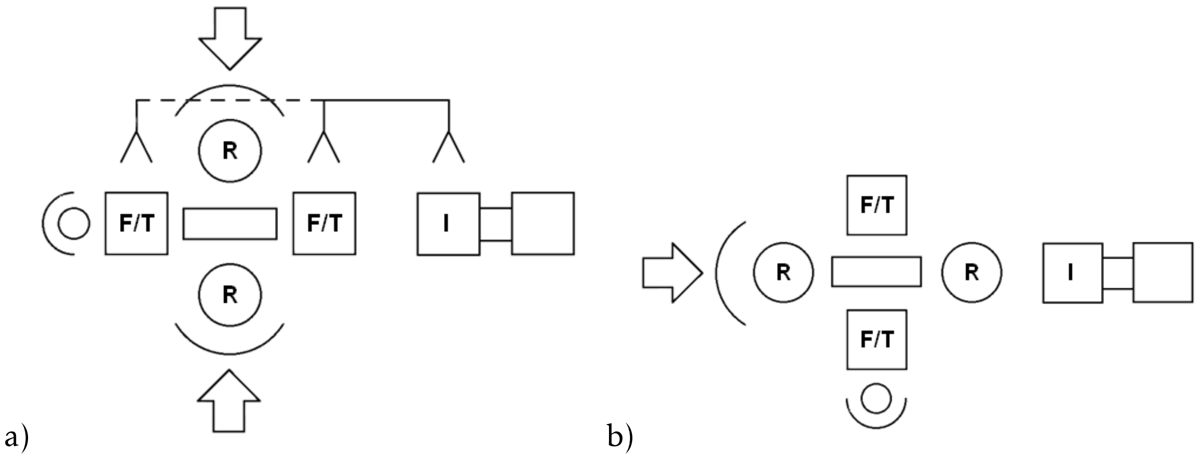


Figure 4.7: *Conceptual model alternatives for a two-robots scenario..*

The use of a second robot in the station would increase the complexity as well as lowering the cycle time. There are also some concerns that this type of setup might require to much space for the station and that safety and clashing risk might be compromised as a result.

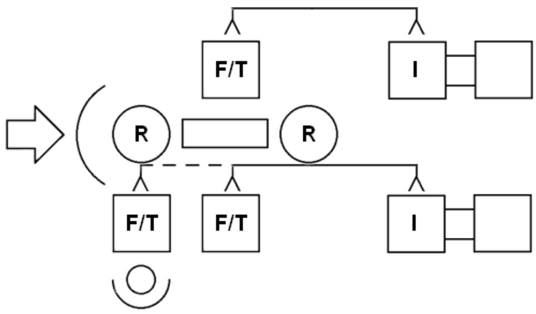


Figure 4.8: *Conceptual model alternative for a three-stations scenario.*

Figure 4.8 shows an alternative vision of how the layout may be structured and and involves a third station that exists today at the Scania Oskarshamn factory. The idea was ultimately scrapped as the project went further.

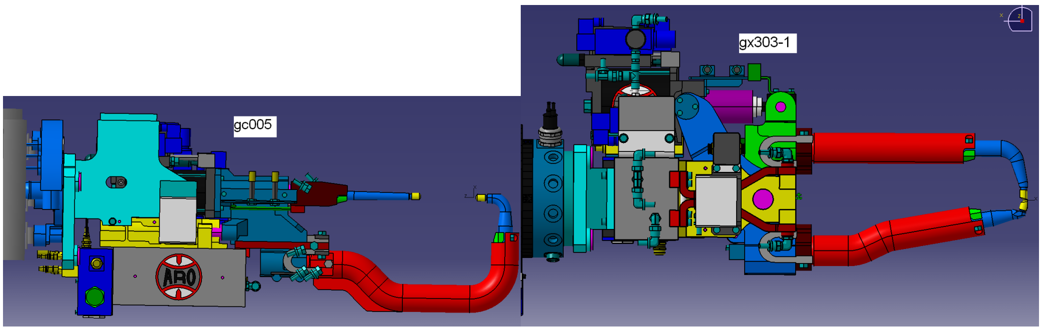
In the end the layout from figure 4.6a was chosen, as the most simple layout it allows for the greatest amount of testing and refinement in a given timeframe while still providing much potential for optimization. It should be noted that the final layout probably will not look exactly as in the layout as the resources will have to be repositioned slightly to allow for greater reachability, this layout in this sense functions like a framework for the very final layout.

4.2.2 Equipment considerations

An automated cell would require additional equipment besides the models that we already received, in the layouts several of these types of equipment can be seen. The simulation of the station would need a number of different devices in order to function properly, what follows is a list of what will be necessary as well as description of the different devices.

1. **Robot for spot welding/arc welding/material handling**: The robot must be of the ABB brand and be able to fulfill the task of welding while properly reaching its target. According to the ABB homepage [12] there are five robots suited for spotwelding, of these only three are usable since only those are available in the model catalog. Further testing based on reachability speed and compability will later be performed to determine the final selection.

2. **Spot welding guns and a Arc welding gun(MIG)**: A number of weld gun models are available to choose from at the beginning, what needs to be done is to decide which of these to use based on their reachability, weight and other parameters. Another interesting dilemma comes from the fact that in the present day there are two types of weld guns employed in the process depending on what parts need to be reached (C type and X type). If only one of these types were needed the cycle time would decrease due to avoidance of tool changing, in further testing this option should be examined further. It is possible that a modification of the fixtures or other parts may allow for this change to be feasible.



(a) C type spot welding gun (b) X type spot welding gun

Figure 4.9: *Examples of both type of welds*

A MIG welding gun will also be necessary to perform a process in station 25, however the relatively small size of the gun should make it much more easy to select.

3. **Fixtures**: One of the planned additions to the fixtures are the turntables, these are mechanic rotators positioned at the bottom of the fixtures. Their purpose is to allow for the fixtures to rotate at command and thereby provide full reachability of the whole fixture without the need of a moving operator or weld robot. Their implementation in the model might not be fully possible as of now since no proper model has been found.

4. **Turntables**: In the current working cell two fixtures are used, the basic idea is that certain parts are welded together in the station 15

fixtures and then moved to the station 25 fixture where the rest of the parts are montaged. Several alternatives to this setup were conceptualized and discussed of which the most prominent one was the idea of a single fixture. However since the workload of the project would increase dramatically if it included a redesigning of fixtures the options were discarded in favor of the original models and two fixture setup. This is not to say there will not be any changes at all, the final fixture design will most likely have some small changes in geometry to accommodate for better reachability as well as some other additions.

5. **HMI**: Since most of the alternative layouts includes an operator there is a need for some type of human machine interface, most likely it will be comprised of a simple button mechanic that is built in Delmia from the ground up.

6. **Tool parking station**: The tool parking station is simply a device where the robot is allowed to put one of its tools (i.e weld gun) when it need to switch them. Many types of these are provided by the manufacturers of the weld gun, meaning they should relatively easy to find.

7. **Part handling system**: The part handling system is supposed to be a system of shelves which will be able to provide the robot to pick up the parts of the product before planting them on the fixture. The specific difference between this system and the one Scania uses today is primarily that these will always place the next part to pick up at the exact same position. This means that the robot can always reach for the same spot to pick up a specific part. Secondly is that they will provide the parts to always be within arms reach of the robot. The first specific can be achieved by the use of a of spring-loaded system and the second one can be achieved by better layout planning. However since this type of tool would need to be constructed from the ground up and therefore necessitates a large time investment it will not be highly prioritized.

8. **Grippers**: Some grippers are needed for the robot to pick up the part of the product, since some parts have small free areas these need to

be delicate enough to accommodate for this.

9. **Fences and other aesthetics**: The station will need to be enclosured in order to minimize the risk of danger to the operator or other persons. It might also need some other visual models to further the realism of the models. This is a low priority for the project since it does not directly affect the simulation.

4.3 Delmia walkthrough

Note: for most of the parts dealing with design in Delmia it will be assumed that the reader is using the Delmia help files as a complementary aid, the help files comes packaged with the Delmia software.

4.3.1 General layout of Delmia

The program Delmia is a part of the Dassault Systèmes program portfolio, the programs of this collection are connected through functions to each other, this places them into a greater system where each one fulfills a specific role. In the figure 4.10 we see an abstract example the structure and how the different programs interact. The three programs in the middle Catia, Delmia and Delmia automation are used for geometry definition, simulation performances and other tasks directly related to virtual manufacturing. In the representation The three programs are blocked on two sides by the program Enovia and its additional program Enovia SmarTeam, these programs relays information of the models between several users and allows changes to be registered directly in between a network of computer. All programs stands on the base of Product Lifecycle Management (PLM) of which it aims to improve.

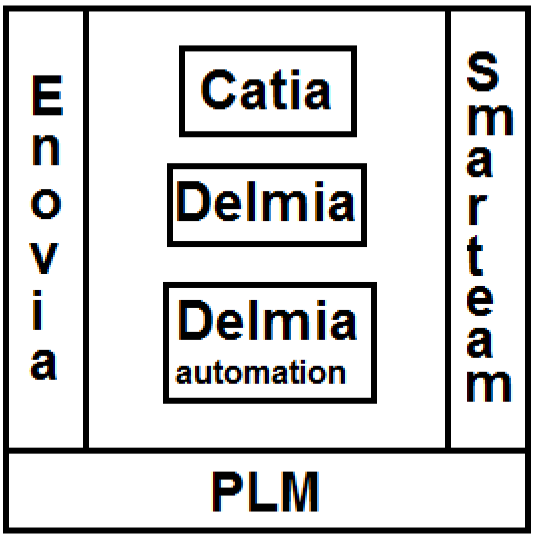


Figure 4.10: *Abstract map of the relationship between Dassault Systèmes' products*

The models of a ”Digital Process for Manufacturing” environment are divided into two types, products and resources, there are also processes used to coordinate tasks between the models. Products are the items that are to be manipulated and worked on in the simulated workcell, in a way they act as a stand in for the input and output of the workcell but with a clearly defined geometry and purpose. The resources are the manipulators, through mechanisms or otherwise, of products, they are commonly associated with specific tasks that they are expected to perform. Robots are one of the most common types of resources but the range of resources are wide and they can include such different things as stationary objects to human models.

A process is a type of sequence set up in order to coordinate the functioning of multiple resources when they work in tandem. By creating activities in the process interface as well as taking other necessary steps any programmable resources can be synchronized and simulated. It is important to consider throughout the project how to properly construct the workcell in order to make it easier to link the resource-centric programming with the more high-level manufacturing process description.

4.3.2 File specifics

Delmia uses a number of unique filename extensions in order to designate their functions in the program and their relations to other types of files. Among these the most relevant to the project are .CATpart, .CATProduct, .CATProcess and .cgr, the CAT text in their name refers to Catia, another software from Dassault systèmes in which these files are also applicable.

A Catpart file contains the basic data of a model including its dimensions, lines, visualization, position etc. This type of file is used as a simple base part which can be put into a directory above it. The CATproduct is used to store several subdirectories such as CATPart files or other CATProduct files. A CATProcess file contains three directories, the process where activities and tasks are stored, Resources where resources in the form of CATproducts are stored and Products where the products in the from of CATproducts are stored.

The cgr extension files lacks any type of set geometrical values for the parts containing only its visual data and data needed for proper simulation. This means that no change can be done the part but at the same time the amount of storage data it uses is vastly smaller. By converting a CATpart file into a cgr file the storage memory it takes may decrease to a tenth the original value, with the consequence that more files are able to fit in a storage and that process simulation becomes smoother. It is preferred to wait with the conversion into cgr files until the model has provided the results expected of it and no more changes are expected on it.

4.3.3 V4 to V5 migration

In order to convert file extensions used in the V4 version of Delmia such as .Model into CATpart extensions used in V5 the function PLMV4toV5Migration is useful. Since the fifth version of Delmia cannot read these types of files properly using this function is necessary to progress. Keep in mind that if that there might be some problems during the migration, clashes between geometries might cause the clashing surfaces to be exempt from the migration and not be part of the resulting CATPart. These types of faults can be solved by fixing the geometry in a V4 version of Delmia or Catia and then migrating them again. To perform a conversion select Tools ¿ Utility and choose PLMV4toV5Migration, from there you decide which models to convert and the specifics of conversion figure 4.11 shows a model in the process.

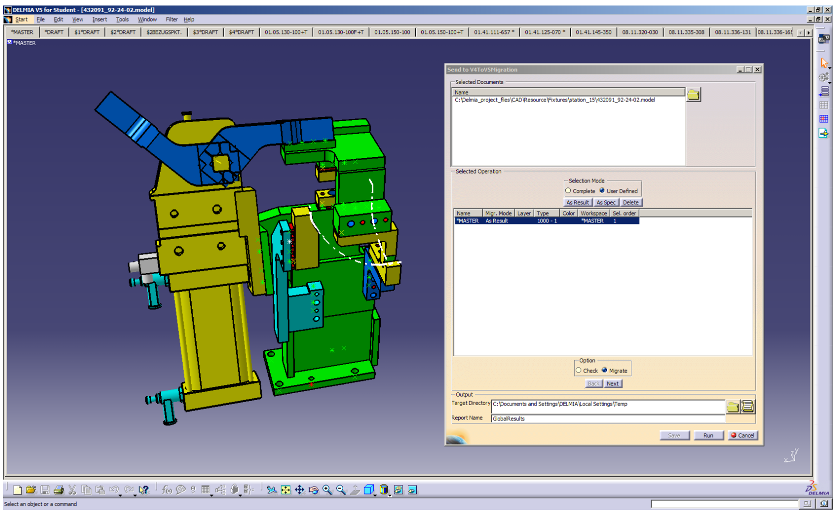


Figure 4.11: *File with a V4 model extension being prepared to migrate to a V5 CATpart extension*

4.3.4 Mechanisms

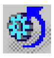
Mechanisms in a simulation environment is defined as systems comprised of rigid bodies (called parts) ability to kinematically move in certain directions, the products of these parts are in the process environment called resources. These type of systems include among other things robotic end effectors, positioning devices, lathes and robots. The goal is generic modeling of forward-kinematic devices that can be driven in joint coordinates and inverse-kinematic devices that can be driven in Cartesian toolpoint coordinates. Creating mechanisms is necessary for proper simulation of positions and movement and should be one of the earliest model sections defined of a simulation model. This section will describe the creation of mechanisms in Delmia by using a step by step structure showing how it is most conveniently performed, additionally the section will also describe the prerequisites and further adjustions critical to the build of the simulation.

4.3.4.1 Device building

In the Device building environment  the tools necessary for defining mechanisms is stored. In the text ahead the different usages of tools will be described with the fixtures of zone 4b used as references to demonstrate how they can be applied. Not all tools and tool functions in Device buildings will be demonstrated if you have any further questions regarding certain functions you should consult the Delmia help manual.

4.3.4.2 Creating joints

The joint command in Delmia creates a direction for the movement for a device and set point from which this movement is based on. There are different types of joints the most basic being of these being the revolute joint, the prismatic joint and the rigid joint, the other types are all based on a variation of combinations of the first two joints mentioned. In order to create a fully functional joint the following portions are required: Two or more products adjacent to each other, a mechanism, a fixed part and (excluding rigid joints) either a a line for each of the products based on the specific point of reference or a frame of reference on each of the products. The first requirement should be achieved by importing the products to be used, the mechanism is created simply by using the "New Mechanism”  tool in the device building toolbar. The third portion can be achieved by using the tool ”Fixed Part”  in the device building toolbar and selecting the product which should be fixed. If there are no lines in the right places on the products it is possible to add them by going to the Part design section of Delmia, however it is usually easier to just add some frames of reference, to create frames first produce some subsections for them in the tree structure by using the tool ”Frames of interest”  in the frames of interest toolbar and then select the product to use. Then create the frame, select ”Frame type”  and choose its position, then do the same thing with the adjacent product, the frames that are to be used for a single joint should be defined in the same spot and the same direction unless you want to move any of the products from its original position.

