INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO
MESTRADO EM ENGENHARIA MECÂNICA

isep

Optimization and improvement of NSCU 1.0. Universal Functional Tester produced by Evoleo Technologi

SANDRA LUDCZAK
Fevereiro de 2016

POLITÉCNICO
DO PORTO

ERASMUS PROJECT

EVOLEO TECHNOLOGIES

Author

SANDRA ŁUDCZAK (1150197)

27.JAN.2016

Acknowledgements

People collaborating in the presented Erasmus Project are listened below:

Ing. Rodolfo Martins is the owner and main chef of EVOLEO Technologies company in which the project was carried out. He was the one to acquaint me into the project, showed main tools for comparing products in the manufacturing process and presented Project Development Process Theories, such as: System Requirements Review, Product Development & Analysis, Critical Design Review. Also, his main role in the project was to monitor the work progress and specify the path of development. Rodolfo Martins was a great help during fulfilling this project and always was open for new ideas.

Ing. Tiago Silva is team member of the Mechanical Team and also supervisor of this project. Thanks to him I have learned a lot about the computer-aided engineering software program Solidworks. Always when doubts or questions have been raised he gave me a helping hand. Together we discussed upcoming ideas, concepts, work progress etc. From my observations he was one of the most efficient employees and EVOLEO Technologies should feel happy to have him.

Ing. Helder Fonseca is one of the General Managers in Evoleo Technologies. He helped me during the verification of requirements, choosing key drivers for my project and providing me with helpful books and information when it was necessary.

Ing. Sara Freitas and Ing. Isabel Pinto – Ing. Freitas and Ing. Pinto helped me to understand the main driver factors I should consider in my project. Together we managed to chose adequate verification methods and define planned actions. Both ladies had always a smile on their faces and were open for any help.

Abstract

The aim of the project was to improve an existing testing machine that is produced by the company EVOLEO Technologies. New conceptions of each part have been invented in order to produce an innovative unit that combines optimal segments from the old construction with the new, improved ones. The machine is meant to be testing different kind of devices that use specific elements like: buttons, knobs, monitors. The main purpose is to create various concepts of components that could be changed in order to lower the cost, weight or to simplify the operating process. Figure 1. shows the already existing discussed device.

Figure 1. NSCU 1.0. Universal Functional Tester – testing machine produced by Evoleo Technologies.

Keywords

Optimization process, Testing machine, EVOLEO Technologies, Device modelling, Automated testing.

List of Contents

List of Symbols and Abbreviations

Abbreviation	Meaning
CDR	Critical Design Review
CEO	Chief Executive Officer
DUT	Device Under Test
ECTS	European Credits Transfer System
EU	European Union
FIT	Failure In Time
MTBF	Mean Time Between Failure
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
PDA	Product Development & Analysis
SME	Small or Medium Enterprise
SRR	System Requirements Review
VCD	Verification Control Document
WCA	Worst Case Analysis

1. INTRODUCTION

Company characterization

The problem

Methods used

1. Introduction

This work was carried out based on an ERASMUS PROJECT in order to receive 30 ECTS points in the academic year 2015/2016. In association with the company EVOLEO TECHNOLOGIES it was possible to initiate a project under the name: "Optimization and improvement of NSCU 1.0. Universal Functional Tester produced by EVOLEO Technologies". In this project the main goal was to optimize the already existing Universal Functional Tester Machine.

1.1. Company characterization

EVOLEO Technologies is a Portuguese SME investing in skills related to the design of critical and highly complex electronic systems. EVOLEO embraces five areas of activity: Space, Transportation, Energy, Health and Industry. Its mission is to provide high-end and differentiated electronic engineering solutions, seeking continuous improvement, flexibility, quality and customer oriented innovation. Its main partners are: Efacec, ESA, EMEF. One of their clients is even BOSCH company. EVOLEO Technologies searches and promotes partnerships and networking with centres of knowledge and industry players in line with its mission of providing high-end and differentiated electronic engineering solutions, seeking continuous improvement, flexibility, quality and customer oriented innovation [1]. EVOLEO Technologies is located in Rua Gonçalo Mendes da Maia 1350–1H, Pedrouços, Maia in Portugal. The work group is created by 20 people, in which there is one main chef, the CEO (Chief Executive Officer), one Deputy CEO, four General managers and 14 engineers working in 7 different classified groups. The organisation chart is shown in Figure 2. The CEO, Deputy - CEO and the General Managers create an own group called *Technical Management Team.*

Currently the company is leading six projects: TDP8, GaNSAT, SEAS, NewP@ss, PEDDIR and CARCODE. For more information it is recommended to visit the website http://evoleotech.com/company/projects/ .

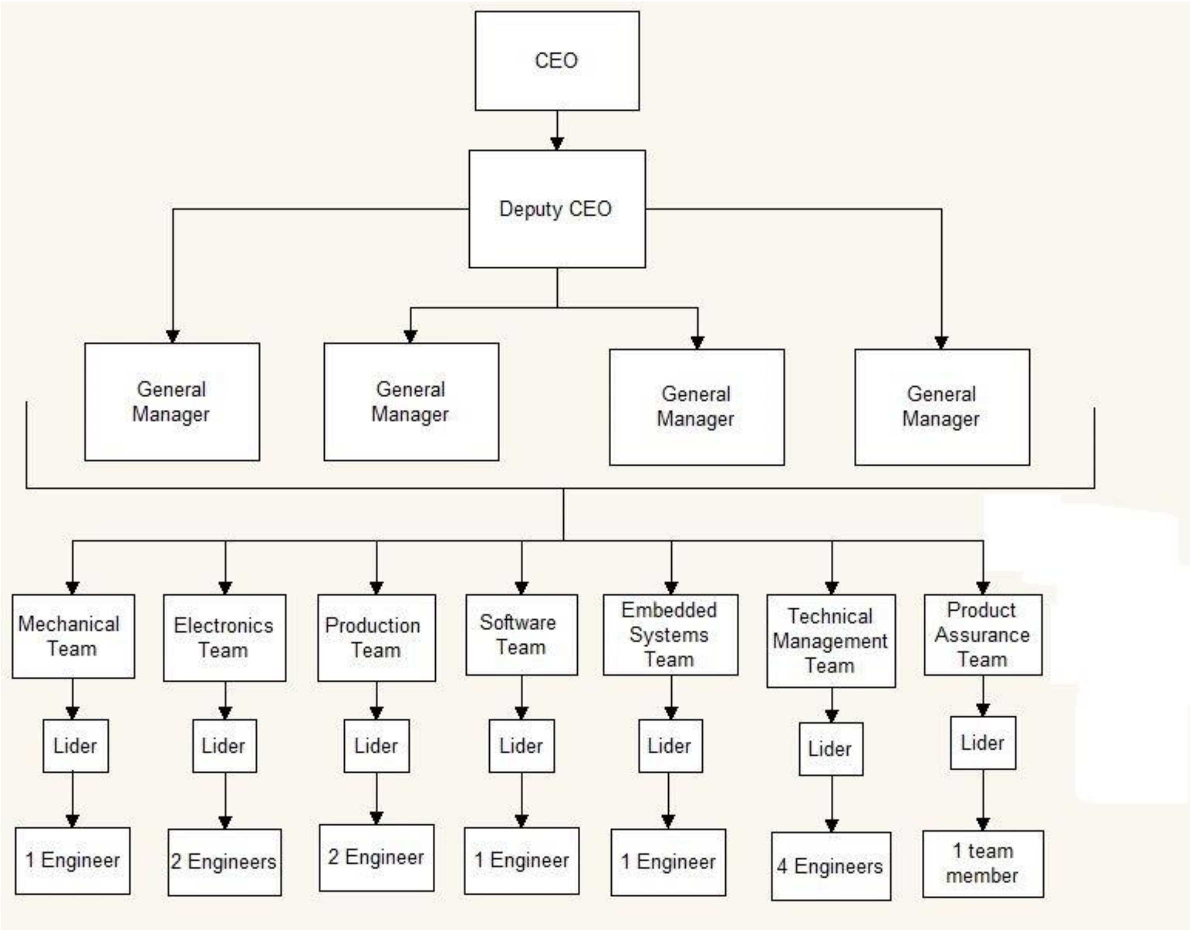


Figure 2. EVOLEO Technologies organisation chart.

1.2. The Problem

In September 2015 EVOLEO Technologies has released the first model of an Universal Functional Tester Machine which main purpose was to test components of a specific device, shown in Figure 3. It is a device produced by BOSCH company. The units that needed to be tested were: the buttons, knob and display. The problem with the prototype machine was that it was customized just to accommodate one specific device (or one with similar dimensions to the ones shown in Figure 3). The need to improve the Universal Functional Tester occurs. It needed to be able to test different – shaped products as well as measure in angles. First, the whole machine was divided into 3 parts, called in this project: *Upper part* – responsible for horizontal movement of the testing ending, *Middle part* – responsible for its vertical movement and *Lower part – being the* placement of product unit with adequate needle pad. Every single stage of the project is mentioned below.

Figure 3. BOSCH product – to be tested.