Now you can define a joint by choosing the correct ”Joint tool” , Revolutionary joint is set as standard when first opening. If you want to use frames of references as definition simply choose ”Joint from axis”  from the kinematic joints sub toolbar instead. After the joint has been defined and assuming everything was done correctly the joint should now work correctly, this means that not only a joint has been created but you should also be able to see in the tree structure that new constraints and a new commands also have been defined. From here you can freely test your mechanism by selecting the tool ”Jog mechanism”  in the Device analysis toolbar, the jog dialog box is pictured in figure 4.12 and is fairly intuitive.

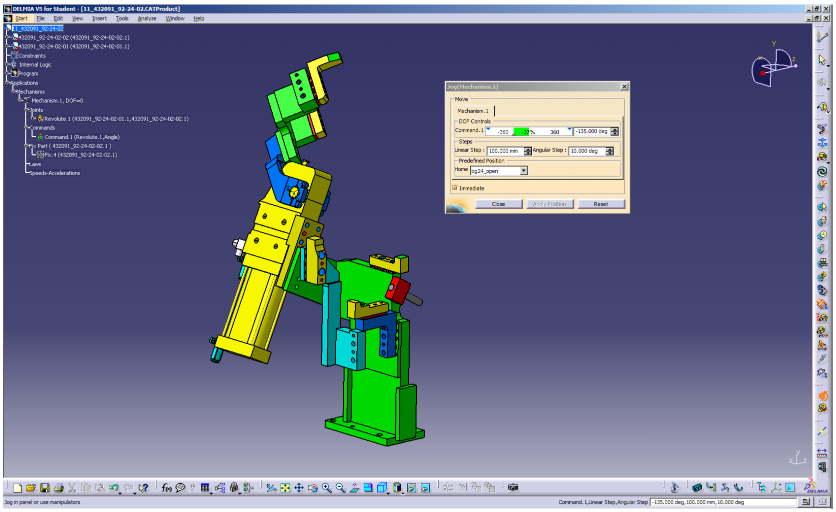


Figure 4.12: *The jog mechanism dialog box in action*

4.3.4.3 Creating home positions

Home positions are the defined set positions for a specific mechanism, these are normally set to the positions where a device is idle or changes direction. To define home position simply choose the "Home position" tool  in the device attributes toolbar, the home positions are defined using the same dialog box as when using Jog mechanism.

4.3.4.4 Creating tasks

Tasks have a number of uses in Delmia and there exist several variations of them, the tasks that appear in Device building are used to define movement between home positions. To create a task use the "Device task" tool  in the device attributes toolbar and from there select the right mechanism and home positions. The figure 4.13 shows how this might look.

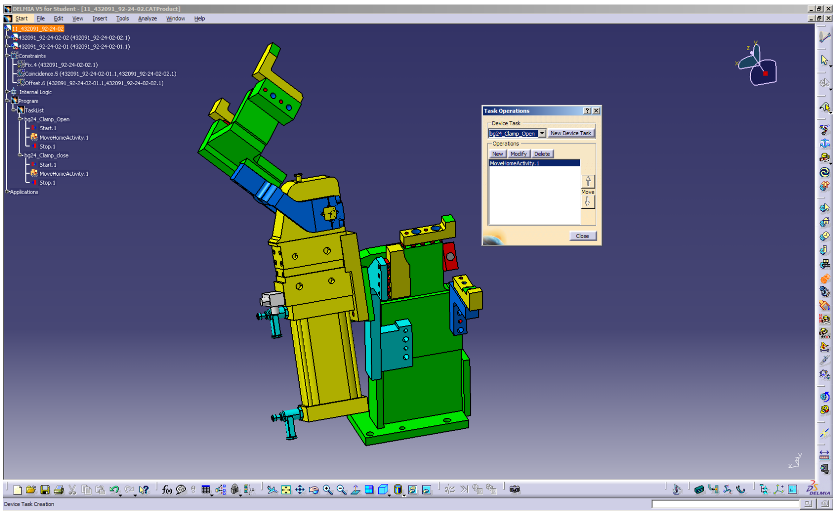


Figure 4.13: *Example of how it would look like when a device task is being defined*

4.3.4.5 Other things to consider

After all this have been done other tools in the device attributes toolbar are still useful, among other things they can be used to change the speed and acceleration of joint movements, alter the boundaries of joint travel and create tool tips. If you need two products to move in tandem with each other during joint movement simply use the tool ”Attach”  from the device attributes toolbar and select a child and parent, remember to select the product from the tree structure and not from the model if it has any child products. Creating more than one mechanism is inadvisable in most cases as two mechanisms can't interact with each other which might create problems if one mechanism has been jogged when the other is activated, if you want two different setups try to create a separate save file instead.

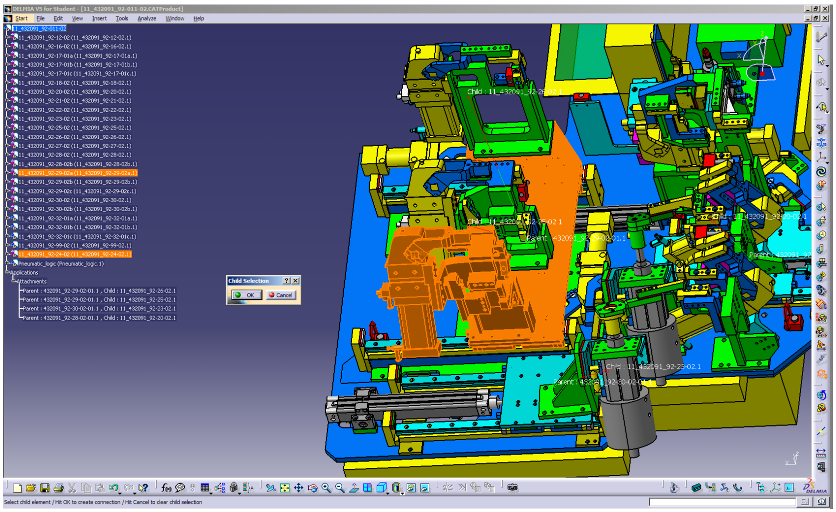


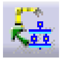
Figure 4.14: *Two products have been attached to each other, the one selected last is the child*

4.3.5 Logic programming

The logic programming allows the user to control behavior of the simulation, when applied to a device it is commonly called the internal logic of that device. By using the different programs operating with Delmia automation it is possible to create a variety of logic behavior which allows us to create internal logic and control logic as well as use predefined logic for creating Human machine interfaces (HMI) such as control panels. These environments include CLM Device Logic design, CSM Module and block editor, HMI Control panel and CLM Device control connection.

4.3.5.1 CLM Device logic design

In this environment is defined the basic internal logic for various devices, a device with a defined internal logic is called a Smart Device. The inputs and outputs (electrical, pneumatic,etc) of these devices are represented by it's ports while the data for the kinematics of the device is stored in the logics block. The language used by Delmia automation is called LCM, it is a part of a family of languages dedicated to describe the behavior of reactionary machines, i.e machines that reacts to input signals given by an external environment. The language is cyclic and is repeated constantly following the same pattern with three stages, first an inactive stage when it is waiting then a reading of inputs and finally a computing of outputs and an update of the system. More information on LCM is in the Delmia help files.

Assuming that you have completed the previous section you should now have a resource with a mechanism and several tasks. Though it is possible to create a functioning internal logic without tasks or even home positions it is not advisable since it requires far more coding and complex behavior. Start by creating the logic by choosing the tool ”Add internal logic”  and then selecting the resource you want to make into a smart device, the type of language used in this case is SFC+ since it is the only one that can manage 3D interactions. A part called internal logic should appear in the tree structure, the second level of this part contains the device’s library which contains a number of functions used in the behavior and a block which is usually named something like IL_Main. A level down in the block reveals four more parts of which the first three consists of the ports which basically handles the I/O of the logic, then the signals which is used to transfer internal signals in the behavior and the instances which are used to communicate between several blocks in the same device. The last one is the behavior, by double clicking on it in the tree structure or using the tool ”Launch behavior editor”  the behavior editor window appears. In this window it is possible to construct the behavior of the smart device, by using the tools in window states, transitions, tasks and other can be called to allow for customization of the behavior. Ports, signals and instances can be created and customized from here as well as from the normal CLM Device logic design window by selecting them in the tree structure. In figure 4.15 we see some ports being defined and in figure 4.16 an example of how a behavior using ports with boolean structure can look. Note: Some of the structure in behavior design has changed from the R18 to the R19 revisions of Delmia, in particular the behavior created by using the tool ”Start task action”  though this should not have any effects on the actual results.

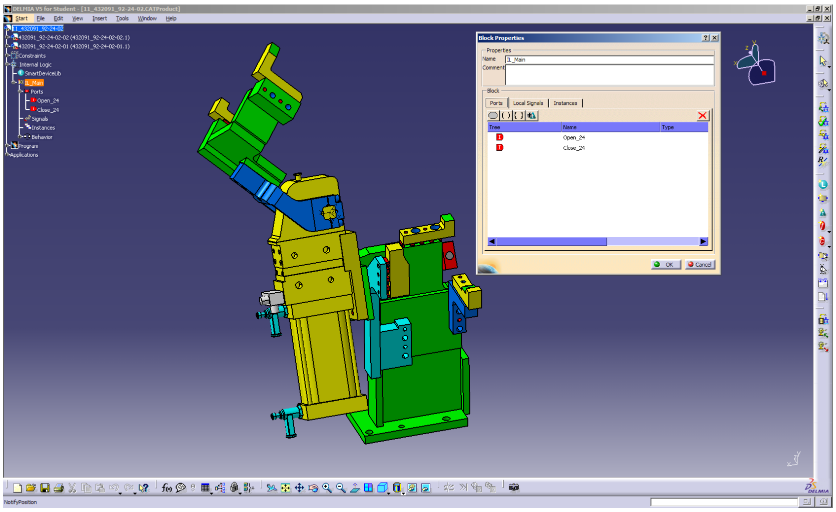


Figure 4.15: *Example of the dialog box where ports are defined*

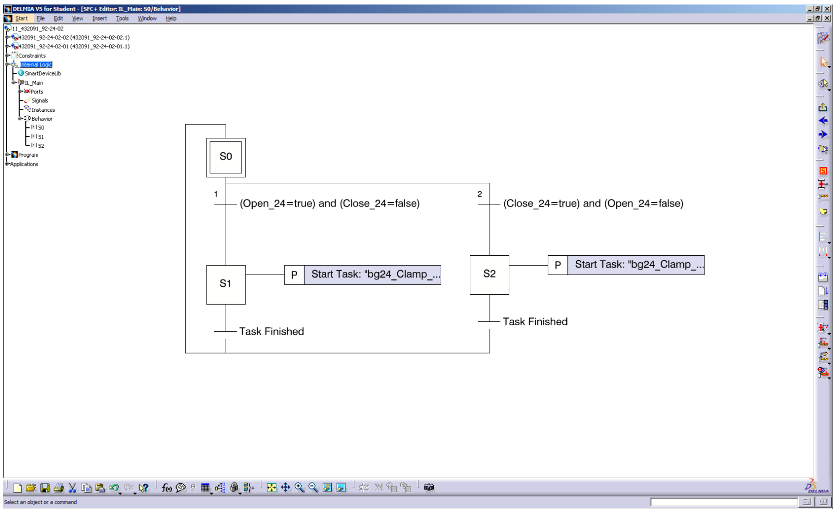
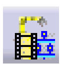
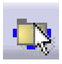


Figure 4.16: *Example of SFC+ programming done in the behavior editor, this particular programming represent the opening and closing of a clamp*

When a behavior with one or more ports used has been constructed and it's build is working it can be simulated by using the tool "Simulate and debug"  in the Simulation toolbar and then selecting the block to simulate. A number of dialog boxes appear including a menu with playback options and a signals monitoring box. Select play to start the simulation, in case the system is waiting for certain signals to register in the port and the smart device does not receive these signals you can change them manually by writing in the field F value (force value) what value you wish a specific port to have.

There are several other tools that can be used in this program, the tool ”Wizard”  in the Device logic design toolbar can be used to combine several smart devices into a smart cell of devices with their own internal logic assuming all these devices are part of the same product. This is useful when you have a number of devices which communicates with each other directly or indirectly and you want them to act as one unit. When you have a smart cell it becomes important to being able to structure settings in the block structure, A device’s block structure can be edited by clicking on the block in the tree structure or selecting the tool ”Launch block editor”  and then the desired block. This brings up the block editor in which the various blocks of the devices are stored within the cell block, the connections to the port are structured from here meaning that you can connect to signals from beyond the cell as well as make devices interact with each other within the cell.

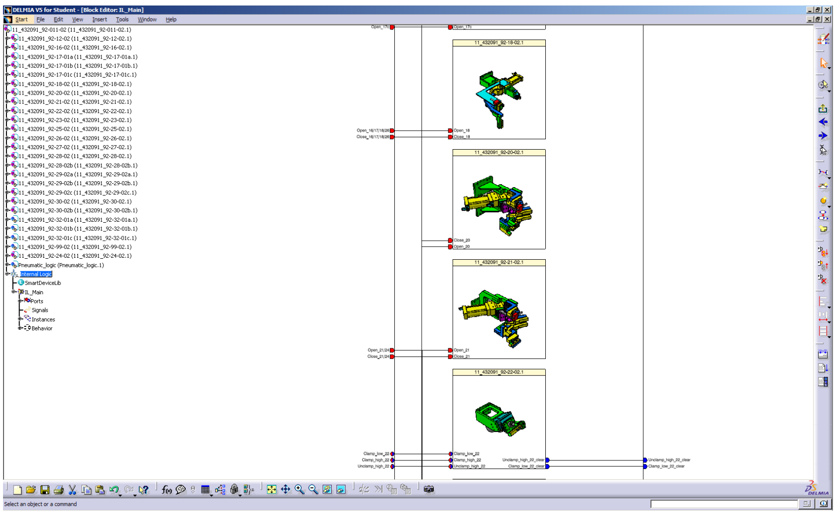
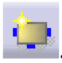
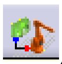


Figure 4.17: *Example of how a section in a block structure might look like after a smart cell has been created*

4.3.5.2 CSM Module and block editor

The CSM Module and block editor is used to create the control logic, the control logic is used to validate the control of the internal logic. Its function is to assume the act of a virtual PLC in Delmia, the responsibilities it has includes the creation of the logic and I/O:s for the whole system rather than for a single part as well as defining a behavior for the function of the system. The control logic uses the same type of structure as any other logic in Delmia so interaction available should be familiar. To create a control module with a block first use the ”New module” tool  and then the ”New block” tool .

4.3.5.3 CLM Device control connection

The CLM Device control connection is where the Execution Environment (EE) is created, this basically is the part where you connect the control logic together with the smart devices. It is also possible to create a control in the environment however this has some disadvantages compared to a separate control logic. Create a new execution environment by running ”Add execution environment”  and selecting the base resource, by now this resource should include the whole workcell. The EE dialog box appears, it's inputs are intuitive so no special instructions are needed to figure out how to add devices and new controls. However if you want to use an already defined control logic you need to click on the block of the control logic to be used in the tree structure and it should appear, if it doesn't restart the dialog box and try again. After the execution environment has been created it can be edited by using the clicking ”Open connection editor” , as described the editor is opened and now the connections can be mapped in similar way to how it was done in the block editor. The figure 4.18 shows the EE of the fixture from station 15, a control panel and one of the blocks of the control module. When the correct connections has been established the whole system can then be simulated using ”Execute simulation” , these simulation controls are almost identical to the equivalent ones for the internal logic and therefore easy to learn.

In all of the Delmia automation environments the programming can be exported as an XML file in order to analyze it in another program. In CLM Device control connection this is done by right clicking the execu-

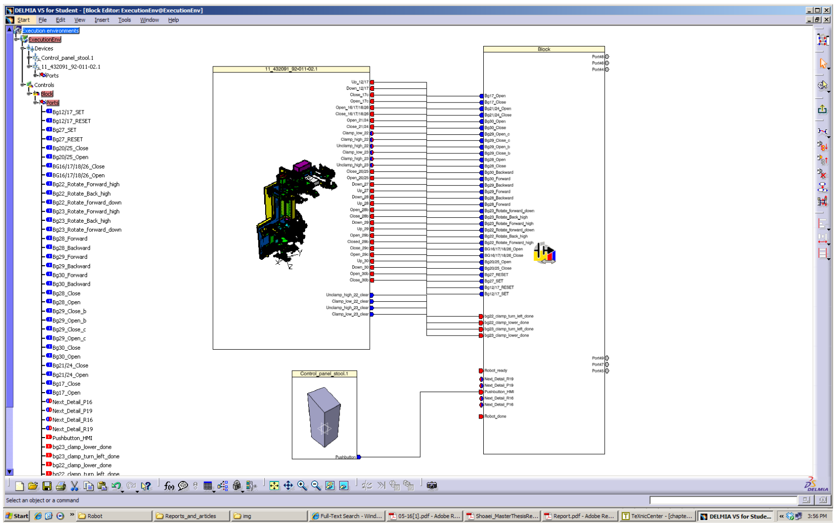


Figure 4.18: *Picture is showing the interaction between two resources, a fixture and a control panel, to a control logic block*

tion environment node in the product tree and choosing "Import/Export Mapping" in the context menu.

4.3.5.4 HMI Control panel

This editor is specifically programmed for creating a certain type of control panel. What it focuses on is creating a separate panel with control devices attached able to be manipulated by the Delmia user, it will manifest as a separate dialog box during simulation of the logic connected to it. The usage of the editor is intuitive and straightforward however the predefined logic it is using uses complicated programming which should not be changed directly by an inexperienced user. If the aim is not to create a control panel controlled through a separate dialog box it would be wiser to create a smart device with manipulable inputs, the HMI Control panel has a very small amount of alternatives in this field.

4.3.6 Process configuration

The process environment provides the means of process and resource definition and offers Delmia's abilities in vertical process planning and simulation applications. Through the use of such tools as Digital Process for Manufacturing (DPM) and device task definition it provides core functions to create, visualize, and verify manufacturing processes, as well as the tools to provide robot feasibility studies. The data can be visualized and processed through a number of different viewers such as the PPM tree, the PERT chart view, the Gantt chart view and the 3D inventory.

This part of the project only deals with the process environment in its basic stages of which some will be detailed in the sections that follows. However much discussion has revolved around how to combine the functioning simulation based on the CLM device logic design and the process environment, there are some information which suggest that communication between these two stages requires some additional

4.3.6.1 Selection of weld gun

Initially there were 19 different options of weldguns to choose amongst all provided by the supplier ARO technologies [13]. Additionally there were several options regarding the structure of the welding layout, namely the options were the choice of using a single type of weldgun to perform all weld spots or using two types of welds, a C-type and a X-type, which each would be able to reach different welds. After some testing it was decided that the first alternative was not feasible due to reachability problems and it was discarded, now two welds needed to be chosen from the initial 19. Several weld guns were disregarded immediately by observation alone, their large frame would make reaching difficult especially in such a small station as this one. An automatic weld gun feasibility study was performed for the rest of the welds, the tool from Delmia was used in this case, basically it works by first defining tags at every weld spot and then using the tool "weld gun collision check"  in Device task definition. This allow for closer inspection of the weld gun's reach in narrow places, by process of elimination eventually welds are selected, the GC001 for the C-gun and the GX318 for the X-gun.

4.3.6.2 Robot analysis

In order to choose the robot several criteria where taken into consideration, the most important ones being reachability and payload limit. As was established previously 5 possible ABB robots are taken into consideration, after deciding what type of weld guns to use a collision detection study was performed from which the most flexible robot that could carry the weight was chosen, the IRB 6620.

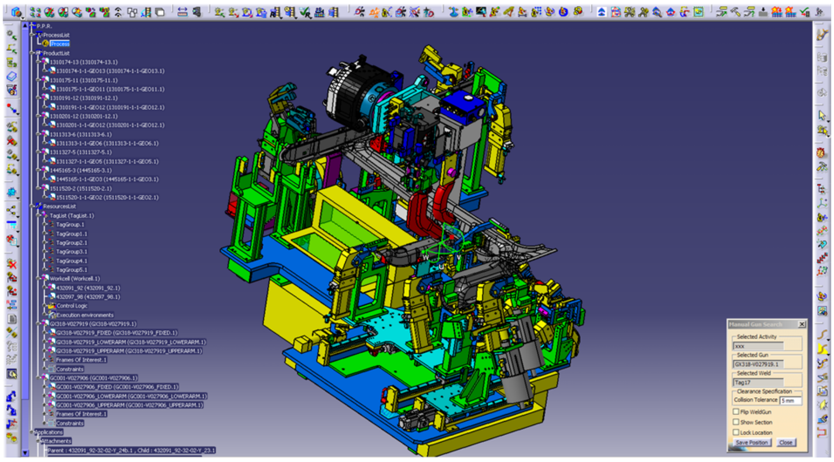
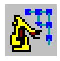


Figure 4.19: *Using the manual "weld gun collision check" tool*

However even with a defined robot there is still the question of where to place it, though the robot already has a loosely based position in the final layout an slightly altered position may allow for greater reachability and provide faster movement. In order to select a target one of the weld guns is first mounted onto the robot then the tool "Auto place robot"  is used, This action will use a grid in order to automatically compute the possible locations for placing a robot that must reach specific points. After selecting the robot and using the tag groups as reference the software will ask the user to define a grid, inside this grid will be defined a number of points which acts as possible placement positions for the robot. The software will compute the robots reachability for every point and define if the position is feasible for for the robot. the specific outputs command it uses are OL: out of limit, FR: fully reachable, PR: Partially reachable, C: clash NR: not reachable, NC: not computed. By using this tool for all possible tags an optimal position should be achieved. The figure 8 from the appendix shows an example of the result from a testing of the tool and figure 4.20 shows the grid.

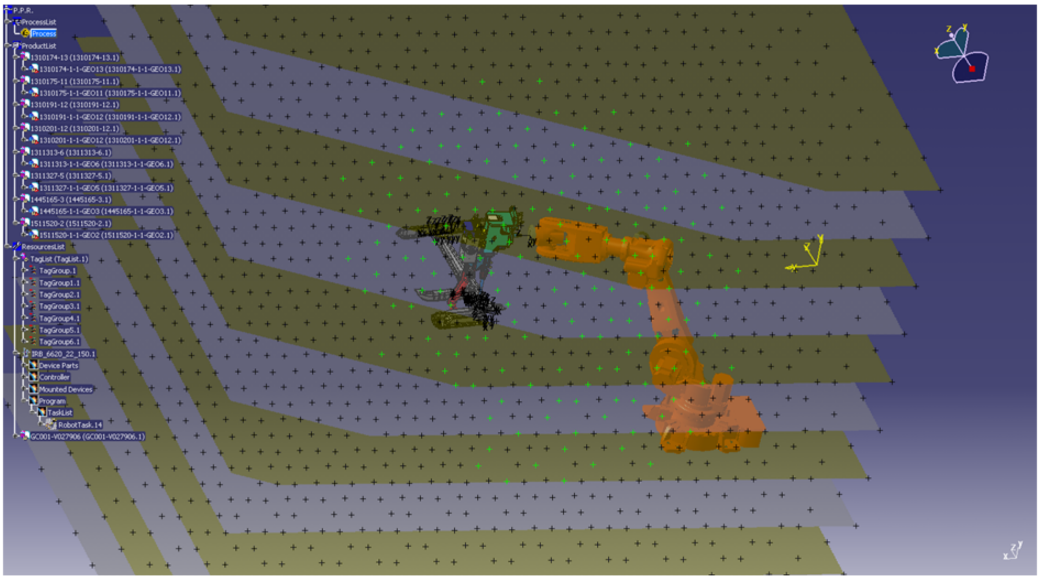


Figure 4.20: *Using the "Auto place robot" grid*

4.4 Embodiment Design

4.4.1 Model realization

Due to the time limits of the project several of the planned stages had to be omitted from the final design, the final stages of the project will most likely be performed by another group. What was of specific interest in this part of the project was the automatization of the fixture as well as the calibration of the robot movement. During the course of the project many choices were made regarding the specific behavior of the fixture, the main ambition was to create a system which would behave as realistically as possible, this was held to the criteria of time, movement, position and accuracy. In practice this meant that the position of the various clamps and other movable objects were based on information that had been collected during the data gathering period.

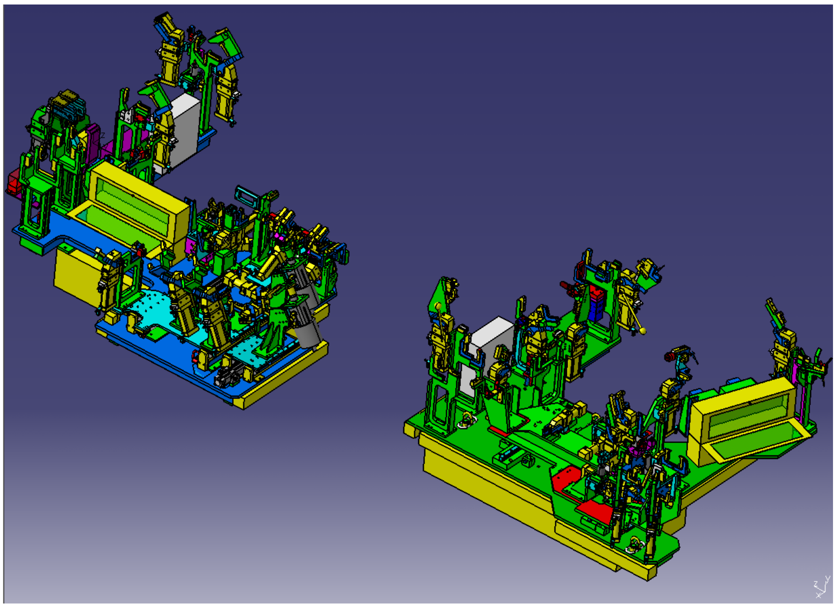


Figure 4.21: *Fixtures of station 15 (L) and 25 (R)*

At times the decisions were made not to follow reality precisely, an example of this is the movement of the clamps and other mechanical fixture parts in relation to each other. In the actual workstation the clamps of the fixtures are mechanically manipulated through the use of pneumatic pipes, since the pressurized air only can travel through one ventilation at a time this causes the clamps to move at different times. However when applied to Delmia the clamps always move at exactly the same time making their movement inconsistent with reality. In order to fix this problem a subroutine would have to be made for the original coding, possibly through the use of an external software, since this would increase the workload of the project while at the same time not providing any specific advantages to the simulation except making it looks nice the prospect of the subroutine was abandoned.

A problem that arose during the development of the functions was that incorrectly defined dimensions in the original model caused the final model used in Delmia to lose some of its geometries. This was the case when the V4 to V5 migration took place, some geometries that clashed with each other in the V4 model disappeared in the V5 model. However since the geometries that disappeared were not especially important this problem was ignored after some consideration.

The fixtures were generally built up in the same manner as have been explained in previous section of the report, they have fully functional mechanics, home positions and device logic design.

4.4.2 Simulation performance

The simulation of the fixture follows a simple sequence based on the planned order of the workstation. The figure 4.22 depicts a flowchart detailing the planned worklow that a future simulation is to be based on. The square actions represent the fixtures and the ellipses represent other resources. However the simulation described in the chart has not yet been completed due to time constraints, what has been focused on is the creation of a working fixture simulation whose actions can be seen in the picture after the flowchart. This simulation has no internal problems and deliver an accurate imitation of real life movements, its possible the speed of the moving parts might have to be adjusted for better accuracy since its difficult to estimate at this point. What it lacks is the interaction between other resources, its output signals goes unanswered since no other simulated part are complete yet and therefore it is reliant on manual output. The I/O signals between resources should be fairly effortless once these are complete. No reliable data can be gathered at this moment, the project will have to continue if it is to have any viewable results.

In the following figures are shown various results of the work done so far, the figure 4.23 shows the different stages of of the station 15 fixture as it being used to assemble the product R19. The product is only there to show how it would be fastened its assembling sequence has not yet been finished, the fixture is fully simulated at this stage. Figures 4.24 and 4.25 show an example of how the final layout might appear. The tables 4.5 and 4.6 shows the various positions of the fixtures devices.