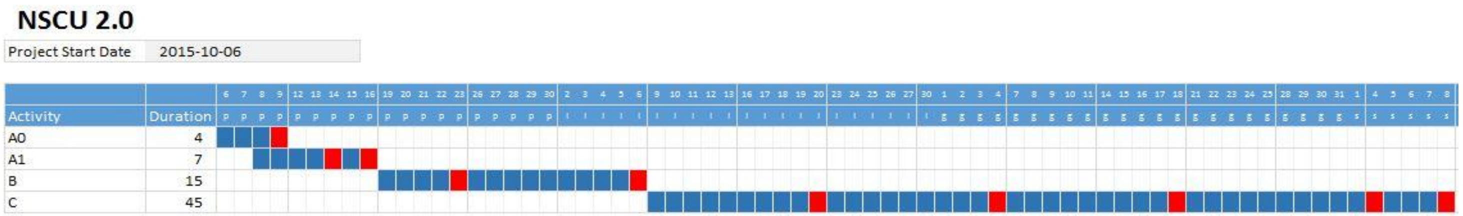
1.3. Methods used

In order to solve the received task it was necessary to do some researches of already existing solutions in the internet, get knowledge from people working at the company who are more experienced in the topic, as well as undergo brain storming[1] sessions with friends and colleagues. Very helpful was also reaching for literature such as: *Dietrich M., Podstawy Konstrukcji Maszyn, Tom 1, Wydawnictwo Naukowo – Techniczne, Tom I, Tom II, 1999, Niezgodziński Michał E., Niezgodziński T., Wytrzymalość materiałów PWN, Warszawa, 2002.* The first stage of the project was to come up with own solutions not to be inspired by any already existing concepts. At this point the main goal of the final project was given (without any details) and imaginary solutions were created. Later, the previous Machine was presented (in order to receive more detailed information) and the old version was optimised. The last step was to create completely new and innovative parts, that needed to be cheap and very reliable. Additionally, in order to evaluate the invented concepts they were designed in the computer-aided engineering software SolidWorks.

[1] Process for generating creative ideas and solutions through intensive and freewheeling group discussion. Every participant is encouraged to think aloud and suggest as many ideas as possible, no matter seemingly how outlandish or bizarre. Analysis, discussion, or criticism of the aired ideas is allowed only when the brainstorming session is over and evaluation session begins.

1.4. Methods

A GANTT chart has been created in order to organize the work and track the achieved results in time. The red fields point out the 'milestones' executed in each phase. It is presented in the Figure 4.



Development phases		Outputs
A0	Concept Phase - User Requirements	Requirement list
A1	Concept Phase - Concept Definition	SWOT or Pros & Cons VCD
B	Preliminary Design	PDR
C	Detailed Design	CDR

A0	2015-10-09	Requirement List
A1	2015-10-14	First concept
A1	2015-10-16	SWOT or Pros & Cons Analysis
B	2015-10-23	First PDR - definition othe subsystems
B	2015-11-06	PDR
C	2015-11-20	Status update
C	2015-12-04	Status update
C	2015-12-18	Status update
C	2015-01-02	CDR
C	2015-01-08	CDR - Final

Figure 4. GANTT chart of the project.

BACKGROUND

Requirements analysis

Product Development Process

Reliability – theoretical terms

2. Background

2.1. Requirements analysis

The first step in designing the Universal Functional Tester was to establish requirements, which the machine needs to fulfil. These mechanical requirements have been divided into two categories – one that have been given by BOSCH company, the other one that have been established by EVOLEO company, during the designing process.

2.1.1. Principal requirements

The company which commissioned the order to test their specified product (Figure 5) came up with special mechanical requirements that should be considered while designing the device. Additionally, the firm emphasized that they are planning to produce a new product in the near future. Its size will be much bigger so the testing machine should be able to accommodate different kinds of products that are needed to be tested. The main conditions are listened underneath. The whole list can be found in the Appendixes Chapter (Attachement 1).

Figure 5. BOSCH product – to be tested.

- The platform shall have a vision system with controlled lighting (darkroom)
- The platform should have a pressure system allowing the mechanical performance of testing the buttons of the product (linear - controller => XY coordination, actuator rotatable with suction (vacuum) to allow the rotation of knob)

- The vision and pinch systems should be programmable in space (x, y) whenever necessary test another type of product
- Exchange of the movable table, on which the product is placed should be done quickly, not slower than 1 min
- The platform should be provided with an interconnection system between measuring equipment and the test fixture
- The connection interface systems should support at least:
    - 2 x RJ45 Cat5e FTP;
      2 X USB 2.0
      Pneumatic -2 x (4mm w / check valve)
      20 X coaxial lines (10x 50 Ohm + 10x 75 Ohm)
      60 X signal lines;
      20 X lines to 230V / 5A
- The platform must be prepared to receive fixture / jig with dimensions enabling the product testing dimensions up to (400 mm x 300 mm x 100 mm)
- The platform must have a 19" rack with a minimum capacity of 12 V
- The platform should be movable
- The Test fixture should be compatible with the platform
- The Test fixture should have a base capable of placing the product
- The test fixture should have a bed of needles (behind) helping to relate the connection points of the product with the machine
- The maximum size of the JIG and / or equipment for placing the product is 80 mm x 90 mm x 110mm
- The platform should respect the BOSCH Standard N62A
- The JIG should allow product updates => exchanging of tested element

- The maximum weight of the JIG and / or equipment for placing the product must be limited to a maximum of 100 N
- If the cassettes weight is more than 100 N (up to 180 N) it has to be supported by another construction

2.1.2. Company requirements

A large list of requirements has been created (Attachement 1). In order to evaluate the different concept ideas in terms of these requirements, they needed to be divided into smaller factors which are listened in Table 1.

Table 1. Key drivers of the project.

Reliability
Maintainability
Availability
Safety
Cost
Functionality
Operability
Appearance

2.2. Product Development Process

In order to start the problem solving of this project it was essential to gain knowledge about the different phases each project requires during its manufacturing process. In theory each product development process is defined by six main phases. Each phase is listened and explained below.

Product Development Process [2] – it is a system of defined steps and tasks (e.g. strategy, organization, concept generation, marketing plan creation, evaluation, and commercialization) of a new product. During that cycle companies establish ideas to follow in order to reach a visible goal at a certain period of time. The different phases of the Product Development Process are following:

A. Conceptual phase [3] – in this phase of project planning the attention is focused on producing ideas and analysing its advantages and disadvantages. The main goal of this phase is to minimize the likelihood of error, manage costs, assess risks, and evaluate the potential success of the intended project.

The conceptual phase in this project was divided into another two phases:

A0. User requirements – It was focused on analyzing and evaluating the requirements given by the principal company (in the case of this project – BOSCH company). Most important key drivers have been chosen, requirements have undergone some changes and future actions considering chosen factors have been planned. Very helpful in this stage was the SRR.

SSR (System Requirements Review) – It is a review aimed to ensure that system requirements have been completely and properly identified and that a clear understanding between the principal and the mandatory exists.

A1. Concepts & System Requirements – in this phase the first concepts have been created, their SWOT analysis have been made and comparisons were undergone.

SWOT analysis – As the letters suggest SWOT is the meaning of Strengths, Weaknesses, Opportunities and Threads of the manufactured, new product concept. Each concept was evaluated by usage of that method. Later, the outcome of has been compared and the best solution has been chosen.

B. PDA (Preliminary Design Analysis) phase – In this stage of the project the different interfaces and subsystems are being defined in order to be aware of all equipment that needs to be considered when producing the given object. A very useful thing is to withdraw connections between the different subsystems and define their sublevels (up to precisely designate their specification). One of the most important analysis that need to be evaluated at this time is the Worst Case Analysis (WCA). Previous material choices are being made.

WCA (Worst Case Analysis) [4] – It is a very important step during manufacturing process. The WCA is meant to detect defects and deficiencies prior to the production and delivery phase and eliminate them. The WCA usually includes stress and derating analysis, failure modes and critical effects as well as reliability prediction. During the WCA it needs to be verified if the product is robust enough to provide operation which meets the system performance specification.

C. Detailed design phase – During the detailed design the manufactured product is being fully defined wherein each subsystem is fully specified. Update of requirements list is highly required. At this stage the Critical Designed Review (CDR) is utilized. Also, some CAD models of the given concept are being made which give valuable information about the three dimensional movement possibilities of the designed product.

CDR (Critical Designed Review) – A strict review over the Verification Control Document is undertaken in which it is determined if the detailed design is satisfying. Eventual changes are being implemented.

D. Testing & Verification phase – During that phase the final concept is being produced. A lot of tests need to be undergone in order to verify the robustness, reliability, functionality etc. Of the manufactured unit. If any deviations from desired norms are being observed one more time the VCD needs to be overviewed and eventually changed.

E. Validation phase – this phase is usually realized together with the principal and the mandatory. The main goal is to prove if the system does exactly what it was built for. One more time it needs to be tested if the machine fulfills all established requirements. It is the last time to amend any changes if necessary.

2.3. Reliability – theoretical terms

In order to come up with innovative solutions that will be reliable valuable knowledge about the below mentioned terms must have been adopted.

Mean Time Between Failure (MTBF) is a reliability term used to provide the amount of failures per million hours for a product. This is the most common inquiry about a product's life span, and is important in the decision-making process of the end user [1].

Mean Time To Repair (MTTR) is the time needed to repair a failed module [1].

Mean Time To Failure (MTTF) is a basic measure of reliability for non-repairable systems. It is the mean time expected until the first failure of a piece of equipment. MTTF is a statistical value and is meant to be the mean over a long period of time and a large number of units. Technically, MTBF should be used only in reference to a repairable item, while MTTF should be used for non-repairable items. However, MTBF is commonly used for both repairable and non-repairable items [1].

Failure In Time (FIT) is another way of reporting MTBF. FIT reports the number of expected failures per one billion hours of operation for a device. This term is used particularly by the semiconductor industry but is also used by component manufacturers. FIT can be quantified in a number of ways: 1000 devices for 1 million hours or 1 million devices for 1000 hours each, and other combinations. FIT and CL (Confidence Limits) are often provided together [1].

$$\mathbf{MTBF} = \mathbf{MTTF} + \mathbf{MTTR} \qquad [1]$$

3. DEVELOPMENT

Problem Analysis

Brainstorming and Preliminary drafts

Selecting the best idea

Developing the main idea

Budgeting

Critical Analysis and Prospects of Development

Equipment Instruction Manual

Maintenance Guidelines

3. Development

In this section, the product manufacturing development is carried out and presented. It is divided into sub – sections in order to distinguish consecutive steps of the work progress.

3.1. Problem analysis

The problem presented in chapter 1.2. needed to be solved. The already existing Testing Machine produced by EVOLEO Technologies needed some very important changes to be made. Firstly, it was to be guaranteed that the future (second edition) device will be able to accommodate products provided with different shapes and sizes, not just one (see Figure 3). That need came up because of future cooperation with BOSCH company, which was seeking the discussed need for testing their new, innovative products. Secondly, the NSCU 1.0. (that is the name given by EVOLEO Technologies for the prototype of the Universal Functional Tester), was not able to test the different devices in angles. If a new product with non – flat areas would be needed to be tested it would not be possible in the old version, which was using only linear actuators. Another problem was being faced – the machine needs to measure in angles. These two mentioned aspects were the main and most important goals of this project. If it would be possible to solve them while improving the cost aspects, appearance, innovation etc. It would be a great advantage.

3.2. Preliminary drafts

The NSCU 2.0 Testing Machine was split into 3 parts. So called ‘upper part’ representing movement in the XY axis, ‘middle part’ realizing the vertical movement and being the actual testing device (with testing endings) and ‘lower part’ being the fixture of the tested product together with the needle pad. In order to visualise which parts of the Universal Functional Tester are meant the old version with mentioned parting is being shown in Figure 6 and Figure 7. These section was divided into three parts, concerning preliminary concepts of each part.

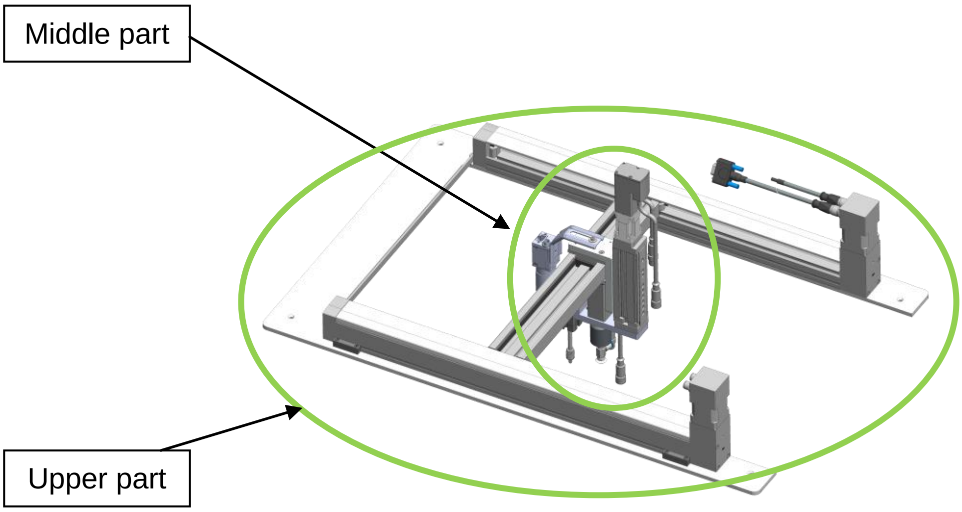


Figure 6. Upper and middle part.

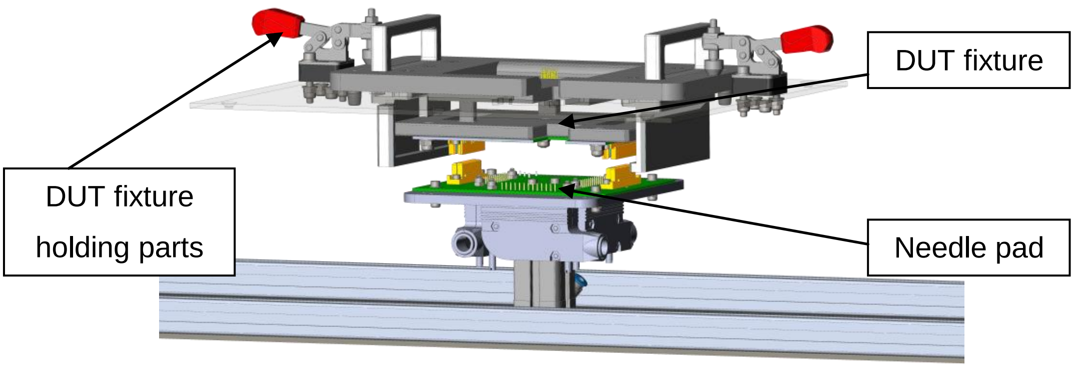


Figure 7. Lower part.

3.2.1. Upper part concepts

Concept I – XY Table

The NSCU 1.0 Prototype Universal Functional Tester used an EXCM XY – Table from Festo company in order to realize the horizontal movement (Figure 8). The table is programmable. It places the actuator at specific XY coordinates in order to undergo the testing at the right position.

Figure 8. EXCM XY - Table from Festo company.

Concept II – Electrical platform with magnet

The upper part is a surface equipped in wire paths that lead current. Thanks to a camera attached to the device the coordinates of the desired tested elements are known. The electricity is lead to the exact XY coordinates. This affects the lower placed magnet, which is connected with the lower testing part, to move in the right position. In order to stop the magnet at a desired position the electrical field needs to be switched off after a certain time. If we know that the delay of the current equals X it is possible to stop the magnet at the wanted length at t – X, where t is the time without counting the delay.

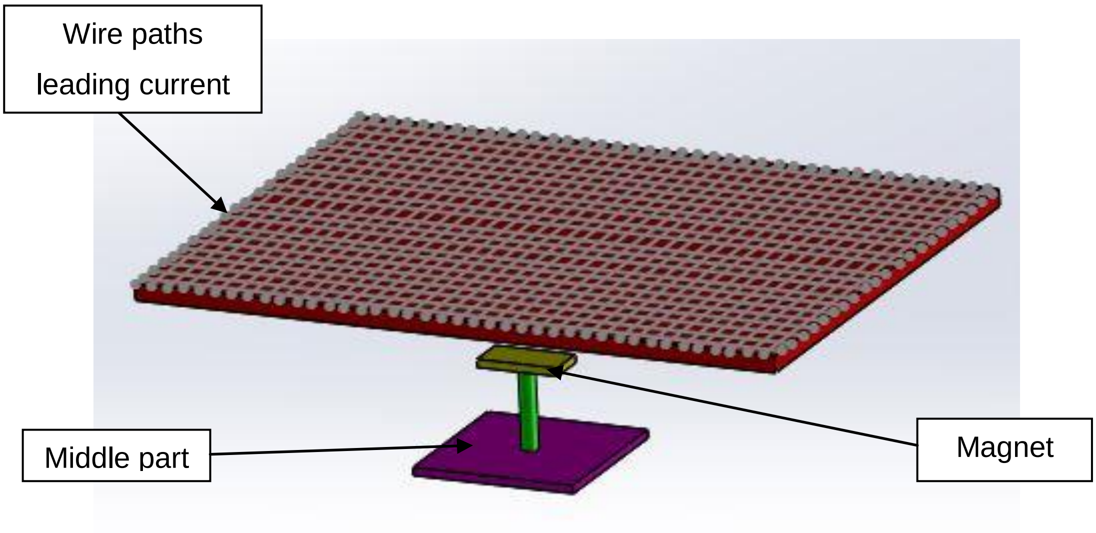


Figure 9. Electrical platform concept.

Concept III – Robotic arm

The rotational movement is realized by a thrust ball bearing. In order to increase the range of mobility of the part an electric actuator is used as shown in Figure 10. Due to that part it is possible to reach the whole desired movement range. Below the mentioned actuator the middle part with the actual testing endings is placed. The joint is realized in a way allowing hinge movement. The system helps in the mobility incensement.

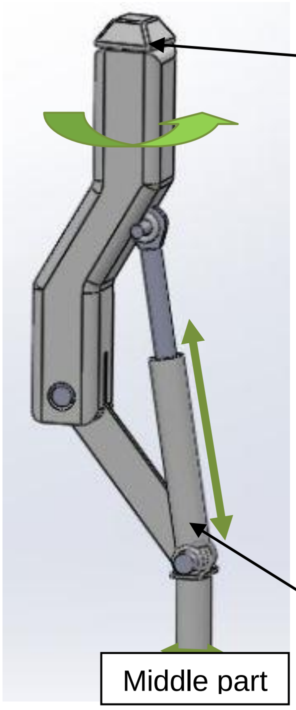


Figure 10. Robotic arm concept.

3.2.2. Middle part concepts

Two main concepts of the middle part (Figure 11) have been created. The middle part was the actual unit that needed to be completely improved, that is why the time focused on this particular device was the longest regarding the whole project. All resulting ideas are summerized below.

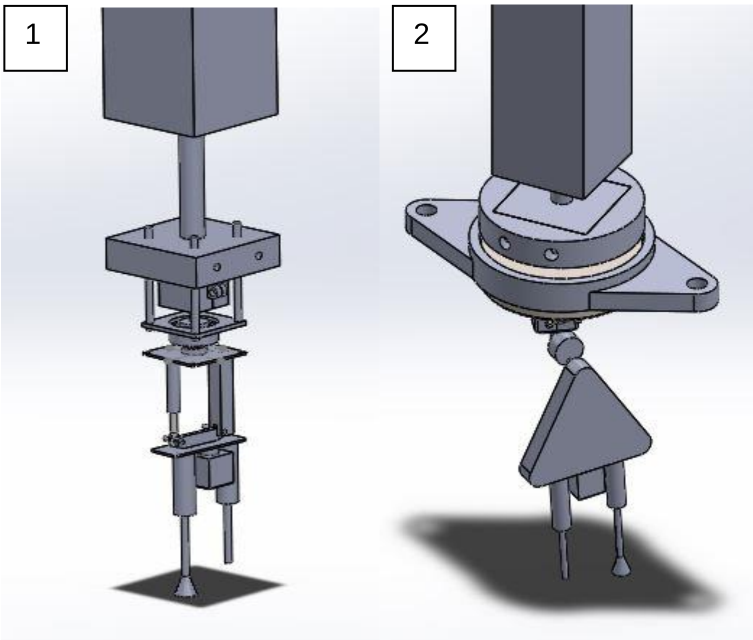


Figure 11. Middle part concepts.