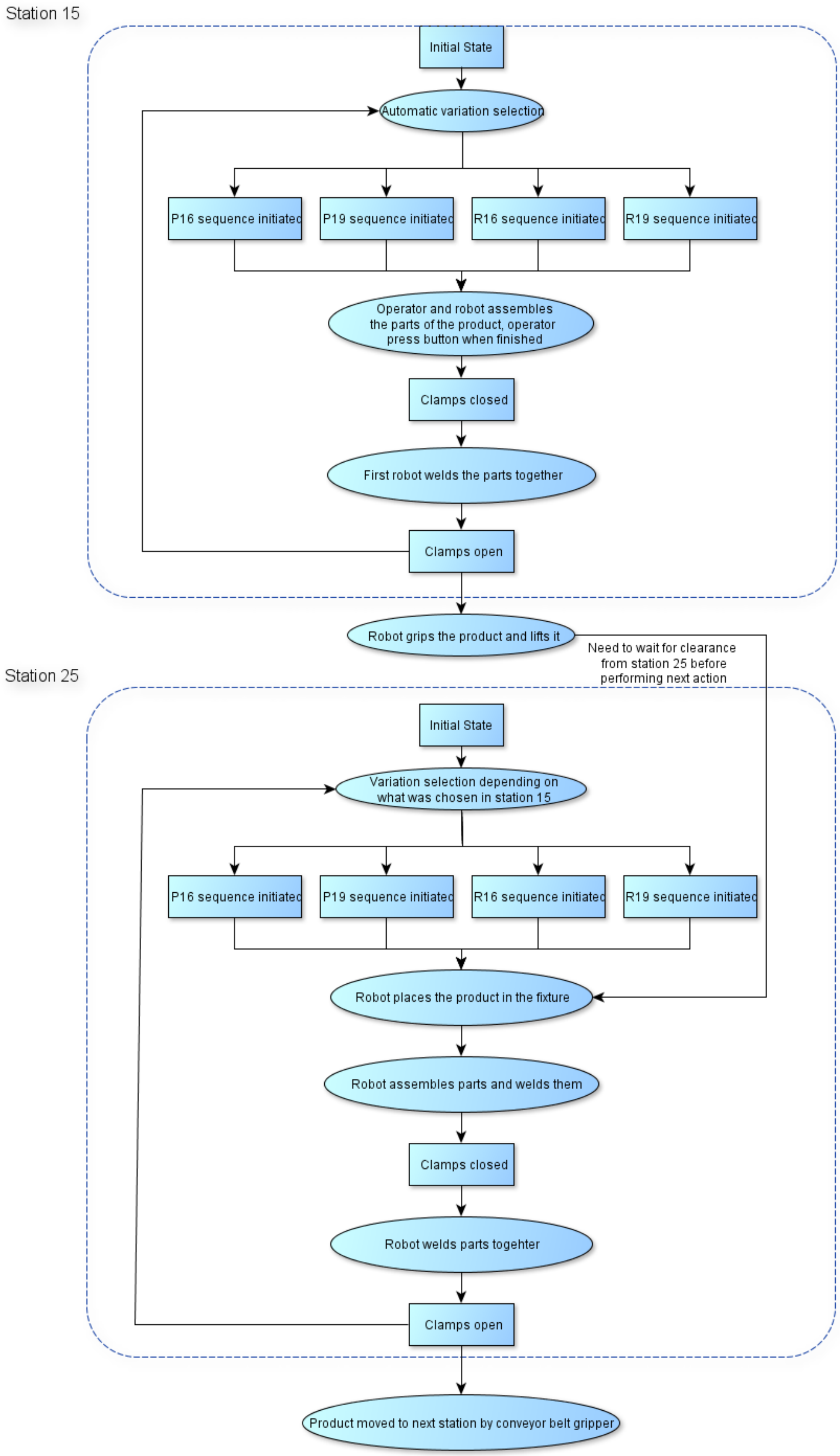


Figure 4.22: *Flowchart of the planned station work flow*

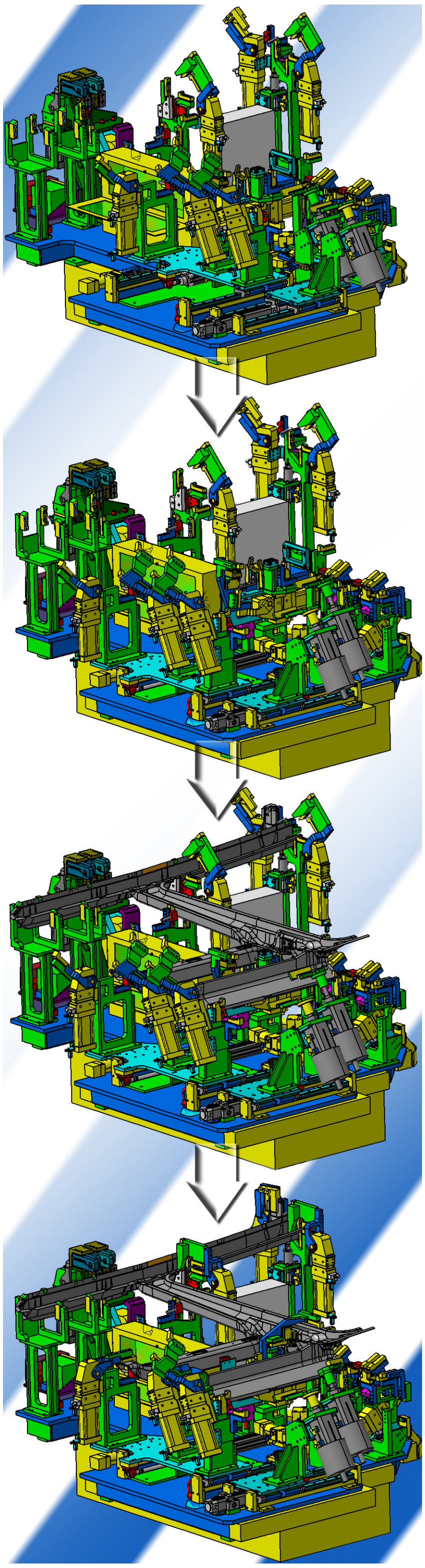


Figure 4.23: *Simulated sequences of the fixture at station 15, P19 product*

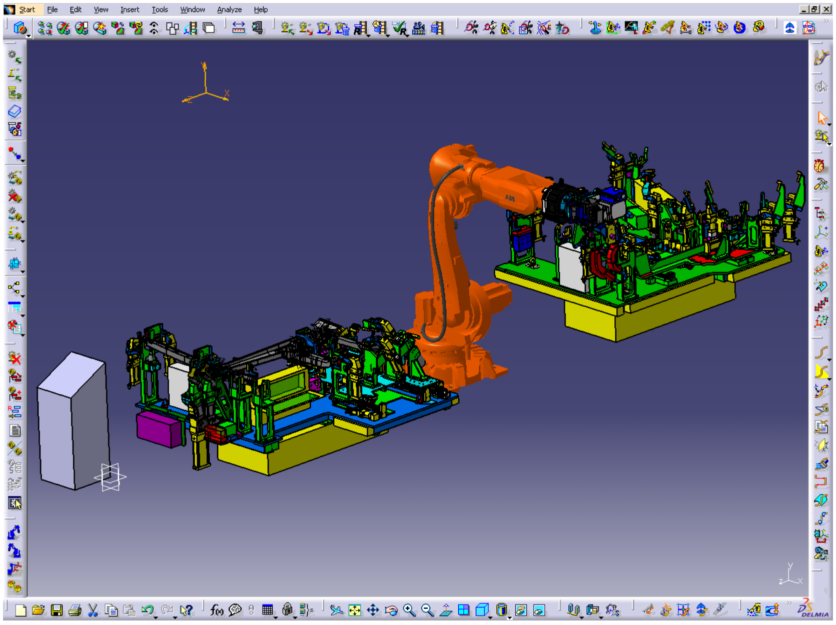


Figure 4.24: *An example of how the layout might look with the HMI interface and robot placed*

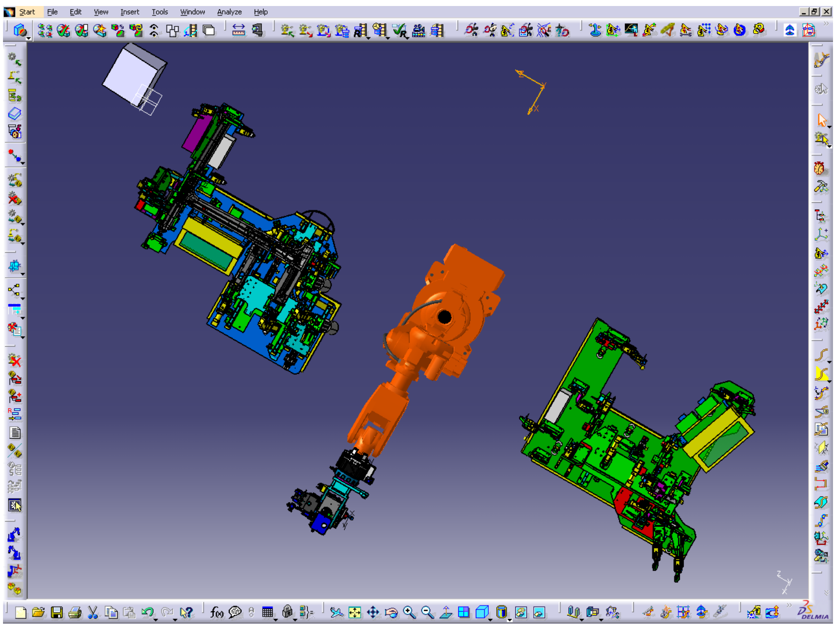


Figure 4.25: *Another angle of the same layout as in figure 4.24*

Table 4.5: Device position table, station 15

Devices and components	1:st home pos.	2:nd home pos.
BG.12.PIN	DOWN	UP
BG.16.CLAMP	OPEN	CLOSED
BG.17.CLAMP1	OPEN	CLOSED
BG.17.CLAMP2	OPEN	CLOSED
BG.17.PIN	DOWN	UP
BG.20.CLAMP	OPEN	CLOSED
BG.21.CLAMP	OPEN	CLOSED
BG.22.ROTCLAMP	OPEN	CLOSED*
BG.23.ROTCLAMP	OPEN	CLOSED*
BG.24.CLAMP	OPEN	CLOSED
BG.25.CLAMP	OPEN	CLOSED
BG.26.CLAMP	OPEN	CLOSED
BG.27.FASTENER	DOWN	UP
BG.28.TABLE	BACKWARD	FORWARD
BG.28.CLAMP	OPEN	CLOSED
BG.29.TABLE	BACKWARD	FORWARD
BG.29.CLAMP1	OPEN	CLOSED
BG.29.CLAMP2	OPEN	CLOSED
BG.30.TABLE	BACKWARD	FORWARD
BG.30.CLAMP	OPEN	CLOSED
BG.32.CLAMP	NOT USED	NOT USED
BG.32.CLAMP	NOT USED	NOT USED

* These devices also have several transitional positions

Table 4.6: Device position table, station 25

Devices and components	1:st home pos.	2:nd home pos.
BG.12.PIN	DOWN	UP
BG.13.PIN	DOWN	UP
BG.14.CLAMP	OPEN	CLOSED
BG.15.CLAMP	OPEN	CLOSED
BG.16.CLAMP	OPEN	CLOSED
BG.18.CLAMP	OPEN	CLOSED
BG.18.LEVER	POS1	POS2
BG.19.CLAMP	OPEN	CLOSED
BG.20.CLAMP	OPEN	CLOSED
BG.20.FASTENER	DOWN	UP
BG.20.LEVER	POS1	POS2
BG.21.CLAMP	OPEN	CLOSED
BG.22.FASTENER	DOWN	UP
BG.22.CLAMP	BACKWARD	FORWARD
BG.23.FASTENER	OPEN	CLOSED
BG.24.CLAMP	OPEN	CLOSED
BG.25.CLAMP	OPEN	CLOSED
BG.27.CLAMP	OPEN	CLOSED
BG.29.TABLE	BACKWARD	FORWARD
BG.29.CLAMP1	OPEN	CLOSED
BG.29.CLAMP2	OPEN	CLOSED

Chapter 5

Conclusions and future work

Implementing the use of digital manufacturing and simulation solutions in a full scale project is a process that has been proven to offer a manageable solution to many problems by improving top down planning and structure of assembly manufacturing. In contrast it also complicates the process by necessitating an approach to the planning and data gathering thats better suited to the specific structure of the program. The introduction of a new product have monumental consequences on the structure of manufacturing lines, these changes stops the production lines with a drastic increase of ramp up times as a result. By adopting Digital factory concepts manufacturers have a greater adaptability in their work in consideration to these types of cases, it allows them to make decisions based on accurate data and provides dynamic analysis of potential systems. At the same time one must structure these projects with regards to the final product, otherwise misrepresentative data, unnecessary follow ups and lack of information regarding certain processes might have unwanted effects on the completion time and quality of the project.

This report provides an in depth study of how a project should be constructed in order to minimize timewaste. At the same time it does not fulfill some of its initial endeavors, as the initial planning of the project stated one of its objectives as "To prepare an automated production systems in a virtual environment using Delmia, while optimizing the cycle time to improve capacity, guaranteeing the reachability and preventing collisions.". So why was this part no fulfilled, most of the problems stemmed from the projects loose structure when defining the work station. Many of the models later used had to be first evaluated based on the premises of the station as well as the layout of the station itself, which also was not defined, this lead to the project getting sidetracked at many parts as several options that were not used in the final version still had to be assessed.

Take as an example the choosing of weld guns, not only was there a choice between 19 different weld guns, there was also the fact that the project initially lacked any method of evaluating these guns. There were also several side options to chose amongst which also needed evaluation, another problem was to try and fit the decision in the larger perspective of the project as at the same time the robot chosen and the structure of the work cell had to be taken into consideration. A lack of centralized knowledge database about the function of the guns or the models of them often made general information difficult to access. The lack of any standardized methods or any predefined criteria proved to consume large amounts of time that could have been better spent elsewhere. None the less the work done so far provides a great basis for future work and will help other projects to avoid timewasting by providing a better structure for the future.

Major works that still remains to be done in the project:

- Inserting the Device logic design defined resources into a process environment.
- Setting up the layout of the workstation in Delmia
- Defining the robots actions in the process environment
- Provide models and functions of the turntables, part handling system, grippers, tool parking station and fences
- Define a coding which allows the PLC structure to be easily identified

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Appendix

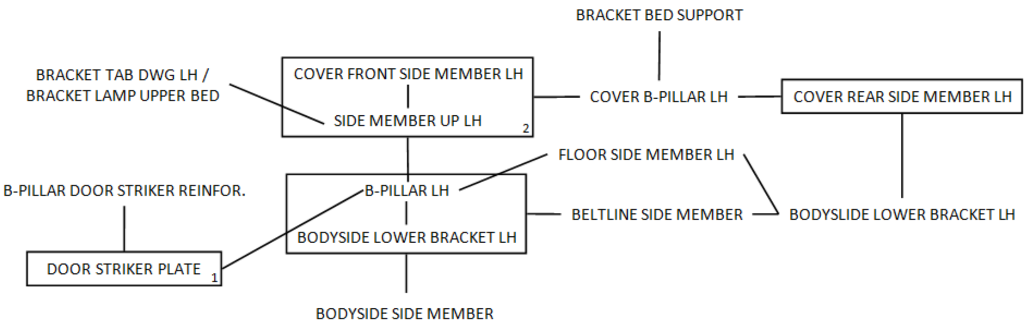
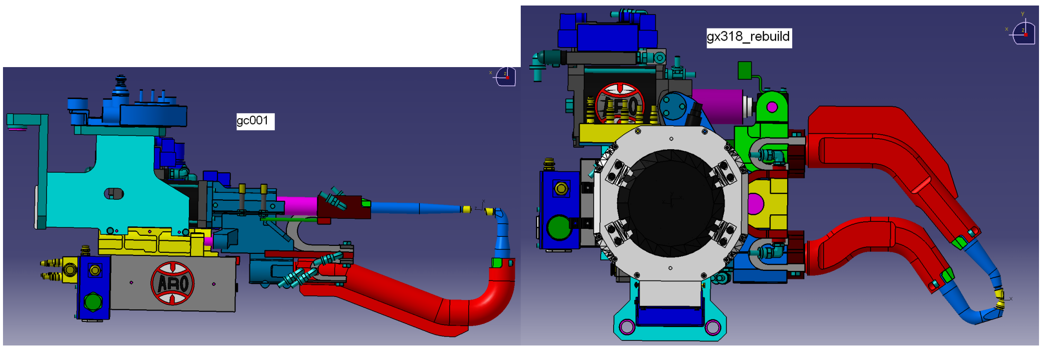


Figure 1: *Alternative Liaison diagram*



(a) gc001 (b) gx318

Figure 2: *The two chosen weld guns*

Figure 3: *The chosen robot IRB 6620*

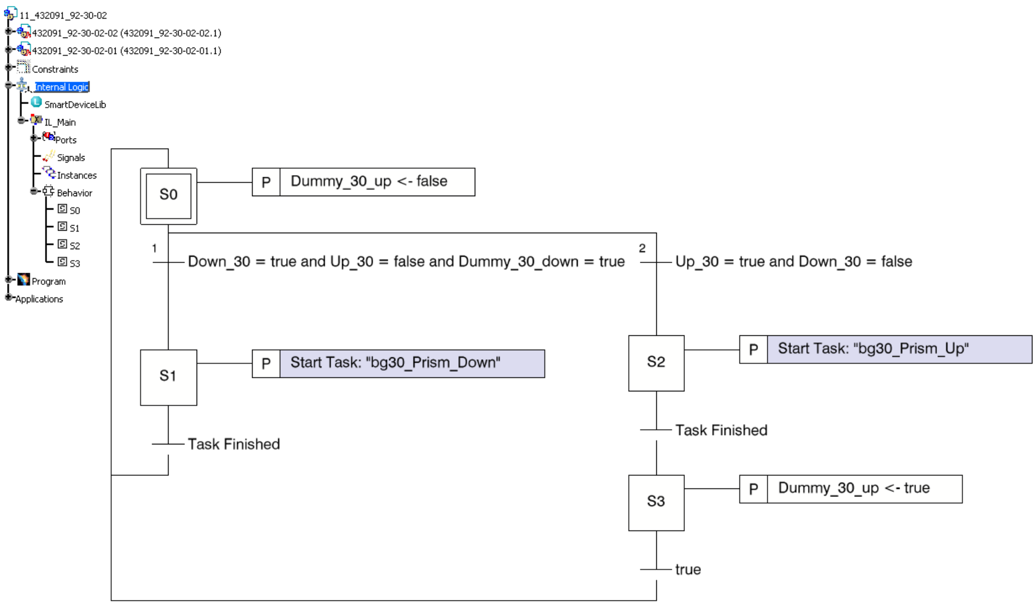


Figure 4: *Example of behavior where the smart device has been programmed to wait for a signal before it moves*