Solution number 2 uses one ball bearing and two servo motors. Possible movements of the construction are shown in Figure 12. The Z – actuator that is already available to the company is used for the vertical movement. An servo mechanism is attached to the Z – actuator, causing rotational movement. In order to relieve the servo motor from axial loads an additional part is placed onto it, that connects it with a bearing – now the bearing is responsible for holding the forces. In order to rotate this servo motor, another servo motor is positioned horizontally to be able to enable lateral movement of the actual testing parts.

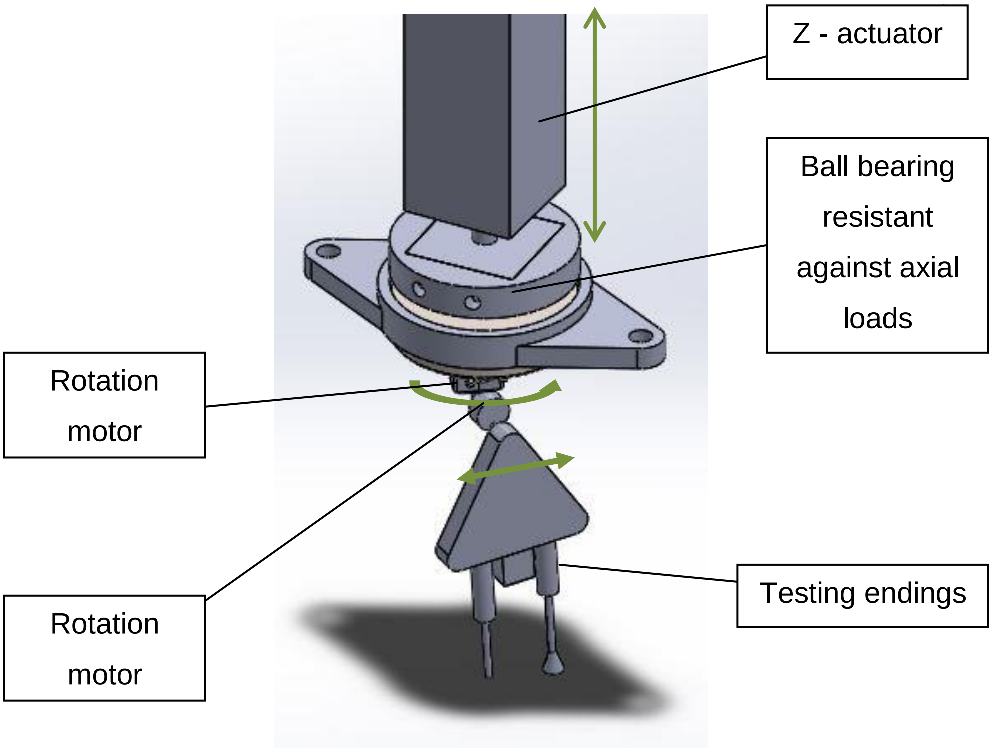


Figure 12. Servo motor middle part concept.

Solution number 1 (Figure 11;1) uses a ball bearing, one servo motor and one electric actuator. Possible movements of the construction are shown in Figure 13. The Z – actuator that is already available to the company is used for the vertical movement. A servo mechanism is used to cause rotation movement. All axial forces are taken over by the bearing due to an element that connects it with the part being attached to the servo mechanism. The main difference between solution 1 and 2 is that solution 1 in order to provide horizontal movement uses an electric actuator that while moving cause inclination of the testing parts. The construction is reliable, because the whole mass is placed vertically (no side elements) and also resistant due to using a stabilizing element and electrical actuator (massive construction).

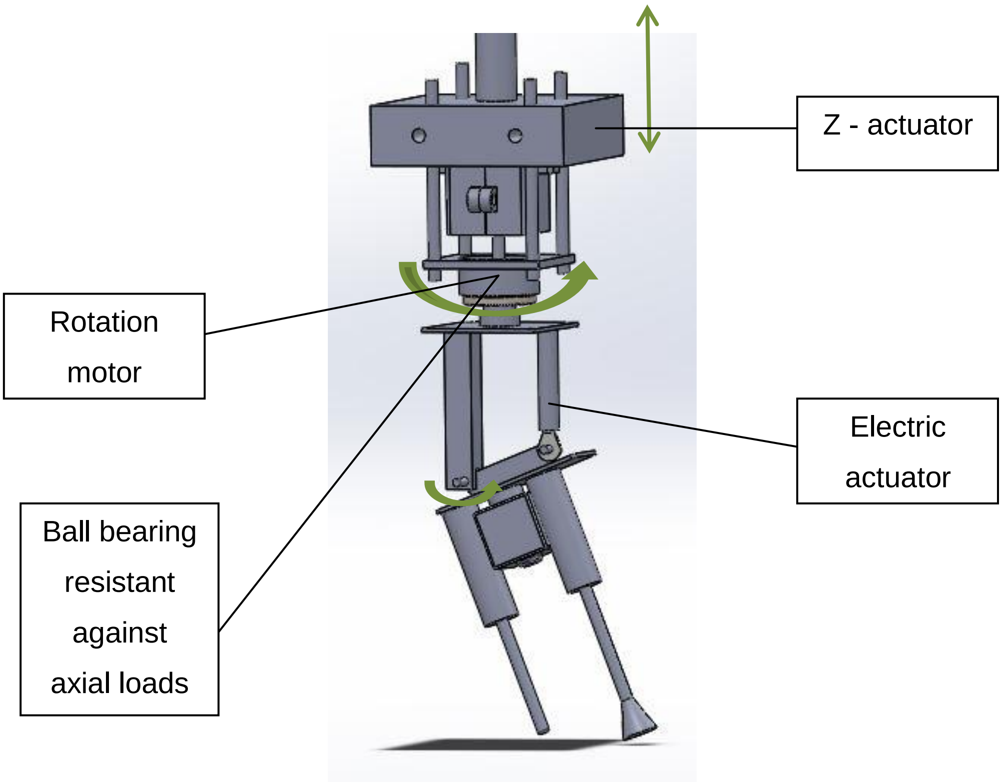


Figure 13. Electric actuator middle part solution - possible movements.

3.2.3. Lower part concepts

The lower part consists of the upper – product holding DUT fixture and the bottom – needle pad holding. Two concepts are shown in Figure 14 (1 – the new, innovative one, 2 – the one used in the previous NSCU 1.0. Universal Functional Tester).

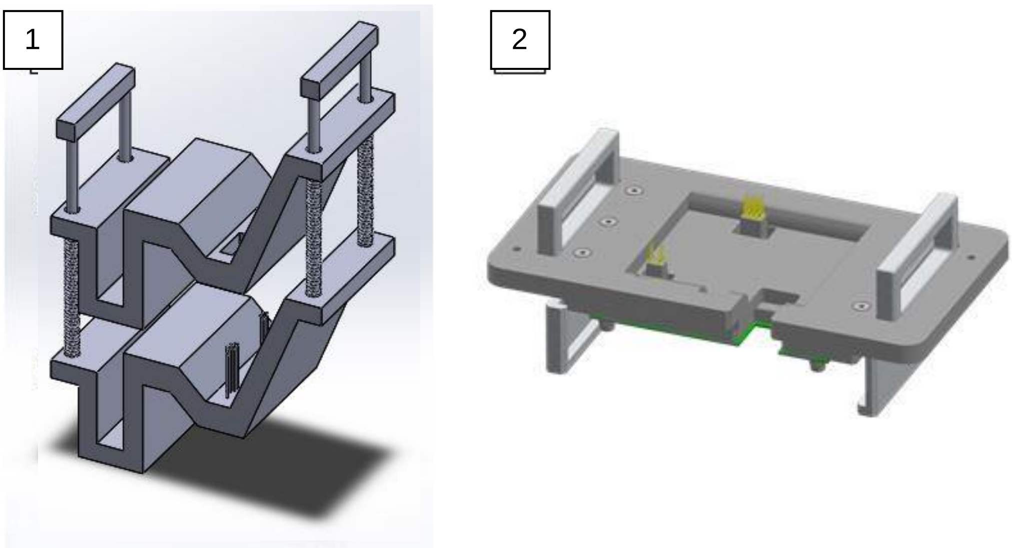


Figure 14. Concepts of Lower part.

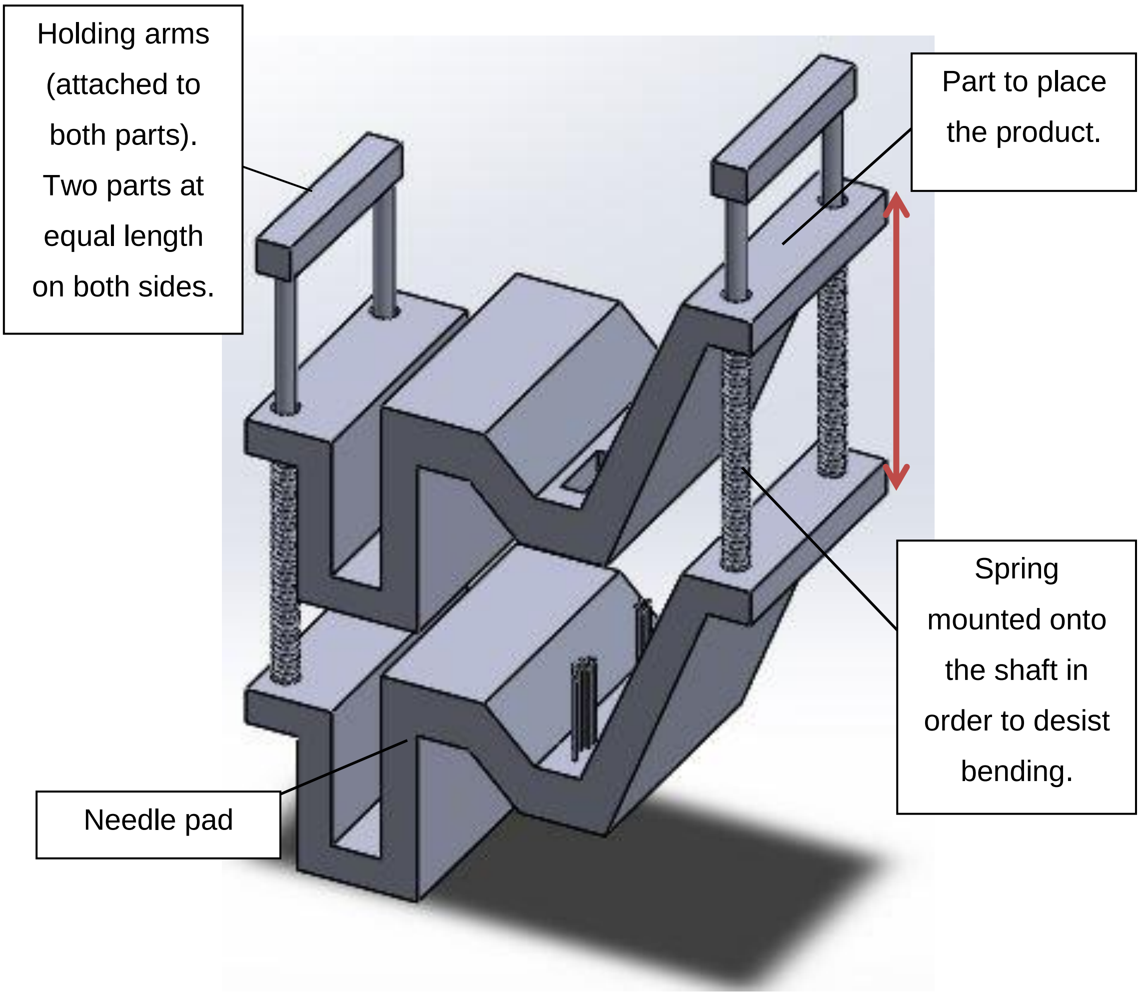


Figure 15. Lower part concept.

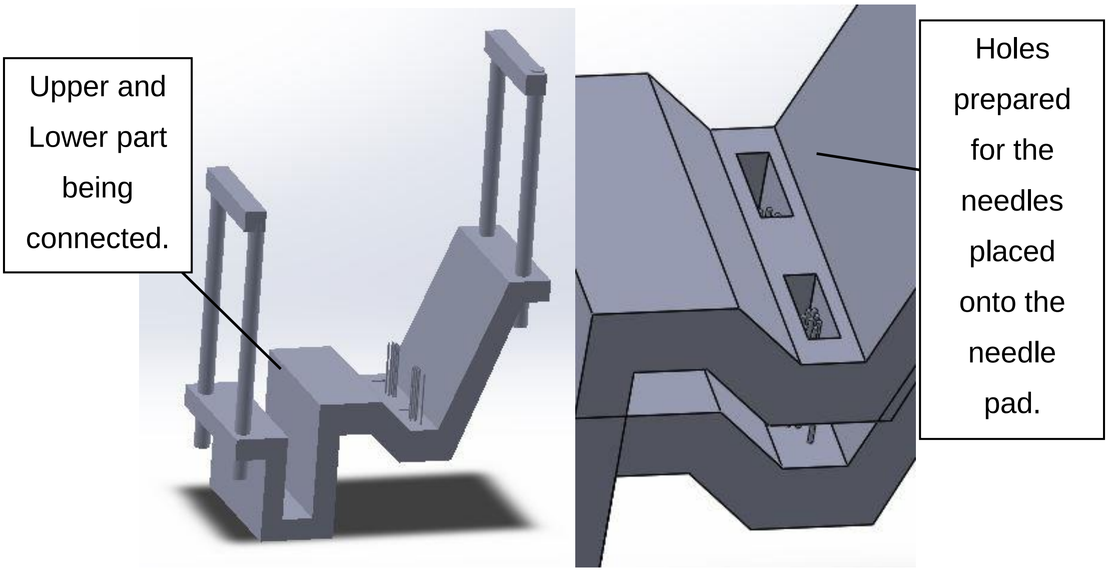


Figure 16. Explanaition of the lower part solution.

Solution number 1 uses expansion springs which hold the needle pad apart from the element responsible for placing the tested product. When the whole testing process begins the

upper part being placed onto the product (for reducing the movement almost to zero) pushes the upper element onto the needle pad – and so connects the needles with their destination. Additionally, the upper part is provided in holes corresponding to the places where the several needles are placed. No complicated mechanisms must be applied and the usage of an electric actuator raising the needle pad is redundant. The construction can be exchanged fast because of a holding element attached to both parts. That is a huge advantage.
Solution number 2 which is already used by EVOLEO Technologies uses an electric actuator which raises the needle pad in order to connect with the product. The construction can be also exchanged fast because of a holding element attached to both parts.

Concepts of holding part of the placed product in the DUT fixture have been made. The results are shown below.

Concept I – Spring holdings

The product is placed in the centre of the table. Two holding platforms on the side, equipped in springs are pushing against the product preventing its movement. On the other two sides there are tapes that stop the movement of the other two edges. Special clips are used to hold the platforms while placing the product which then are released in order to hold the sample.

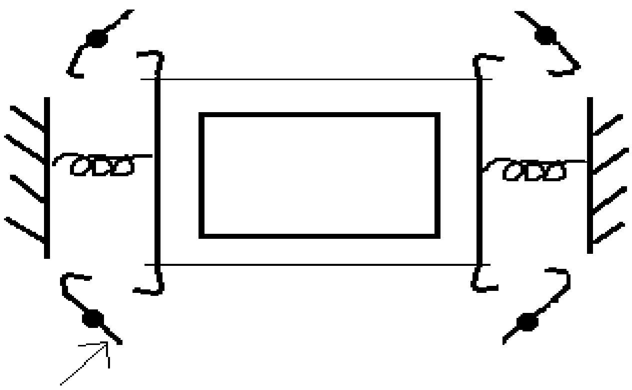


Figure 17. Spring holding concept.

Concept II – Tape

The product is adhered to a rough surface. A tape is fixed on its corner and is being loosen or tighten depending on desire to rigidly place the product or exchange it.

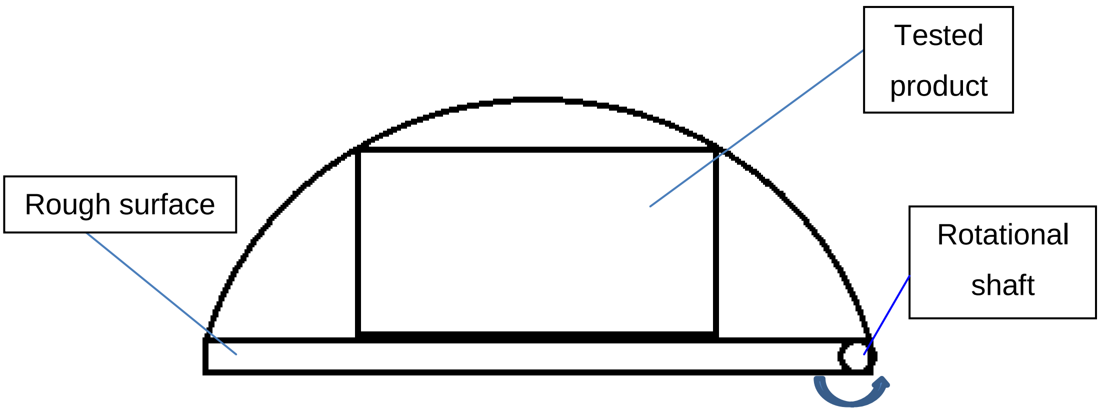


Figure 18. Tape table.

Concept III – Corner holdings

On two opposite corners are holding blocks that are connected with tapes. These tapes are rolled up on special blocks that automatically release (while exchanging the product) or strengthen (while holding it still). To consider: The blocks used to manipulate the tape could be placed on both sides – a possibility of constant releasing and strengthening of tape would provided.

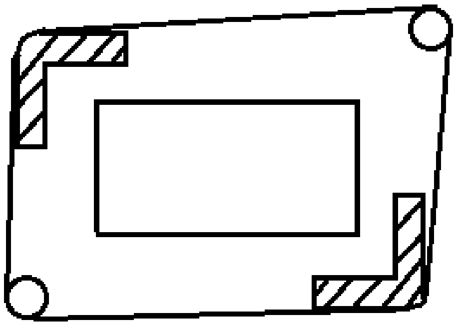


Figure 19. Corner holdings.

The element that is responsible for holding the product to be tested is presented in Figure 20. Drawing a) shows a solution using a shaft that while moving horizontally cause displacement of the blocks due to a tape that is (depending on the wanted result) tensioned or loosened. A similar solution is shown in Figure b) where the difference lies in the shafts, which in this example rotate, causing the winding and unrolling of the tape => resulting as well with displacement of the blocks.