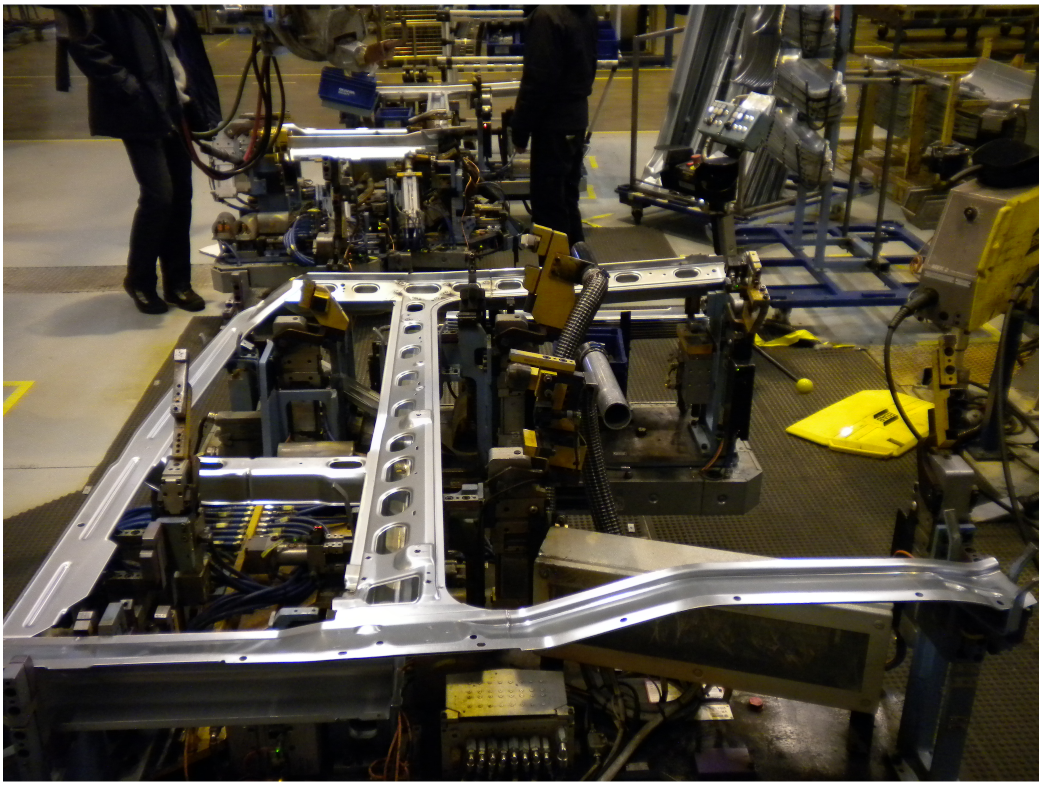
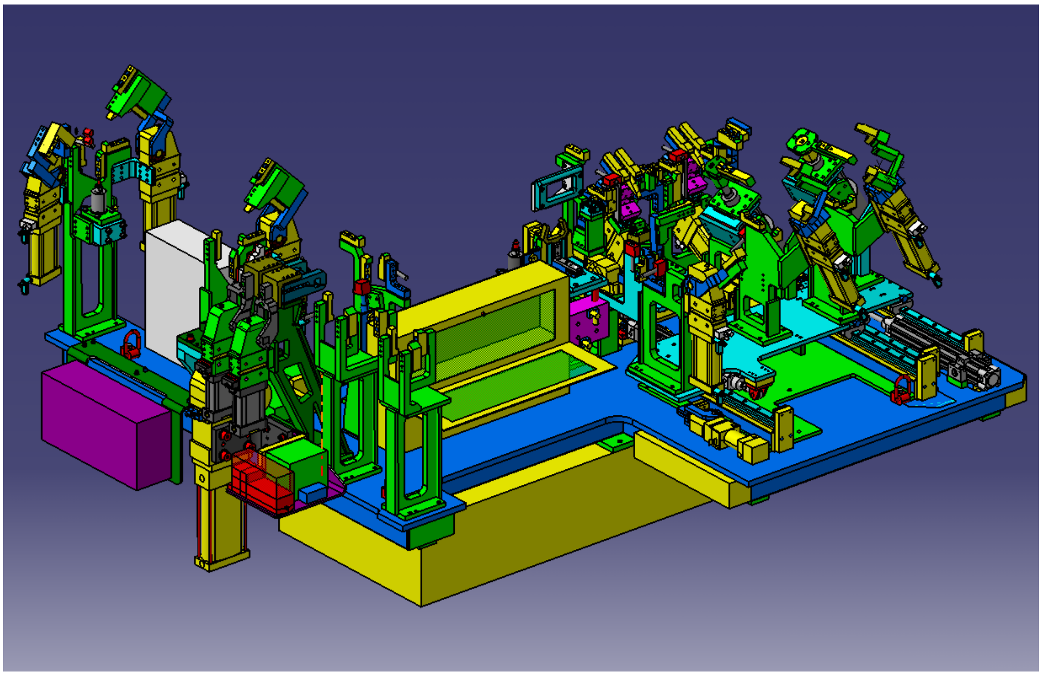
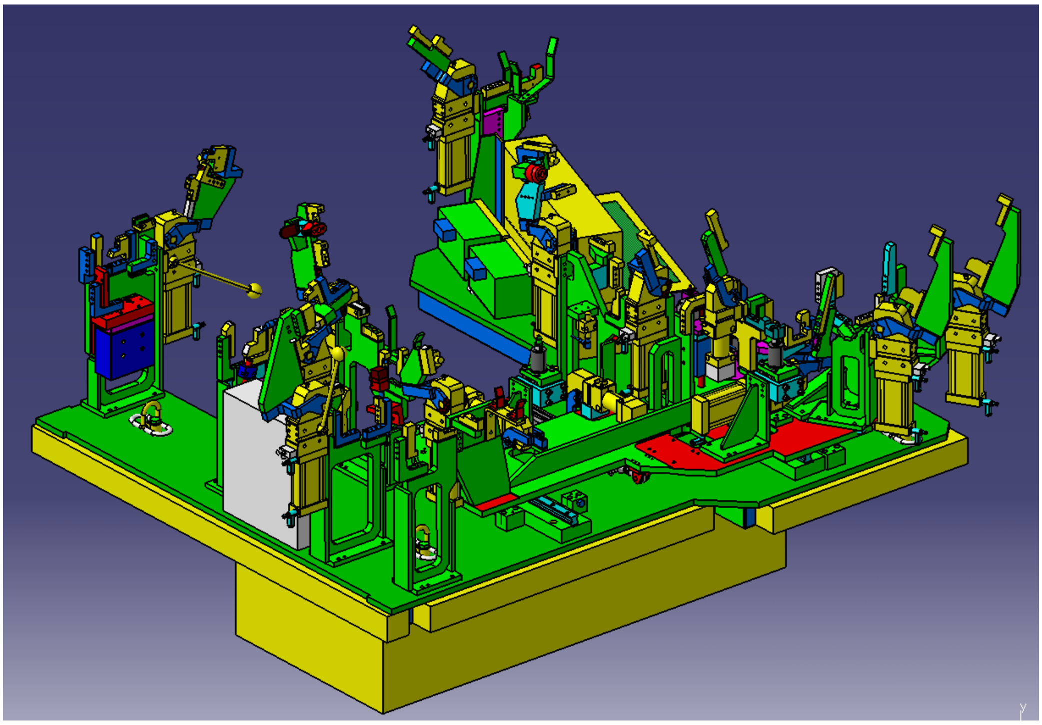