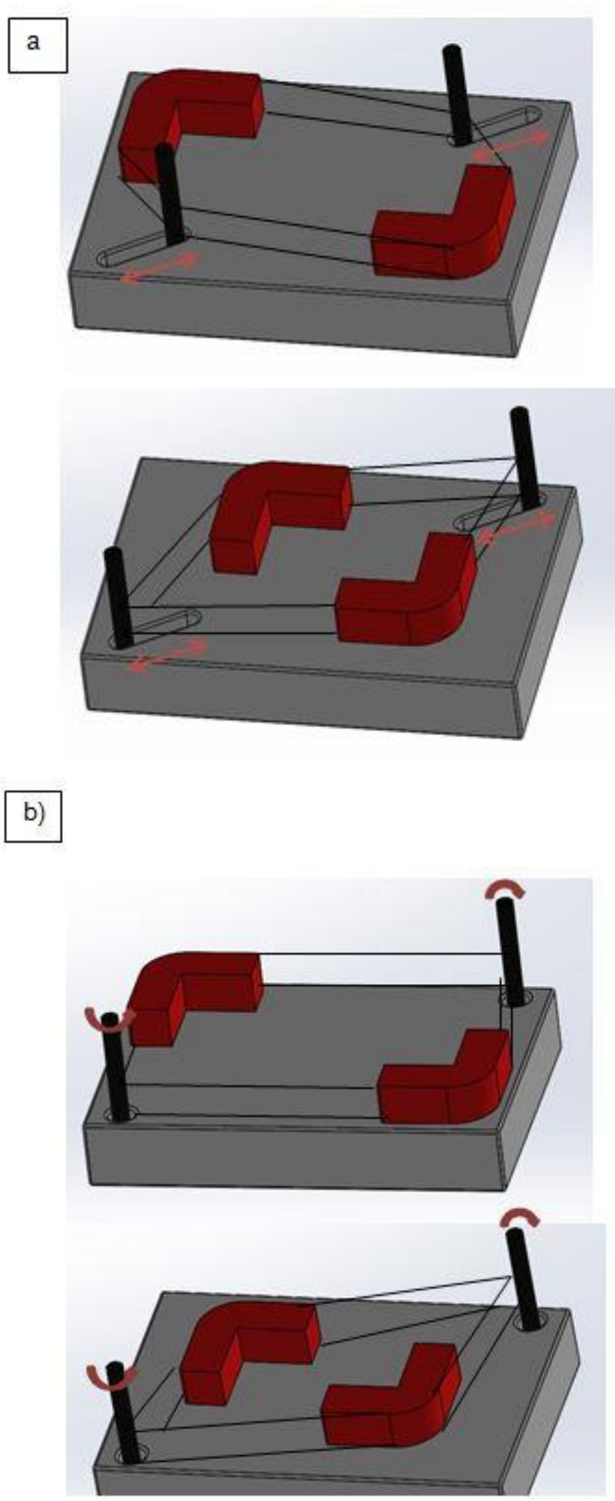


Figure 20. Concepts of lower part: a) using moving shafts b)using rotating shafts.

Concept IV – Hinge holding

Another solution is shown in Figure 21. The method is a lot cheaper from the previous versions. It is simply a part doing a hinge movement in order to immobilize the DUT.

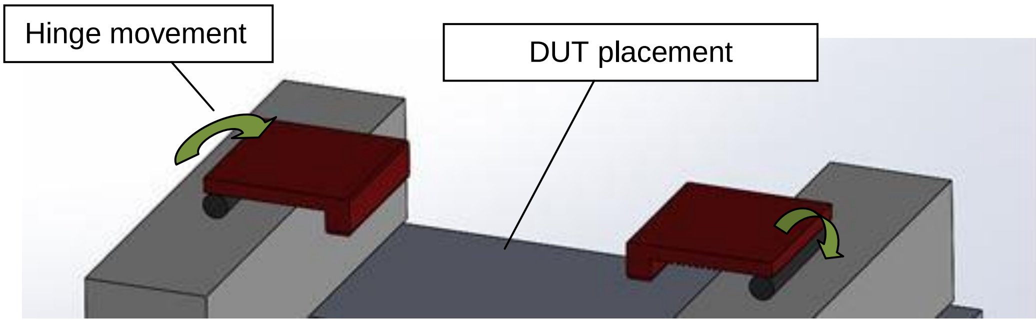


Figure 21. Hinge holding.

In order to test the desired device its back part has to be removed. This is because there has to be a connection with the electric elements inside. After this operation a table equipped in needles and other indispensable units is raised. Now the electrical devices can signal if each part is working correctly.

The product is placed in a pin plug, that exactly corresponds to the backside of the device to be tested. A 'click' sound is the sign for the user that the product is correctly placed.

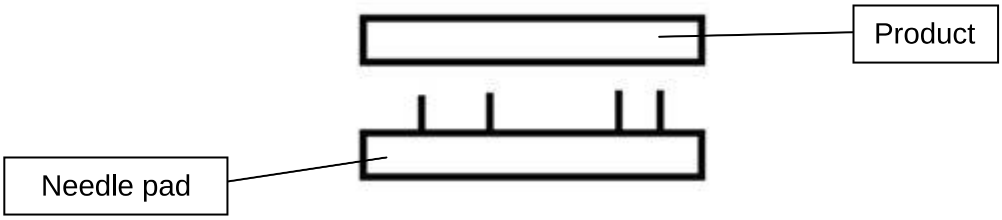


Figure 22. Connection of DUT fixture and needle pad.

3.3. Selecting the best idea

This Chapter is dedicated to all analysis regarding the constructions preliminary designs. Besides SWOT analysis' there have also been made comparisons based on the main key drivers chosen. Table 2 shows the factors that were taking into concern, together with their validation values and explanation of each single driver.

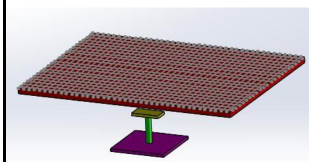
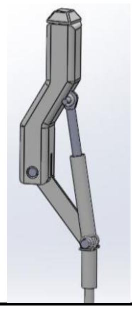
Table 2. Requirements and verification values list.

Driver	Things to consider	Verification value
Reliability	- Does the components last long, without failure (at least two years)?	10
	- Will the construction carry the weight of all components? Is it necessary to use an additional support?	
	- Will the construction be stable in every case?	
	- Is it necessary to take great care over the construction (does it need a weekly/monthly etc. service)?	
	- Will a problem occur during restarting machine if it is not used for a longer time?	
Safety	- Is the machine capable of causing harm to the user?	9
	- Does the machine stop movement automatically in case of emergency?	
	- Does the machine fulfill all needed safety standards?	
Maintainability	- Can the parts be easily exchanged by the user?	8
	- Is there a component that needs to be exchanged after a certain period of time?	
Operability	- Is the machine to be easy operated by the user?	7
	- Does the machine need an engineer to use it/ Does someone involved in the project needs to supervise?	
	- Is it easy to move the machine? Is it movable?	
	- Do you have to use strength to move it?	
	- Time needed to change configurations.	
Availability	- How long can the machine work in a row?	6
Cost	- How high are the costs in comparison to the previous used devices?	5
Innovation/ Appearance/ Design	- Does the appearance encourage the client to buy the product?	4
	- How is it different from the others being on the market?	
	- What makes it unique and reliable at the same time?	
Functionality	- Does the device comply with the posed requirements?	3
	- Does the individual parts work well together?	

3.3.1. Upper part selection

A SWOT analysis has been undergone in order to choose the best concept. For appointing a winner solution points have been distributed. A positive aspect equals +1 point, a negative one -1 point. The concept which gains the highest score automatically wins. Table 3 shows the comparison.

Table 3. Upper part SWOT analysis.

SWOT	XY – Table	Magnetic platform	R obotic arm
			
STRENGTHS	Already used/tested solution	Innovative solution	Less space needed for equipment
	High reliability factor (practical verification)	Fast working	Realises horizontal and vertical movement at one time
	High maintainability factor (practical verification)		
	Construction the most robust		
WEAKNESSES	Construction needs much space	Very complicated construction	Higher amount of components - smaller reliability factor
	Inaccurate positioning (zero point calibration needed)	Need of a large amount of components (including electrical devices)	More partial movements needed for accurate positioning
		Current delay causing trouble in positioning	
		Magnets resistance and size of interaction field	
OPPORTUNITIES	-	New invention on the market -> opportunities for the company to evolve	Universal part
THREADS	-	More time – consuming, need of gathering professional knowledge about the dependence of electric and magnetic field	Positioning could be time consuming
+	4	3	3
-	2	5	3
SUM	**2**	**-2**	**0**

The winning construction is the XY – Table. It is an already tested and satisfying solution. Although it had similar points in the STRENGTH section, the two remaining parts had too many disadvantages that would appear while choosing them.

As the XY – Table turned out to be the best solution, another analysis regarding the chosen key drivers (see Chapter 2.1.2.) has been made. The result is shown by a radial diagram (Figure 23).

Table 4. XY – Table analysis regarding key drivers.

Driver	Verification +	Verification -	Verification value
Reliability	Construction stable in every case, can hold desired weight Long lasting without failure Consrtuction doesn't need regular service The components will work properly afer a long term of no usage Already tested construction	-	1
Safety	Safety cases are preserved, all standards are included, an 'safety button' is provided	-	1
Maintainability	No parts need to be replaced after a specified period of time	Exchange of parts could be problematic	0,5
Operability	To be operated easily by user No need for supervising during usage Easy movable construction Just a short workshop needed to show the usage and different capabilities of the machine	Problem with calibration of zero point	0,8
Availability		-	1
Cost	Construction already bought	Large cost - already existing product	0,5
Innovation/ Appearance/ Design	Professional appearance	-	1
Functionality	Supports all of the functional requirements	-	1

	Before weight summary	After weight summary
 XY Table		

Figure 23. Radial diagram XY – Table analysis.

3.3.2. Middle part selection

Two concepts of this part have been created. In order to evaluate witch concept is stronger an analysis regarding the requirements (together with their verification values) in has been made. It is to be mentioned that the solutions presented in 3.2.2. (at this stage) have undergone little changes as realistic parts have been selected. That is why their appearance slightly changed (Figure 24).

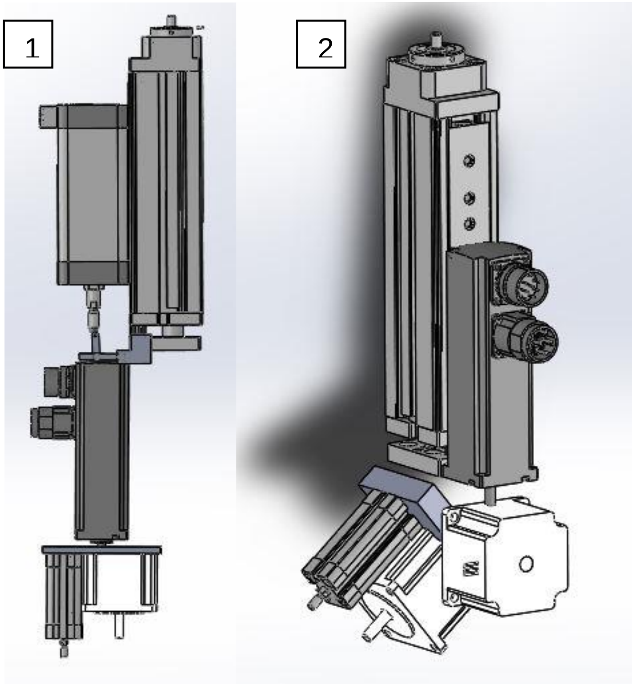


Figure 24. Improved concepts of middle part.

Algorithms showing components of each concept have been created. It delivers knowledge about which devices are related to one another, to predict which parts will stop working in case of failure of one of the other parts.

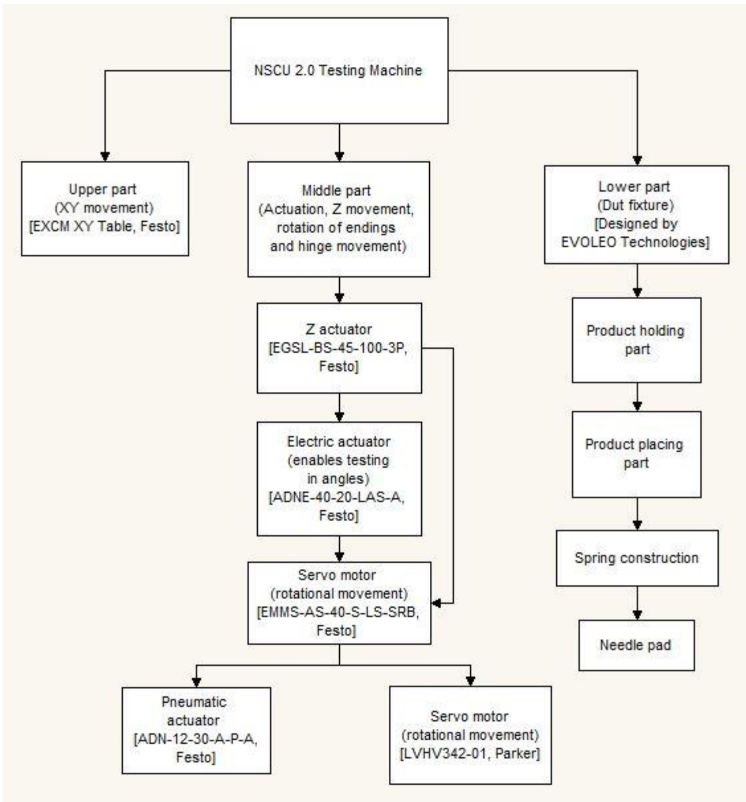


Figure 25. Algorithm of NSCU 2.0 Testing Machine – I concept.

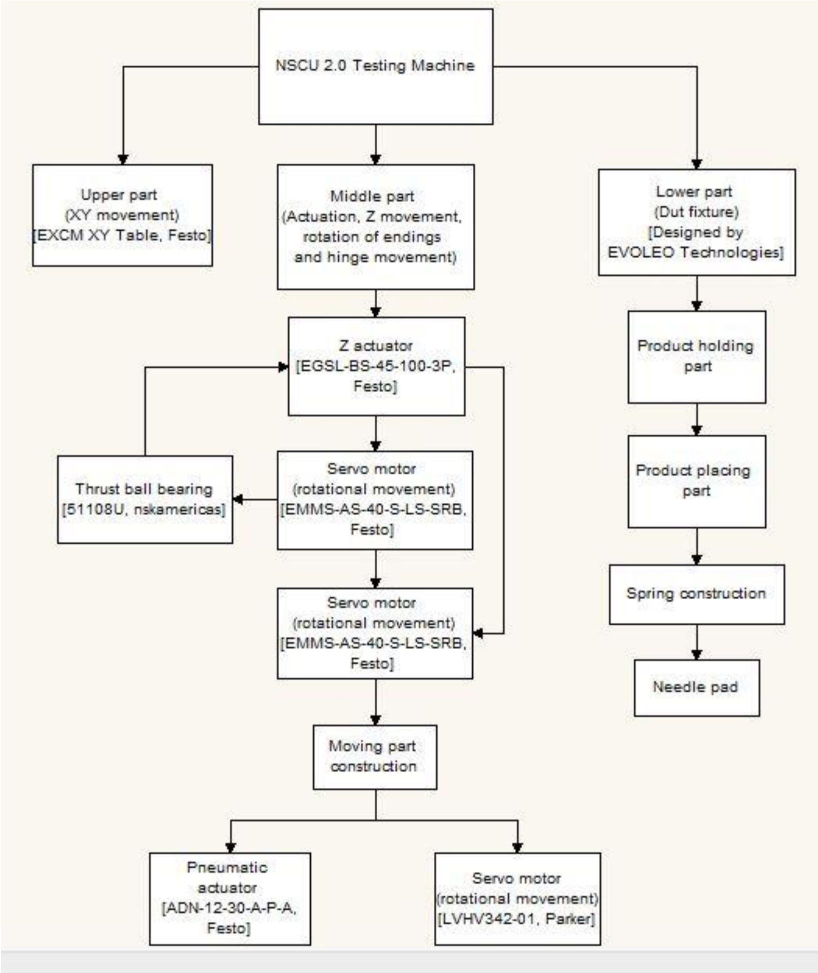


Figure 26. Algorithm of NSCU 2.0 Testing Machine II concept.

1. Reliability

In order to define the reliability of a construction the below listened definitions need to be known. Knowing the Probability of Failure per Hour (PFH) (see Chapter 2.3) it is easy to count the possibility of failure during 2 years. Afterwards this value is being subtracted from 1 in order to get the reliability value for each component during 2 years (one of the requirements).

$$Reliability = 1 - (PFH \cdot 24h \cdot 365days \cdot 2years) \qquad [2]$$

Table 5. Reliability table for concept I.

Device	PFH	Reliability
Electric actuator [ADNE-40-20-LAS-A, Festo]	10–7	0,998
Servo motor [EMMS-AS-40-S-LS-SRB, Festo]	3×10^{-6}	0,947
Servo motor [LVHV342-01, Parker]	3×10^{-6}	0,947
Pneumatic actuator [ADN-12-30-A-P-A, Festo]	10–7	0,998
Whole middle part	3×10^{-26}	**0,898**

The constructions reliability is almost 90%. That is a satisfying result.

Table 6. Reliability table for concept II.

Device	PFH	Reliability
Servo motor [EMMS-AS-40-S-LS-SRB, Festo]	3×10^{-6}	0,947
Servo motor [EMMS-AS-40-S-LS-SRB, Festo]	3×10^{-6}	0,947
Servo motor [LVHV342-01, Parker]	3×10^{-6}	0,947
Pneumatic actuator [ADN-12-30-A-P-A, Festo]	10–7	0,998
Thrust ball bearing [51108U, nskamericas] [14]	3×10^{-6}	0,947
Whole middle part	3×10^{-26}	**0,803**

The reliability of the second concept is 9,5% less reliable than the first version due to the amount of components. It is because of the amount of components. The first solution has 5 main components, whilst the second has 6 main parts.

2. Technology

Comparison of pneumatic and electrical actuation systems has been made in order to choose the best possible concept. Regarding different sources of information the Table 7 was created [5, 6, 7].

Table 7. Pneumatic and electric actuation comparison.

	Electromechanical Design	Pneumatic Design
Space Required	1x	3x
Controllability	Excellent, Very precise	Good
Load	Very good	Good
Accuracy	Excellent	Sufficient
Speed	Good	Excellent
Maintenance	Very good	Sufficient
Noise	Very good	Sufficient
Installed Cost	Good	Very good
Operating Cost	Good	Very good
Total Cost	Good	Very good
Environment	Excellent	Sufficient

Based on Table 7, the electrical actuator is obviously better for the need of the NSCU 2.0 Testing Machine, because it needs to be very accurate. Because of the speed though, the pneumatic actuator is used for the ending intended for actuating the buttons of the tested product.

3. Maintainability [13]

In maintainability the most important factors are the Mean Time Between Failure (MTBF) and Mean Time To Failure (MTTF) and Probability of Failure per Hour (PFH) (see Chapter 2.3). The important values for both concepts are listened below.

Table 8. Maintainability table for concept I.

Device	$MTTF_d$ [years]	PFH
Electric actuator [ADNE-40-20-LAS-A, Festo]	30	≤ 10–7 < 10–6
Servo motor [EMMS-AS-40-S-LS-SRB, Festo]	10	$\leq 3 \times 10^{-6} < 10^{-5}$
Servo motor [LVHV342-01, Parker]	10	$\leq 3 \times 10^{-6} < 10^{-5}$
Pneumatic actuator [ADN-12-30-A-P-A, Festo]	30	≤ 10–7 < 10–6

Table 9. Maintainability requirement Table.