Figure 5: *The real world workcell at the Scania factory in Oskarshamn*

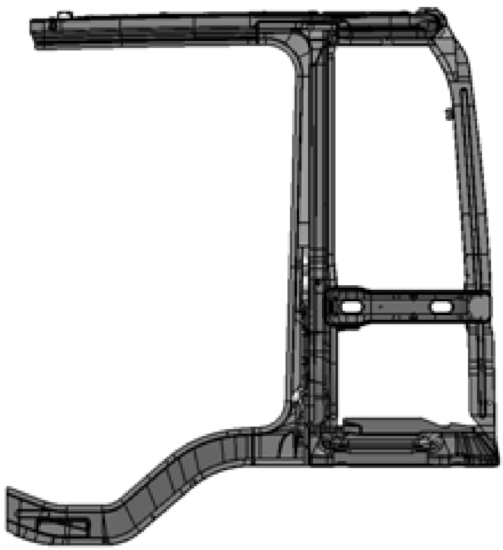


(a) Station15



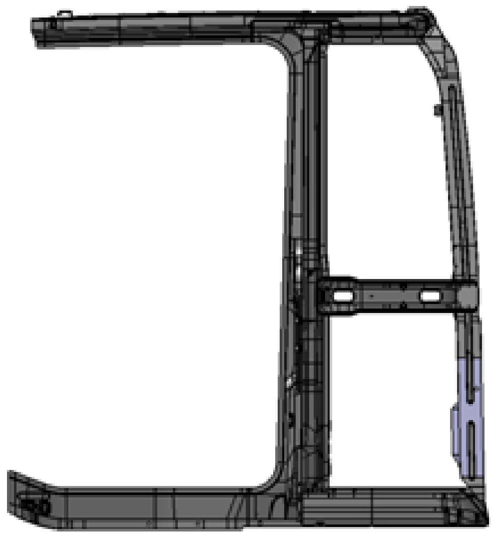
(b) Station25

Figure 6: *Both of the fixtures used*



(a) P16

(b) P19



(c) R16

(d) R19

Figure 7: *All different products*

Using World Axis					Position.242	1210.589	1333.028	1631.698	OL	Position.497	3086.894	-356.972	6009.519	NR	Position.752	4065.582	1333.028	2073.818	NR
					Position.243	1210.589	995.028	1631.698	OL	Position.498	3086.894	-694.972	6009.519	NR	Position.753	4065.582	995.028	2073.818	NR
No. of Points					Position.244	1210.589	657.028	1631.698	OL	Position.499	3086.894	-1032.97	6009.52	NR	Position.754	4065.582	657.028	2073.818	NR
1000					Position.245	1210.589	319.028	1631.698	OL	Position.500	2189.277	2009.028	-2304	NR	Position.755	4065.582	319.028	2073.818	NR
					Position.246	1210.589	-18.972	1631.698	OL	Position.501	2189.277	1671.028	-2304	NR	Position.756	4065.582	-18.972	2073.818	NR
No Of Robot Sequence					Position.247	1210.589	-356.972	1631.698	OL	Position.502	2189.277	1333.028	-2304	NR	Position.757	4065.582	-356.972	2073.818	NR
1					Position.248	1210.589	-694.972	1631.698	OL	Position.503	2189.277	995.028	-2304	NR	Position.758	4065.582	-694.972	2073.818	NR
					Position.249	1210.589	-1032.97	1631.698	OL	Position.504	2189.277	657.028	-2304	NR	Position.759	4065.582	-1032.97	2073.818	NR
Robot Sequences Analysed					Position.250	1370.222	2009.028	2544.953	NR	Position.505	2189.277	319.028	-2304	NR	Position.760	4225.214	2009.028	2987.073	NR
TagGroup1.1					Position.251	1370.222	1671.028	2544.953	NR	Position.506	2189.277	-18.972	-2304	NR	Position.761	4225.214	1671.028	2987.073	NR
					Position.252	1370.222	1333.028	2544.953	NR	Position.507	2189.277	-356.972	-2304	NR	Position.762	4225.214	1333.028	2987.073	NR
					Position.253	1370.222	995.028	2544.953	NR	Position.508	2189.277	-694.972	-2304	NR	Position.763	4225.214	995.028	2987.073	NR
Positions	XCord	YCord	ZCord	Status	Position.254	1370.222	657.028	2544.953	OL	Position.509	2189.277	-1032.97	-2304	NR	Position.764	4225.214	657.028	2987.073	NR
Position.0	-506.083	2009.028	-1832.87	NR	Position.255	1370.222	319.028	2544.953	OL	Position.510	2348.909	2009.028	-1390.75	NR	Position.765	4225.214	319.028	2987.073	NR
Position.1	-506.083	1671.028	-1832.87	NR	Position.256	1370.222	-18.972	2544.953	FR	Position.511	2348.909	1671.028	-1390.75	NR	Position.766	4225.214	-18.972	2987.073	NR
Position.2	-506.083	1333.028	-1832.87	NR	Position.257	1370.222	-356.972	2544.953	FR	Position.512	2348.909	1333.028	-1390.75	NR	Position.767	4225.214	-356.972	2987.073	NR
Position.3	-506.083	995.028	-1832.87	NR	Position.258	1370.222	-694.972	2544.953	FR	Position.513	2348.909	995.028	-1390.75	NR	Position.768	4225.214	-694.972	2987.073	NR
Position.4	-506.083	657.028	-1832.87	NR	Position.259	1370.222	-1032.97	2544.953	NR	Position.514	2348.909	657.028	-1390.75	NR	Position.769	4225.214	-1032.97	2987.073	NR
Position.5	-506.083	319.028	-1832.87	NR	Position.260	1529.854	2009.028	3458.208	NR	Position.515	2348.909	319.028	-1390.75	NR	Position.770	4384.846	2009.028	3900.328	NR
Position.6	-506.083	-18.972	-1832.87	NR	Position.261	1529.854	1671.028	3458.208	NR	Position.516	2348.909	-18.972	-1390.75	NR	Position.771	4384.846	1671.028	3900.328	NR
Position.7	-506.083	-356.972	-1832.87	NR	Position.262	1529.854	1333.028	3458.208	NR	Position.517	2348.909	-356.972	-1390.75	NR	Position.772	4384.846	1333.028	3900.328	NR
Position.8	-506.083	-694.972	-1832.87	NR	Position.263	1529.854	995.028	3458.208	NR	Position.518	2348.909	-694.972	-1390.75	NR	Position.773	4384.846	995.028	3900.328	NR
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Position.10	-346.451	2009.028	-919.614	NR	Position.265	1529.854	319.028	3458.208	NR	Position.520	2508.541	2009.028	-477.493	NR	Position.775	4384.846	319.028	3900.328	NR
Position.11	-346.451	1671.028	-919.614	NR	Position.266	1529.854	-18.972	3458.208	NR	Position.521	2508.541	1671.028	-477.493	NR	Position.776	4384.846	-18.972	3900.328	NR
Position.12	-346.451	1333.028	-919.614	NR	Position.267	1529.854	-356.972	3458.208	NR	Position.522	2508.541	1333.028	-477.493	NR	Position.777	4384.846	-356.972	3900.329	NR
Position.13	-346.451	995.028	-919.614	NR	Position.268	1529.854	-694.972	3458.208	NR	Position.523	2508.541	995.028	-477.493	NR	Position.778	4384.846	-694.972	3900.329	NR
Position.14	-346.451	657.028	-919.614	NR	Position.269	1529.854	-1032.97	3458.208	NR	Position.524	2508.541	657.028	-477.493	NR	Position.779	4384.846	-1032.97	3900.329	NR
Position.15	-346.451	319.028	-919.614	NR	Position.270	1689.486	2009.028	4371.463	NR	Position.525	2508.541	319.028	-477.493	FR	Position.780	4544.478	2009.028	4813.583	NR
Position.16	-346.451	-18.972	-919.614	NR	Position.271	1689.486	1671.028	4371.463	NR	Position.526	2508.541	-18.972	-477.493	FR	Position.781	4544.478	1671.028	4813.583	NR
Position.17	-346.451	-356.972	-919.614	NR	Position.272	1689.486	1333.028	4371.463	NR	Position.527	2508.541	-356.972	-477.493	NR	Position.782	4544.478	1333.028	4813.584	NR
Position.18	-346.451	-694.972	-919.614	NR	Position.273	1689.486	995.028	4371.463	NR	Position.528	2508.541	-694.972	-477.493	NR	Position.783	4544.478	995.028	4813.584	NR
Position.19	-346.451	-1032.97	-919.614	NR	Position.274	1689.486	657.028	4371.463	NR	Position.529	2508.541	-1032.97	-477.493	NR	Position.784	4544.478	657.028	4813.584	NR
Position.20	-186.819	2009.028	-6.359	NR	Position.275	1689.486	319.028	4371.463	NR	Position.530	2668.173	2009.028	435.762	NR	Position.785	4544.478	319.028	4813.584	NR
Position.21	-186.819	1671.028	-6.359	NR	Position.276	1689.486	-18.972	4371.463	NR	Position.531	2668.173	1671.028	435.762	NR	Position.786	4544.478	-18.972	4813.584	NR
Position.22	-186.819	1333.028	-6.359	NR	Position.277	1689.486	-356.972	4371.463	NR	Position.532	2668.173	1333.028	435.762	FR	Position.787	4544.478	-356.972	4813.584	NR
Position.23	-186.819	995.028	-6.359	NR	Position.278	1689.486	-694.972	4371.463	NR	Position.533	2668.173	995.028	435.762	FR	Position.788	4544.478	-694.972	4813.584	NR
Position.24	-186.819	657.028	-6.359	NR	Position.279	1689.486	-1032.97	4371.463	NR	Position.534	2668.173	657.028	435.762	OL	Position.789	4544.478	-1032.97	4813.584	NR
Position.25	-186.819	319.028	-6.359	NR	Position.280	1849.118	2009.028	5284.718	NR	Position.535	2668.173	319.028	435.762	OL	Position.790	4704.11	2009.028	5726.839	NR
Position.26	-186.819	-18.972	-6.359	NR	Position.281	1849.118	1671.028	5284.718	NR	Position.536	2668.173	-18.972	435.762	OL	Position.791	4704.11	1671.028	5726.839	NR
Position.27	-186.819	-356.972	-6.359	NR	Position.282	1849.118	1333.028	5284.718	NR	Position.537	2668.173	-356.972	435.762	OL	Position.792	4704.11	1333.028	5726.839	NR
Position.28	-186.819	-694.972	-6.359	NR	Position.283	1849.118	995.028	5284.718	NR	Position.538	2668.173	-694.972	435.762	FR	Position.793	4704.11	995.028	5726.839	NR
Position.29	-186.819	-1032.97	-6.359	NR	Position.284	1849.118	657.028	5284.718	NR	Position.539	2668.173	-1032.97	435.762	FR	Position.794	4704.11	657.028	5726.839	NR
Position.30	-27.187	2009.028	906.896	NR	Position.285	1849.118	319.028	5284.718	NR	Position.540	2827.805	2009.028	1349.017	NR	Position.795	4704.11	319.028	5726.839	NR
Position.31	-27.187	1671.028	906.896	NR	Position.286	1849.118	-18.972	5284.718	NR	Position.541	2827.805	1671.028	1349.017	NR	Position.796	4704.11	-18.972	5726.839	NR
Position.32	-27.187	1333.028	906.896	NR	Position.287	1849.118	-356.972	5284.718	NR	Position.542	2827.805	1333.028	1349.017	OL	Position.797	4704.11	-356.972	5726.839	NR
Position.33	-27.187	995.028	906.896	NR	Position.288	1849.118	-694.972	5284.718	NR	Position.543	2827.805	995.028	1349.017	OL	Position.798	4704.11	-694.972	5726.839	NR
Position.34	-27.187	657.028	906.896	OL	Position.289	1849.118	-1032.97	5284.718	NR	Position.544	2827.805	657.028	1349.017	OL	Position.799	4704.11	-1032.97	5726.839	NR
Position.35	-27.187	319.028	906.896	OL	Position.290	2008.75	2009.028	6197.973	NR	Position.545	2827.805	319.028	1349.017	OL	Position.800	3806.493	2009.028	-2586.68	NR
Position.36	-27.187	-18.972	906.896	OL	Position.291	2008.75	1671.028	6197.973	NR	Position.546	2827.805	-18.972	1349.017	OL	Position.801	3806.493	1671.028	-2586.68	NR
Position.37	-27.187	-356.972	906.896	OL	Position.292	2008.75	1333.028	6197.973	NR	Position.547	2827.805	-356.972	1349.017	FR	Position.802	3806.493	1333.028	-2586.68	NR
Position.38	-27.187	-694.972	906.896	OL	Position.293	2008.75	995.028	6197.973	NR	Position.548	2827.805	-694.972	1349.017	FR	Position.803	3806.493	995.028	-2586.68	NR
Position.39	-27.187	-1032.97	906.896	OL	Position.294	2008.75	657.028	6197.973	NR	Position.549	2827.805	-1032.97	1349.017	FR	Position.804	3806.493	657.028	-2586.68	NR
Position.40	132.445	2009.028	1820.151	NR	Position.295	2008.75	319.028	6197.973	NR	Position.550	2987.438	2009.028	2262.272	NR	Position.805	3806.493	319.028	-2586.68	NR
Position.41	132.445	1671.028	1820.151	NR	Position.296	2008.75	-18.972	6197.973	NR	Position.551	2987.438	1671.028	2262.272	NR	Position.806	3806.493	-18.972	-2586.68	NR
Position.42	132.445	1333.028	1820.151	NR	Position.297	2008.75	-356.972	6197.973	NR	Position.552	2987.438	1333.028	2262.272	NR	Position.807	3806.493	-356.972	-2586.68	NR
Position.43	132.445	995.028	1820.151	NR	Position.298	2008.75	-694.972	6197.973	NR	Position.553	2987.438	995.028	2262.272	NR	Position.808	3806.493	-694.972	-2586.68	NR
Position.44	132.445	657.028	1820.151	NR	Position.299	2008.75	-1032.97	6197.973	NR	Position.554	2987.438	657.028	2262.272	OL	Position.809	3806.493	-1032.97	-2586.68	NR
Position.45	132.445	319.028	1820.151	NR	Position.300	1111.133	2009.028	-2115.55	NR	Position.555	2987.438	319.028	2262.272	OL	Position.810	3966.125	2009.028	-1673.43	NR
Position.46	132.445	-18.972	1820.151	NR	Position.301	1111.133	1671.028	-2115.55	NR	Position.556	2987.438	-18.972	2262.272	FR	Position.811	3966.125	1671.028	-1673.43	NR
Position.47	132.445	-356.972	1820.151	NR	Position.302	1111.133	1333.028	-2115.55	NR	Position.557	2987.438	-356.972	2262.272	FR	Position.812	3966.125	1333.028	-1673.43	NR
Position.48	132.445	-694.972	1820.151	NR	Position.303	1111.133	995.028	-2115.55	NR	Position.558	2987.438	-694.972	2262.272	FR	Position.813	3966.125	995.028	-1673.43	NR
Position.49	132.445	-1032.97	1820.152	NR	Position.304	1111.133	657.028	-2115.55	NR	Position.559	2987.438	-1032.97	2262.272	FR	Position.814	3966.125	657.028	-1673.43	NR
Position.50	292.078	2009.028	2733.406	NR	Position.305	1111.133	319.028	-2115.55	NR	Position.560	3147.07	2009.028	3175.527	NR	Position.815	3966.125	319.028	-1673.43	NR
Position.51	292.078	1671.028	2733.406	NR	Position.306	1111.133	-18.972	-2115.55	NR	Position.561	3147.07	1671.028	3175.527	NR	Position.816	3966.125	-18.972	-1673.43	NR
Position.52	292.078	1333.028	2733.406	NR	Position.307	1111.133	-356.972	-2115.55	NR	Position.562	3147.07	1333.028	3175.527	NR	Position.817	3966.125	-356.972	-1673.43	NR
Position.53	292.078	995.028	2733.406	NR	Position.308	1111.133	-694.972	-2115.55	NR	Position.563	3147.07	995.028	3175.527	NR	Position.818	3966.125	-694.972	-1673.43	NR
Position.54	292.078	657.028	2733.407	NR	Position.309	1111.133	-1032.97	-2115.55	NR	Position.564	3147.07	657.028	3175.527	NR	Position.819	3966.125	-1032.97	-1673.43	NR
Position.55	292.078	319.028	2733.407	NR	Position.310	1270.765	2009.028	-1202.3	NR	Position.565	3147.07	319.028	3175.527	NR	Position.820	4125.757	2009.028	-760.174	NR
Position.56	292.078	-18.972	2733.407	NR	Position.311	1270.765	1671.028	-1202.3	NR	Position.566	3147.07	-18.972	3175.527	NR	Position.821	4125.757	1671.028	-760.174	NR
Position.57	292.078	-356.972	2733.407	NR	Position.312	1270.765	1333.028	-1202.3	NR	Position.567	3147.07	-356.972	3175.527	NR	Position.822	4125.757	1333.028	-760.174	NR
Position.58	292.078	-694.972	2733.407	NR	Position.313	1270.765	995.028	-1202.3	NR	Position.568	3147.07	-694.972	3175.527	NR	Position.823	4125.757	995.028	-760.174	NR
Position.59	292.078	-1032.97	2733.407	NR	Position.314	1270.765	657.028	-1202.3	NR	Position.569	3147.07	-1032.97	3175.527	NR	Position.824	4125.757	657.028	-760.174	NR
Position.60	451.71	2009.028	3646.662	NR	Position.315	1270.765	319.028	-1202.3	NR	Position.570	3306.702	2009.028	4088.782	NR	Position.825	4125.757	319.028	-760.174	NR
Position.61	451.71	1671.028	3646.662	NR	Position.316	1270.765	-18.972	-1202.3	NR	Position.571	3306.702	1671.028	4088.782	NR	Position.826	4125.757	-18.972	-760.174	NR
Position.62	451.71	1333.028	3646.662	NR	Position.317	1270.765	-356.972	-1202.3	NR	Position.572	3306.702	1333.028	4088.782	NR	Position.827	4125.757	-356.972	-760.174	NR
Position.63	451.71	995.028	3646.662	NR	Position.318	1270.765	-694.972	-1202.3	NR	Position.573	3306.702	995.028	4088.782	NR	Position.828	4125.757	-694.972	-760.174	NR
Position.64	451.71	657.028	3646.662	NR	Position.319	1270.765	-1032.97	-1202.3	NR	Position.574	3306.702	657.028	4088.782	NR	Position.829	4125.757	-1032.97	-760.174	NR
Position.65	451.71	319.028	3646.662	NR	Position.320	1430.397	2009.028	-289.04	NR	Position.575	3306.702	319.028	4088.782	NR	Position.830	4285.389	2009.028	153.081	NR
Position.66	451.71	-18.972	3646.662	NR	Position.321	1430.397	1671.028	-289.04	NR	Position.576	3306.702	-18.972	4088.782	NR	Position.831	4285.389	1671.028	153.081	NR
Position.67	451.71	-356.972	3646.662	NR	Position.322	1430.397	1333.028	-289.04	NR	Position.577	3306.702	-356.972	4088.782	NR	Position.832	4285.389	1333.028	153.081	NR
Position.68	451.71	-694.972	3646.662	NR	Position.323	1430.397	995.028	-289.04	NR	Position.578	3306.702	-694.972	4088.782	NR	Position.833	4285.389	995.028	153.081	NR
Position.69	451.71	-1032.97	3646.662	NR	Position.324	1430.397	657.028	-289.04	FR	Position.579	3306.702	-1032.97	4088.782	NR	Position.834	4285.389	657.028	153.081	NR
Position.70	611.342	2009.028	4559.917	NR	Position.325	1430.397	319.028	-289.04	FR	Position.580	3466.334	2009.028	5002.037	NR	Position.835	4285.389	319.028	153.081	NR
Position.71	611.342	1671.028	4559.917	NR	Position.326	1430.397	-18.972	-289.04	FR	Position.581	3466.334	1671.028	5002.037	NR	Position.836	4285.389	-18.972	153.081	NR
Position.72	611.342	1333.028	4559.917	NR	Position.327	1430.397	-356.972	-289.04	FR	Position.582	3466.334	1333.028	5002.037	NR	Position.837	4285.389	-356.972	153.081	NR
Position.73	611.342	995.028	4559.917	NR	Position.328	1430.397	-694.972	-289.039	NR	Position.583	3466.334	995.028	5002.037	NR	Position.838	4285.389	-694.972	153.081	NR
Position.74	611.342	657.028	4559.917	NR	Position.329	1430.397	-1032.97	-289.039	NR	Position.584	3466.334	657.028	5002.037	NR	Position.839	4285.389	-1032.97	153.081	NR
Position.75	611.342	319.028	4559.917	NR	Position.330	1590.029	2009.028	624.215	NR	Position.585	3466.334	319.028	5002.037	NR	Position.840	4445.021	2009.028	1066.336	NR
Position.76	611.342	-18.972	4559.917	NR	Position.331	1590.029	1671.028	624.215	FR	Position.586	3466.334	-18.972	5002.037	NR	Position.841	4445.021	1671.028	1066.336	NR
Position.77	611.342	-356.972	4559.917	NR	Position.332	1590.029	1333.028	624.215	FR	Position.587	3466.334	-356.972	5002.037	NR	Position.842	4445.021	1333.028	1066.336	NR
Position.78	611.342	-694.972	4559.917	NR	Position.333	1590.029	995.028	624.216	FR	Position.588	3466.334	-694.972	5002.037	NR	Position.843	4445.021	995.028	1066.336	NR
Position.79	611.342	-1032.97	4559.917	NR	Position.334	1590.029	657.028	624.216	OL	Position.589	3466.334	-1032.97	5002.037	NR	Position.844	4445.021	657.028	1066.336	NR
Position.80	770.974	2009.028	5473.172	NR	Position.335	1590.029	319.028	624.216	OL	Position.590	3625.966	2009.028	5915.292	NR	Position.845	4445.021	319.028	1066.336	NR
Position.81	770.974	1671.028	5473.172	NR	Position.336	1590.029	-18.972	624.216	OL	Position.591	3625.966	1671.028	5915.292	NR	Position.846	4445.021	-18.972	1066.336	NR
Position.82	770.974	1333.028	5473.172	NR	Position.337	1590.029	-356.972	624.216	OL	Position.592	3625.966	1333.028	5915.292	NR	Position.847	4445.021	-356.972	1066.336	NR
Position.83	770.974	995.028	5473.172	NR	Position.338	1590.029	-694.972	624.216	OL	Position.593	3625.966	995.028	5915.292	NR	Position.848	4445.021	-694.972	1066.336	NR
Position.84	770.974	657.028	5473.172	NR	Position.339	1590.029	-1032.97	624.216	OL	Position.594	3625.966	657.028	5915.292	NR	Position.849	4445.021	-1032.97	1066.336	NR
Position.85	770.974	319.028	5473.172	NR	Position.340	1749.661	2009.028	1537.471	NR	Position.595	3625.966	319.028	5915.293	NR	Position.850	4604.654	2009.028	1979.591	NR
Position.86	770.974	-18.972	5473.172	NR	Position.341	1749.661	1671.028	1537.471	NR	Position.596	3625.966	-18.972	5915.293	NR	Position.851	4604.654	1671.028	1979.591	NR
Position.87	770.974	-356.972	5473.172	NR	Position.342	1749.661	1333.028	1537.471	OL	Position.597	3625.966	-356.972	5915.293	NR	Position.852	4604.654	1333.028	1979.591	NR
Position.88	770.974	-694.972	5473.172	NR	Position.343	1749.661	995.028	1537.471	OL	Position.598	3625.966	-694.972	5915.293	NR	Position.853	4604.654	995.028	1979.591	NR
Position.89	770.974	-1032.97	5473.172	NR	Position.344	1749.661	657.028	1537.471	OL	Position.599	3625.966	-1032.97	5915.293	NR	Position.854	4604.654	657.028	1979.591	NR
Position.90	930.606	2009.028	6386.427	NR	Position.345	1749.661	319.028	1537.471	OL	Position.600	2728.349	2009.028	-2398.23	NR	Position.855	4604.654	319.028	1979.591	NR
Position.91	930.606	1671.028	6386.427	NR	Position.346	1749.661	-18.972	1537.471	OL	Position.601	2728.349	1671.028	-2398.23	NR	Position.856	4604.654	-18.972	1979.591	NR
Position.92	930.606	1333.028	6386.427	NR	Position.347	1749.661	-356.972	1537.471	OL	Position.602	2728.349	1333.028	-2398.23	NR	Position.857	4604.654	-356.972	1979.591	NR
Position.93	930.606	995.028	6386.427	NR	Position.348	1749.661	-694.972	1537.471	OL	Position.603	2728.349	995.028	-2398.23	NR	Position.858	4604.654	-694.972	1979.591	NR
Position.94	930.606	657.028	6386.427	NR	Position.349	1749.661	-1032.97	1537.471	OL	Position.604	2728.349	657.028	-2398.23	NR	Position.859	4604.654	-1032.97	1979.591	NR
Position.95	930.606	319.028	6386.427	NR	Position.350	1909.294	2009.028	2450.726	NR	Position.605	2728.349	319.028	-2398.23	NR	Position.860	4764.286	2009.028	2892.846	NR
Position.96	930.606	-18.972	6386.427	NR	Position.351	1909.294	1671.028	2450.726	NR	Position.606	2728.349	-18.972	-2398.23	NR	Position.861	4764.286	1671.028	2892.846	NR
Position.97	930.606	-356.972	6386.427	NR	Position.352	1909.294	1333.028	2450.726	NR	Position.607	2728.349	-356.972	-2398.23	NR	Position.862	4764.286	1333.028	2892.846	NR
Position.98	930.606	-694.972	6386.427	NR	Position.353	1909.294	995.028	2450.726	OL	Position.608	2728.349	-694.972	-2398.23	NR	Position.863	4764.286	995.028	2892.846	NR
Position.99	930.606	-1032.97	6386.427	NR	Position.354	1909.294	657.028	2450.726	OL	Position.609	2728.349	-1032.97	-2398.23	NR	Position.864	4764.286	657.028	2892.846	NR
Position.100	32.989	2009.028	-1927.1	NR	Position.355	1909.294	319.028	2450.726	OL	Position.610	2887.981	2009.028	-1484.98	NR	Position.865	4764.286	319.028	2892.846	NR
Position.101	32.989	1671.028	-1927.1	NR	Position.356	1909.294	-18.972	2450.726	OL	Position.611	2887.981	1671.028	-1484.98	NR	Position.866	4764.286	-18.972	2892.846	NR
Position.102	32.989	1333.028	-1927.1	NR	Position.357	1909.294	-356.972	2450.726	FR	Position.612	2887.981	1333.028	-1484.98	NR	Position.867	4764.286	-356.972	2892.846	NR
Position.103	32.989	995.028	-1927.1	NR	Position.358	1909.294	-694.972	2450.726	FR	Position.613	2887.981	995.028	-1484.98	NR	Position.868	4764.286	-694.972	2892.846	NR
Position.104	32.989	657.028	-1927.1	NR	Position.359	1909.294	-1032.97	2450.726	NR	Position.614	2887.981	657.028	-1484.98	NR	Position.869	4764.286	-1032.97	2892.847	NR
Position.105	32.989	319.028	-1927.1	NR	Position.360	2068.926	2009.028	3363.981	NR	Position.615	2887.981	319.028	-1484.98	NR	Position.870	4923.918	2009.028	3806.101	NR
Position.106	32.989	-18.972	-1927.1	NR	Position.361	2068.926	1671.028	3363.981	NR	Position.616	2887.981	-18.972	-1484.98	NR	Position.871	4923.918	1671.028	3806.101	NR
Position.107	32.989	-356.972	-1927.1	NR	Position.362	2068.926	1333.028	3363.981	NR	Position.617	2887.981	-356.972	-1484.98	NR	Position.872	4923.918	1333.028	3806.101	NR
Position.108	32.989	-694.972	-1927.1	NR	Position.363	2068.926	995.028	3363.981	NR	Position.618	2887.981	-694.972	-1484.98	NR	Position.873	4923.918	995.028	3806.102	NR
Position.109	32.989	-1032.97	-1927.1	NR	Position.364	2068.926	657.028	3363.981	NR	Position.619	2887.981	-1032.97	-1484.98	NR	Position.874	4923.918	657.028	3806.102	NR
Position.110	192.621	2009.028	-1013.84	NR	Position.365	2068.926	319.028	3363.981	NR	Position.620	3047.613	2009.028	-571.72	NR	Position.875	4923.918	319.028	3806.102	NR
Position.111	192.621	1671.028	-1013.84	NR	Position.366	2068.926	-18.972	3363.981	NR	Position.621	3047.613	1671.028	-571.72	NR	Position.876	4923.918	-18.972	3806.102	NR
Position.112	192.621	1333.028	-1013.84	NR	Position.367	2068.926	-356.972	3363.981	NR	Position.622	3047.613	1333.028	-571.72	NR	Position.877	4923.918	-356.972	3806.102	NR
Position.113	192.621	995.028	-1013.84	NR	Position.368	2068.926	-694.972	3363.981	NR	Position.623	3047.613	995.028	-571.72	NR	Position.878	4923.918	-694.972	3806.102	NR
Position.114	192.621	657.028	-1013.84	NR	Position.369	2068.926	-1032.97	3363.981	NR	Position.624	3047.613	657.028	-571.72	NR	Position.879	4923.918	-1032.97	3806.102	NR
Position.115	192.621	319.028	-1013.84	NR	Position.370	2228.558	2009.028	4277.236	NR	Position.625	3047.613	319.028	-571.72	NR	Position.880	5083.55	2009.028	4719.357	NR
Position.116	192.621	-18.972	-1013.84	NR	Position.371	2228.558	1671.028	4277.236	NR	Position.626	3047.613	-18.972	-571.72	NR	Position.881	5083.55	1671.028	4719.357	NR
Position.117	192.621	-356.972	-1013.84	NR	Position.372	2228.558	1333.028	4277.236	NR	Position.627	3047.613	-356.972	-571.72	NR	Position.882	5083.55	1333.028	4719.357	NR
Position.118	192.621	-694.972	-1013.84	NR	Position.373	2228.558	995.028	4277.236	NR	Position.628	3047.613	-694.972	-571.72	NR	Position.883	5083.55	995.028	4719.357	NR
Position.119	192.621	-1032.97	-1013.84	NR	Position.374	2228.558	657.028	4277.236	NR	Position.629	3047.613	-1032.97	-571.72	NR	Position.884	5083.55	657.028	4719.357	NR
Position.120	352.253	2009.028	-100.586	NR	Position.375	2228.558	319.028	4277.236	NR	Position.630	3207.245	2009.028	341.535	NR	Position.885	5083.55	319.028	4719.357	NR
Position.121	352.253	1671.028	-100.586	NR	Position.376	2228.558	-18.972	4277.236	NR	Position.631	3207.245	1671.028	341.535	NR	Position.886	5083.55	-18.972	4719.357	NR
Position.122	352.253	1333.028	-100.586	NR	Position.377	2228.558	-356.972	4277.236	NR	Position.632	3207.245	1333.028	341.535	FR	Position.887	5083.55	-356.972	4719.357	NR
Position.123	352.253	995.028	-100.586	NR	Position.378	2228.558	-694.972	4277.236	NR	Position.633	3207.245	995.028	341.535	FR	Position.888	5083.55	-694.972	4719.357	NR

Position.124	352.253	657.028	-100.586	NR	Position.379	2228.558	-1032.97	4277.236	NR	Position.634	3207.245	657.028	341.535	FR	Position.889	5083.55	-1032.97	4719.357	NR
Position.125	352.253	319.028	-100.586	NR	Position.380	2388.19	2009.028	5190.491	NR	Position.635	3207.245	319.028	341.535	FR	Position.890	5243.182	2009.028	5632.612	NR
Position.126	352.253	-18.972	-100.586	NR	Position.381	2388.19	1671.028	5190.491	NR	Position.636	3207.245	-18.972	341.535	FR	Position.891	5243.182	1671.028	5632.612	NR
Position.127	352.253	-356.972	-100.586	NR	Position.382	2388.19	1333.028	5190.491	NR	Position.637	3207.245	-356.972	341.535	FR	Position.892	5243.182	1333.028	5632.612	NR
Position.128	352.253	-694.972	-100.586	NR	Position.383	2388.19	995.028	5190.491	NR	Position.638	3207.245	-694.972	341.535	FR	Position.893	5243.182	995.028	5632.612	NR
Position.129	352.253	-1032.97	-100.586	NR	Position.384	2388.19	657.028	5190.491	NR	Position.639	3207.245	-1032.97	341.535	NR	Position.894	5243.182	657.028	5632.612	NR
Position.130	511.885	2009.028	812.669	NR	Position.385	2388.19	319.028	5190.491	NR	Position.640	3366.877	2009.028	1254.79	NR	Position.895	5243.182	319.028	5632.612	NR
Position.131	511.885	1671.028	812.669	NR	Position.386	2388.19	-18.972	5190.491	NR	Position.641	3366.877	1671.028	1254.79	NR	Position.896	5243.182	-18.972	5632.612	NR
Position.132	511.885	1333.028	812.669	OL	Position.387	2388.19	-356.972	5190.491	NR	Position.642	3366.877	1333.028	1254.79	NR	Position.897	5243.182	-356.972	5632.612	NR
Position.133	511.885	995.028	812.669	OL	Position.388	2388.19	-694.972	5190.491	NR	Position.643	3366.877	995.028	1254.79	OL	Position.898	5243.182	-694.972	5632.612	NR
Position.134	511.885	657.028	812.669	OL	Position.389	2388.19	-1032.97	5190.491	NR	Position.644	3366.877	657.028	1254.79	FR	Position.899	5243.182	-1032.97	5632.612	NR
Position.135	511.885	319.028	812.669	OL	Position.390	2547.822	2009.028	6103.746	NR	Position.645	3366.877	319.028	1254.79	FR	Position.900	4345.565	2009.028	-2680.91	NR
Position.136	511.885	-18.972	812.669	OL	Position.391	2547.822	1671.028	6103.746	NR	Position.646	3366.877	-18.972	1254.79	FR	Position.901	4345.565	1671.028	-2680.91	NR
Position.137	511.885	-356.972	812.669	OL	Position.392	2547.822	1333.028	6103.746	NR	Position.647	3366.877	-356.972	1254.79	FR	Position.902	4345.565	1333.028	-2680.91	NR
Position.138	511.885	-694.972	812.669	OL	Position.393	2547.822	995.028	6103.746	NR	Position.648	3366.877	-694.972	1254.79	FR	Position.903	4345.565	995.028	-2680.91	NR
Position.139	511.885	-1032.97	812.669	OL	Position.394	2547.822	657.028	6103.746	NR	Position.649	3366.877	-1032.97	1254.79	FR	Position.904	4345.565	657.028	-2680.91	NR
Position.140	671.517	2009.028	1725.924	NR	Position.395	2547.822	319.028	6103.746	NR	Position.650	3526.51	2009.028	2168.045	NR	Position.905	4345.565	319.028	-2680.91	NR
Position.141	671.517	1671.028	1725.924	NR	Position.396	2547.822	-18.972	6103.746	NR	Position.651	3526.51	1671.028	2168.045	NR	Position.906	4345.565	-18.972	-2680.91	NR
Position.142	671.517	1333.028	1725.924	NR	Position.397	2547.822	-356.972	6103.746	NR	Position.652	3526.51	1333.028	2168.045	NR	Position.907	4345.565	-356.972	-2680.91	NR
Position.143	671.517	995.028	1725.924	OL	Position.398	2547.822	-694.972	6103.746	NR	Position.653	3526.51	995.028	2168.045	NR	Position.908	4345.565	-694.972	-2680.91	NR
Position.144	671.517	657.028	1725.924	OL	Position.399	2547.822	-1032.97	6103.746	NR	Position.654	3526.51	657.028	2168.045	NR	Position.909	4345.565	-1032.97	-2680.91	NR
Position.145	671.517	319.028	1725.925	OL	Position.400	1650.205	2009.028	-2209.78	NR	Position.655	3526.51	319.028	2168.045	NR	Position.910	4505.197	2009.028	-1767.66	NR
Position.146	671.517	-18.972	1725.925	OL	Position.401	1650.205	1671.028	-2209.78	NR	Position.656	3526.51	-18.972	2168.045	FR	Position.911	4505.197	1671.028	-1767.66	NR
Position.147	671.517	-356.972	1725.925	OL	Position.402	1650.205	1333.028	-2209.78	NR	Position.657	3526.51	-356.972	2168.045	FR	Position.912	4505.197	1333.028	-1767.66	NR
Position.148	671.517	-694.972	1725.925	OL	Position.403	1650.205	995.028	-2209.78	NR	Position.658	3526.51	-694.972	2168.045	NR	Position.913	4505.197	995.028	-1767.66	NR
Position.149	671.517	-1032.97	1725.925	NR	Position.404	1650.205	657.028	-2209.78	NR	Position.659	3526.51	-1032.97	2168.045	NR	Position.914	4505.197	657.028	-1767.66	NR
Position.150	831.15	2009.028	2639.18	NR	Position.405	1650.205	319.028	-2209.78	NR	Position.660	3686.142	2009.028	3081.3	NR	Position.915	4505.197	319.028	-1767.66	NR
Position.151	831.15	1671.028	2639.18	NR	Position.406	1650.205	-18.972	-2209.78	NR	Position.661	3686.142	1671.028	3081.3	NR	Position.916	4505.197	-18.972	-1767.66	NR
Position.152	831.15	1333.028	2639.18	NR	Position.407	1650.205	-356.972	-2209.78	NR	Position.662	3686.142	1333.028	3081.3	NR	Position.917	4505.197	-356.972	-1767.66	NR
Position.153	831.15	995.028	2639.18	NR	Position.408	1650.205	-694.972	-2209.78	NR	Position.663	3686.142	995.028	3081.3	NR	Position.918	4505.197	-694.972	-1767.66	NR
Position.154	831.15	657.028	2639.18	NR	Position.409	1650.205	-1032.97	-2209.78	NR	Position.664	3686.142	657.028	3081.3	NR	Position.919	4505.197	-1032.97	-1767.66	NR
Position.155	831.15	319.028	2639.18	NR	Position.410	1809.837	2009.028	-1296.52	NR	Position.665	3686.142	319.028	3081.3	NR	Position.920	4664.829	2009.028	-854.401	NR
Position.156	831.15	-18.972	2639.18	OL	Position.411	1809.837	1671.028	-1296.52	NR	Position.666	3686.142	-18.972	3081.3	NR	Position.921	4664.829	1671.028	-854.401	NR
Position.157	831.15	-356.972	2639.18	NR	Position.412	1809.837	1333.028	-1296.52	NR	Position.667	3686.142	-356.972	3081.3	NR	Position.922	4664.829	1333.028	-854.401	NR
Position.158	831.15	-694.972	2639.18	NR	Position.413	1809.837	995.028	-1296.52	NR	Position.668	3686.142	-694.972	3081.3	NR	Position.923	4664.829	995.028	-854.401	NR
Position.159	831.15	-1032.97	2639.18	NR	Position.414	1809.837	657.028	-1296.52	NR	Position.669	3686.142	-1032.97	3081.3	NR	Position.924	4664.829	657.028	-854.401	NR
Position.160	990.782	2009.028	3552.435	NR	Position.415	1809.837	319.028	-1296.52	NR	Position.670	3845.774	2009.028	3994.555	NR	Position.925	4664.829	319.028	-854.401	NR
Position.161	990.782	1671.028	3552.435	NR	Position.416	1809.837	-18.972	-1296.52	NR	Position.671	3845.774	1671.028	3994.555	NR	Position.926	4664.829	-18.972	-854.401	NR
Position.162	990.782	1333.028	3552.435	NR	Position.417	1809.837	-356.972	-1296.52	NR	Position.672	3845.774	1333.028	3994.555	NR	Position.927	4664.829	-356.972	-854.401	NR
Position.163	990.782	995.028	3552.435	NR	Position.418	1809.837	-694.972	-1296.52	NR	Position.673	3845.774	995.028	3994.555	NR	Position.928	4664.829	-694.972	-854.401	NR
Position.164	990.782	657.028	3552.435	NR	Position.419	1809.837	-1032.97	-1296.52	NR	Position.674	3845.774	657.028	3994.555	NR	Position.929	4664.829	-1032.97	-854.401	NR
Position.165	990.782	319.028	3552.435	NR	Position.420	1969.469	2009.028	-383.267	NR	Position.675	3845.774	319.028	3994.555	NR	Position.930	4824.461	2009.028	58.854	NR
Position.166	990.782	-18.972	3552.435	NR	Position.421	1969.469	1671.028	-383.267	NR	Position.676	3845.774	-18.972	3994.555	NR	Position.931	4824.461	1671.028	58.854	NR
Position.167	990.782	-356.972	3552.435	NR	Position.422	1969.469	1333.028	-383.267	NR	Position.677	3845.774	-356.972	3994.555	NR	Position.932	4824.461	1333.028	58.854	NR
Position.168	990.782	-694.972	3552.435	NR	Position.423	1969.469	995.028	-383.267	FR	Position.678	3845.774	-694.972	3994.555	NR	Position.933	4824.461	995.028	58.854	NR
Position.169	990.782	-1032.97	3552.435	NR	Position.424	1969.469	657.028	-383.266	FR	Position.679	3845.774	-1032.97	3994.555	NR	Position.934	4824.461	657.028	58.854	NR
Position.170	1150.414	2009.028	4465.69	NR	Position.425	1969.469	319.028	-383.266	FR	Position.680	4005.406	2009.028	4907.81	NR	Position.935	4824.461	319.028	58.854	NR
Position.171	1150.414	1671.028	4465.69	NR	Position.426	1969.469	-18.972	-383.266	FR	Position.681	4005.406	1671.028	4907.81	NR	Position.936	4824.461	-18.972	58.854	NR
Position.172	1150.414	1333.028	4465.69	NR	Position.427	1969.469	-356.972	-383.266	FR	Position.682	4005.406	1333.028	4907.81	NR	Position.937	4824.461	-356.972	58.854	NR
Position.173	1150.414	995.028	4465.69	NR	Position.428	1969.469	-694.972	-383.266	NR	Position.683	4005.406	995.028	4907.81	NR	Position.938	4824.461	-694.972	58.854	NR
Position.174	1150.414	657.028	4465.69	NR	Position.429	1969.469	-1032.97	-383.266	NR	Position.684	4005.406	657.028	4907.81	NR	Position.939	4824.461	-1032.97	58.854	NR
Position.175	1150.414	319.028	4465.69	NR	Position.430	2129.101	2009.028	529.989	NR	Position.685	4005.406	319.028	4907.81	NR	Position.940	4984.093	2009.028	972.109	NR
Position.176	1150.414	-18.972	4465.69	NR	Position.431	2129.101	1671.028	529.989	FR	Position.686	4005.406	-18.972	4907.811	NR	Position.941	4984.093	1671.028	972.109	NR
Position.177	1150.414	-356.972	4465.69	NR	Position.432	2129.101	1333.028	529.989	FR	Position.687	4005.406	-356.972	4907.811	NR	Position.942	4984.093	1333.028	972.109	NR
Position.178	1150.414	-694.972	4465.69	NR	Position.433	2129.101	995.028	529.989	OL	Position.688	4005.406	-694.972	4907.811	NR	Position.943	4984.093	995.028	972.109	NR
Position.179	1150.414	-1032.97	4465.69	NR	Position.434	2129.101	657.028	529.989	OL	Position.689	4005.406	-1032.97	4907.811	NR	Position.944	4984.093	657.028	972.109	NR
Position.180	1310.046	2009.028	5378.945	NR	Position.435	2129.101	319.028	529.989	OL	Position.690	4165.038	2009.028	5821.065	NR	Position.945	4984.093	319.028	972.109	NR
Position.181	1310.046	1671.028	5378.945	NR	Position.436	2129.101	-18.972	529.989	OL	Position.691	4165.038	1671.028	5821.066	NR	Position.946	4984.093	-18.972	972.109	NR
Position.182	1310.046	1333.028	5378.945	NR	Position.437	2129.101	-356.972	529.989	OL	Position.692	4165.038	1333.028	5821.066	NR	Position.947	4984.093	-356.972	972.109	NR
Position.183	1310.046	995.028	5378.945	NR	Position.438	2129.101	-694.972	529.989	OL	Position.693	4165.038	995.028	5821.066	NR	Position.948	4984.093	-694.972	972.109	NR
Position.184	1310.046	657.028	5378.945	NR	Position.439	2129.101	-1032.97	529.989	OL	Position.694	4165.038	657.028	5821.066	NR	Position.949	4984.093	-1032.97	972.109	NR
Position.185	1310.046	319.028	5378.945	NR	Position.440	2288.733	2009.028	1443.244	NR	Position.695	4165.038	319.028	5821.066	NR	Position.950	5143.726	2009.028	1885.364	NR
Position.186	1310.046	-18.972	5378.945	NR	Position.441	2288.733	1671.028	1443.244	NR	Position.696	4165.038	-18.972	5821.066	NR	Position.951	5143.726	1671.028	1885.364	NR
Position.187	1310.046	-356.972	5378.945	NR	Position.442	2288.733	1333.028	1443.244	OL	Position.697	4165.038	-356.972	5821.066	NR	Position.952	5143.726	1333.028	1885.364	NR
Position.188	1310.046	-694.972	5378.945	NR	Position.443	2288.733	995.028	1443.244	OL	Position.698	4165.038	-694.972	5821.066	NR	Position.953	5143.726	995.028	1885.364	NR
Position.189	1310.046	-1032.97	5378.945	NR	Position.444	2288.733	657.028	1443.244	OL	Position.699	4165.038	-1032.97	5821.066	NR	Position.954	5143.726	657.028	1885.364	NR
Position.190	1469.678	2009.028	6292.2	NR	Position.445	2288.733	319.028	1443.244	OL	Position.700	3267.421	2009.028	-2492.46	NR	Position.955	5143.726	319.028	1885.364	NR
Position.191	1469.678	1671.028	6292.2	NR	Position.446	2288.733	-18.972	1443.244	OL	Position.701	3267.421	1671.028	-2492.46	NR	Position.956	5143.726	-18.972	1885.364	NR
Position.192	1469.678	1333.028	6292.2	NR	Position.447	2288.733	-356.972	1443.244	OL	Position.702	3267.421	1333.028	-2492.46	NR	Position.957	5143.726	-356.972	1885.364	NR
Position.193	1469.678	995.028	6292.2	NR	Position.448	2288.733	-694.972	1443.244	OL	Position.703	3267.421	995.028	-2492.46	NR	Position.958	5143.726	-694.972	1885.364	NR
Position.194	1469.678	657.028	6292.2	NR	Position.449	2288.733	-1032.97	1443.244	OL	Position.704	3267.421	657.028	-2492.46	NR	Position.959	5143.726	-1032.97	1885.364	NR
Position.195	1469.678	319.028	6292.2	NR	Position.450	2448.366	2009.028	2356.499	NR	Position.705	3267.421	319.028	-2492.46	NR	Position.960	5303.358	2009.028	2798.619	NR
Position.196	1469.678	-18.972	6292.2	NR	Position.451	2448.366	1671.028	2356.499	NR	Position.706	3267.421	-18.972	-2492.46	NR	Position.961	5303.358	1671.028	2798.619	NR
Position.197	1469.678	-356.972	6292.2	NR	Position.452	2448.366	1333.028	2356.499	NR	Position.707	3267.421	-356.972	-2492.46	NR	Position.962	5303.358	1333.028	2798.619	NR
Position.198	1469.678	-694.972	6292.2	NR	Position.453	2448.366	995.028	2356.499	OL	Position.708	3267.421	-694.972	-2492.46	NR	Position.963	5303.358	995.028	2798.619	NR
Position.199	1469.678	-1032.97	6292.2	NR	Position.454	2448.366	657.028	2356.499	OL	Position.709	3267.421	-1032.97	-2492.46	NR	Position.964	5303.358	657.028	2798.619	NR
Position.200	572.061	2009.028	-2021.32	NR	Position.455	2448.366	319.028	2356.499	OL	Position.710	3427.053	2009.028	-1579.2	NR	Position.965	5303.358	319.028	2798.62	NR
Position.201	572.061	1671.028	-2021.32	NR	Position.456	2448.366	-18.972	2356.499	OL	Position.711	3427.053	1671.028	-1579.2	NR	Position.966	5303.358	-18.972	2798.62	NR
Position.202	572.061	1333.028	-2021.32	NR	Position.457	2448.366	-356.972	2356.499	FR	Position.712	3427.053	1333.028	-1579.2	NR	Position.967	5303.358	-356.972	2798.62	NR
Position.203	572.061	995.028	-2021.32	NR	Position.458	2448.366	-694.972	2356.499	FR	Position.713	3427.053	995.028	-1579.2	NR	Position.968	5303.358	-694.972	2798.62	NR
Position.204	572.061	657.028	-2021.32	NR	Position.459	2448.366	-1032.97	2356.499	FR	Position.714	3427.053	657.028	-1579.2	NR	Position.969	5303.358	-1032.97	2798.62	NR
Position.205	572.061	319.028	-2021.32	NR	Position.460	2607.998	2009.028	3269.754	NR	Position.715	3427.053	319.028	-1579.2	NR	Position.970	5462.99	2009.028	3711.875	NR
Position.206	572.061	-18.972	-2021.32	NR	Position.461	2607.998	1671.028	3269.754	NR	Position.716	3427.053	-18.972	-1579.2	NR	Position.971	5462.99	1671.028	3711.875	NR
Position.207	572.061	-356.972	-2021.32	NR	Position.462	2607.998	1333.028	3269.754	NR	Position.717	3427.053	-356.972	-1579.2	NR	Position.972	5462.99	1333.028	3711.875	NR
Position.208	572.061	-694.972	-2021.32	NR	Position.463	2607.998	995.028	3269.754	NR	Position.718	3427.053	-694.972	-1579.2	NR	Position.973	5462.99	995.028	3711.875	NR
Position.209	572.061	-1032.97	-2021.32	NR	Position.464	2607.998	657.028	3269.754	NR	Position.719	3427.053	-1032.97	-1579.2	NR	Position.974	5462.99	657.028	3711.875	NR
Position.210	731.693	2009.028	-1108.07	NR	Position.465	2607.998	319.028	3269.754	NR	Position.720	3586.685	2009.028	-665.947	NR	Position.975	5462.99	319.028	3711.875	NR
Position.211	731.693	1671.028	-1108.07	NR	Position.466	2607.998	-18.972	3269.754	NR	Position.721	3586.685	1671.028	-665.947	NR	Position.976	5462.99	-18.972	3711.875	NR
Position.212	731.693	1333.028	-1108.07	NR	Position.467	2607.998	-356.972	3269.754	NR	Position.722	3586.685	1333.028	-665.947	NR	Position.977	5462.99	-356.972	3711.875	NR
Position.213	731.693	995.028	-1108.07	NR	Position.468	2607.998	-694.972	3269.754	NR	Position.723	3586.685	995.028	-665.947	NR	Position.978	5462.99	-694.972	3711.875	NR
Position.214	731.693	657.028	-1108.07	NR	Position.469	2607.998	-1032.97	3269.754	NR	Position.724	3586.685	657.028	-665.947	NR	Position.979	5462.99	-1032.97	3711.875	NR
Position.215	731.693	319.028	-1108.07	NR	Position.470	2767.63	2009.028	4183.009	NR	Position.725	3586.685	319.028	-665.947	NR	Position.980	5622.622	2009.028	4625.13	NR
Position.216	731.693	-18.972	-1108.07	NR	Position.471	2767.63	1671.028	4183.009	NR	Position.726	3586.685	-18.972	-665.947	NR	Position.981	5622.622	1671.028	4625.13	NR
Position.217	731.693	-356.972	-1108.07	NR	Position.472	2767.63	1333.028	4183.009	NR	Position.727	3586.685	-356.972	-665.947	NR	Position.982	5622.622	1333.028	4625.13	NR
Position.218	731.693	-694.972	-1108.07	NR	Position.473	2767.63	995.028	4183.009	NR	Position.728	3586.685	-694.972	-665.947	NR	Position.983	5622.622	995.028	4625.13	NR
Position.219	731.693	-1032.97	-1108.07	NR	Position.474	2767.63	657.028	4183.009	NR	Position.729	3586.685	-1032.97	-665.947	NR	Position.984	5622.622	657.028	4625.13	NR
Position.220	891.325	2009.028	-194.813	NR	Position.475	2767.63	319.028	4183.009	NR	Position.730	3746.317	2009.028	247.308	NR	Position.985	5622.622	319.028	4625.13	NR
Position.221	891.325	1671.028	-194.813	NR	Position.476	2767.63	-18.972	4183.009	NR	Position.731	3746.317	1671.028	247.308	NR	Position.986	5622.622	-18.972	4625.13	NR
Position.222	891.325	1333.028	-194.813	NR	Position.477	2767.63	-356.972	4183.009	NR	Position.732	3746.317	1333.028	247.308	NR	Position.987	5622.622	-356.972	4625.13	NR
Position.223	891.325	995.028	-194.813	NR	Position.478	2767.63	-694.972	4183.009	NR	Position.733	3746.317	995.028	247.308	NR	Position.988	5622.622	-694.972	4625.13	NR
Position.224	891.325	657.028	-194.813	NR	Position.479	2767.63	-1032.97	4183.009	NR	Position.734	3746.317	657.028	247.308	FR	Position.989	5622.622	-1032.97	4625.13	NR
Position.225	891.325	319.028	-194.813	NR	Position.480	2927.262	2009.028	5096.264	NR	Position.735	3746.317	319.028	247.308	FR	Position.990	5782.254	2009.028	5538.385	NR
Position.226	891.325	-18.972	-194.813	NR	Position.481	2927.262	1671.028	5096.264	NR	Position.736	3746.317	-18.972	247.308	FR	Position.991	5782.254	1671.028	5538.385	NR
Position.227	891.325	-356.972	-194.813	NR	Position.482	2927.262	1333.028	5096.264	NR	Position.737	3746.317	-356.972	247.308	NR	Position.992	5782.254	1333.028	5538.385	NR
Position.228	891.325	-694.972	-194.813	NR	Position.483	2927.262	995.028	5096.264	NR	Position.738	3746.317	-694.972	247.308	NR	Position.993	5782.254	995.028	5538.385	NR
Position.229	891.325	-1032.97	-194.813	NR	Position.484	2927.262	657.028	5096.264	NR	Position.739	3746.317	-1032.97	247.308	NR	Position.994	5782.254	657.028	5538.385	NR
Position.230	1050.957	2009.028	718.442	NR	Position.485	2927.262	319.028	5096.264	NR	Position.740	3905.949	2009.028	1160.563	NR	Position.995	5782.254	319.028	5538.385	NR
Position.231	1050.957	1671.028	718.442	NR	Position.486	2927.262	-18.972	5096.264	NR	Position.741	3905.949	1671.028	1160.563	NR	Position.996	5782.254	-18.972	5538.385	NR
Position.232	1050.957	1333.028	718.442	FR	Position.487	2927.262	-356.972	5096.264	NR	Position.742	3905.949	1333.028	1160.563	NR	Position.997	5782.254	-356.972	5538.385	NR
Position.233	1050.957	995.028	718.442	FR	Position.488	2927.262	-694.972	5096.264	NR	Position.743	3905.949	995.028	1160.563	NR	Position.998	5782.254	-694.972	5538.385	NR
Position.234	1050.957	657.028	718.442	FR	Position.489	2927.262	-1032.97	5096.264	NR	Position.744	3905.949	657.028	1160.563	NR	Position.999	5782.254	-1032.97	5538.385	NR
Position.235	1050.957	319.028	718.442	FR	Position.490	3086.894	2009.028	6009.519	NR	Position.745	3905.949	319.028	1160.563	OL					
Position.236	1050.957	-18.972	718.442	OL	Position.491	3086.894	1671.028	6009.519	NR	Position.746	3905.949	-18.972	1160.563	FR	OL: Out of limit				
Position.237	1050.957	-356.972	718.443	OL	Position.492	3086.894	1333.028	6009.519	NR	Position.747	3905.949	-356.972	1160.563	FR	FR: Fully Reachable				
Position.238	1050.957	-694.972	718.443	FR	Position.493	3086.894	995.028	6009.519	NR	Position.748	3905.949	-694.972	1160.563	FR	PR: Partially Reachable				
Position.239	1050.957	-1032.97	718.443	FR	Position.494	3086.894	657.028	6009.519	NR	Position.749	3905.949	-1032.97	1160.563	NR	C : Clash				
Position.240	1210.589	2009.028	1631.697	NR	Position.495	3086.894	319.028	6009.519	NR	Position.750	4065.582	2009.028	2073.818	NR	NC: Not Computed				
Position.241	1210.589	1671.028	1631.698	NR	Position.496	3086.894	-18.972	6009.519	NR	Position.751	4065.582	1671.028	2073.818	NR					

Figure 8: *Example of data gotten from using the "Auto place robot" tool*