REQ. NR	REQ. description	Solution
REQ.074	At least 2 years working without failure.	Construction will work without failure at least 10 years

Table 10. Maintainability table for concept II.

Device	**$MTTF_d$ [years]**	**PFH**
Servo motor [EMMS-AS-40-S-LS-SRB, Festo]	10	≤ 10–7 < 10–6
Servo motor [LVHV342-01, Parker]	10	$\leq 3 \times 10^{-6}$ $< 10^{-5}$
Servo motor [LVHV342-01, Parker]	10	$\leq 3 \times 10^{-6}$ $< 10^{-5}$
Pneumatic actuator [ADN-12-30-A-P-A, Festo]	30	≤ 10–7 < 10–6
Thrust ball bearing [51108U, nskamericas]	42	$\leq 3 \times 10^{-6}$ $< 10^{-5}$

The Mean Time To Failure for trust ball bearings is to be calculated with the underneath equation [3]:

$$MTTF = 5 \cdot \frac{10^6}{60n}\left(\frac{C}{P}\right)^3 \quad [3]$$

Where:

L10 : Basic rating life

C : Basic dynamic load rating, N {kgf}

P : Equivalent dynamic load, N {kgf}

n : Rotational speed, min-1

For the chosen bearing the figures below are listened:

$C = 27100$ kgf [N]

$P = 2770\ kgf$ [N]

$n = 3600\ \frac{1}{min}$

$$\mathrm{MTTF} = 5 \cdot \frac{10^6}{60 \cdot 3600 \frac{1}{min}} \left(\frac{271000\ \cancel{kgf}}{2770\ \cancel{kgf}} \right)^3 = 21678017{,}41\ \mathrm{min} \approx 42\ years$$

Both constructions should last without failure at least 10 years.

4. Cost

Elements used to create the middle part together with their cost summary are listened in Table 11 and Table 12.

Table 11. Cost table for concept I.

Device	**Cost**
Z actuator [EGSL-BS-45-100-3P, Festo]	1039, 13 EUR [10] + controllers
Electric actuator [ADNE-40-20-LAS-A, Festo]	101,42 EUR [33]
Servo motor [LVHV342-01, Parker]	256,48 EUR [8]
Servo motor [LVHV342-01, Parker]	256,48 EUR [8]
Pneumatic actuator [ADN-12-30-A-P-A, Festo]	112,75 EUR [11]
Total cost:	**1766,26 EUR**

Table 12. Cost table for concept II.

Device	**Cost**
Z actuator [EGSL-BS-45-100-3P, Festo]	1039, 13 EUR [10] + controllers
Servo motor [EMMS-AS-40-S-LS-SRB, Festo]	774,36 EUR
Servo motor [LVHV342-01, Parker]	256,48 EUR [8]
Servo motor [LVHV342-01, Parker]	256,48 EUR [8]
Pneumatic actuator [ADN-12-30-A-P-A, Festo]	112,75 EUR [11]
Total cost:	**2439,20 EUR**

5. Safety

Table 13. Safety requirement table.

REQ. NR	REQ. description	Solution
REQ.070	The platform must use a safety PLC whose software is certified to ISO 13849-1 standard.	Safety ISO 13849-1 standards will be provided.

In both constructions there are no dangerous components which could potentially hurt the user.

6. Availability

One of the principal requirements was that the machine needs to work without failure 365 working days a year, 24 hours per day. Therefore all components should be able to perform at least $6{,}3 \cdot 10^6 \frac{\text{cycles}}{\text{year}}$, as was calculated in equation 5. An average cycle time of 5 s is assumed.

$$n_{op} = \frac{d_{op} \cdot h_{op} \cdot 3600\frac{s}{h}}{t_{cycle}} = \frac{365\frac{d}{y} \cdot 24\frac{h}{d} \cdot 3600\frac{s}{h}}{5\frac{s}{cycle}} = 6,3 \cdot 10^6 \ \frac{cycles}{year} \qquad [4]$$

7. Functionality

CONCEPT I

In order to define the range which the construction is able to achieve calculation have been made. The assumption was that the testing endings should be able to measure in the angle of at least 150° (75° each side). The arms marked in Figure 27 with the 'X' sign is the surface of the movable table in different positions of the device (max. left and right inclination).

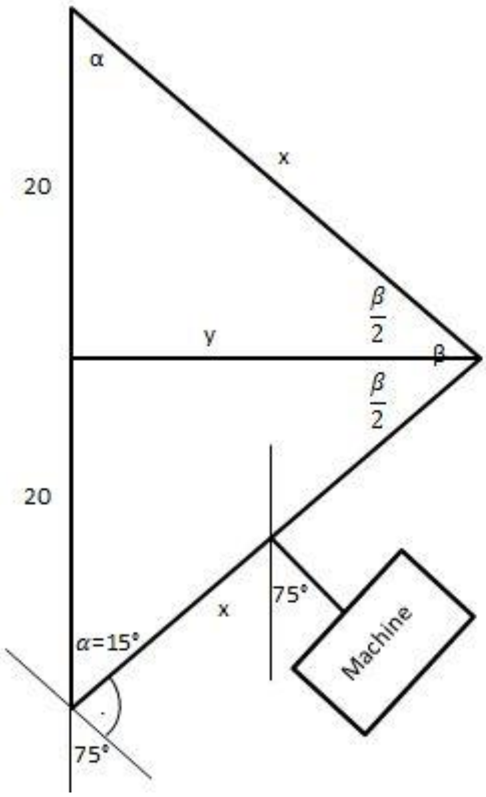


Figure 27. Graphical presentation of calculations.

Using the law of cosines, sines and Pythagoras law the below equations have been made.

Because: $75^\circ + 90^\circ + \alpha = 180^\circ \rightarrow \alpha = 15^\circ$ and $2\alpha + \beta = 180^\circ \rightarrow \beta = 150^\circ$

$$\frac{x}{sin90^\circ} = \frac{y}{sin\alpha} \rightarrow sin\alpha = \frac{y}{x}$$

$$y^2 = 20^2 + x^2 - 40x cos\alpha$$

$$cos\alpha = \sqrt{1 - sin^2\alpha}$$

$$y^2 + 20^2 = x^2 \rightarrow y = \sqrt{x^2 - 400}$$

$$\sqrt{x^2 - 400}^2 = 20^2 + x^2 - 40x\sqrt{1 - sin^2\alpha}$$

$$\cancel{x^2} - 400 = 20^2 + \cancel{x^2} - 40x\sqrt{1 - sin^2\alpha}$$

$$\cancel{800}20 = \cancel{40}x\sqrt{1 - sin^2\alpha}$$

$$400 = x^2(1 - sin^2\alpha)$$

$$x = \sqrt{\frac{400}{1 - sin^2\alpha}} = \sqrt{\frac{400}{1 - sin^2 15}} = \sqrt{\frac{400}{1 - 0{,}067}} = \sqrt{428{,}73} \approx 20{,}7\,mm$$

$$y \approx 20{,}7 \cdot sin15^\circ \approx 5{,}36\,mm$$

To reach the wanted limit of 150° it is required to have an distance of 5,35 mm between the hook of the actuator and the fixture of the movable table. Therefore the part connecting the table with the actuator should be 20,7 mm - 5,36 mm = 15,34 mm.

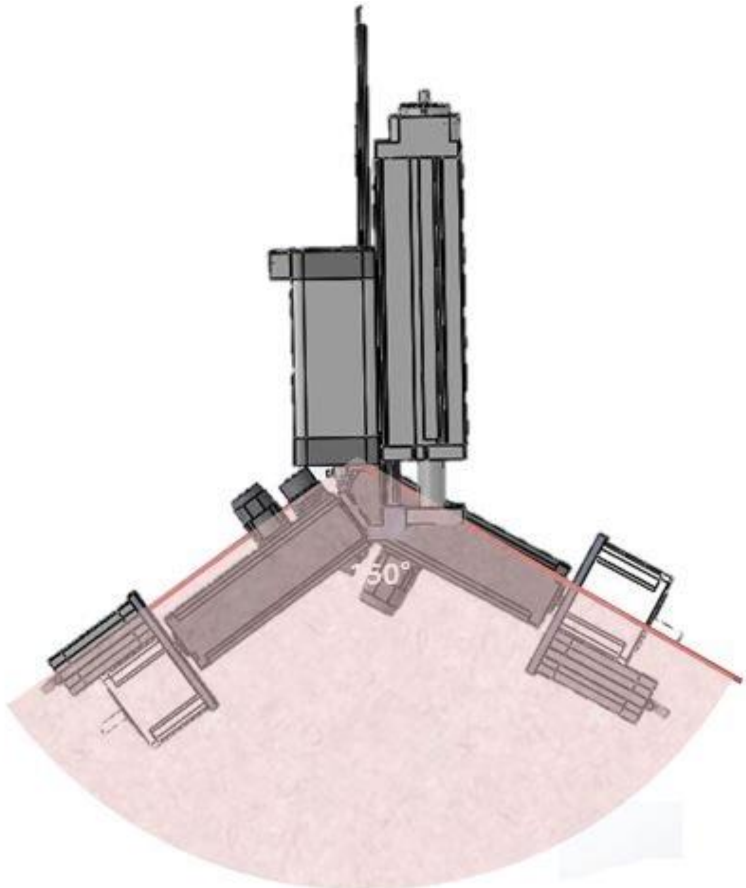


Figure 28. Angle range of concept I.

The construction allows movement in the Vertical direction until 100 mm and the swing of the construction until 75° in each direction.

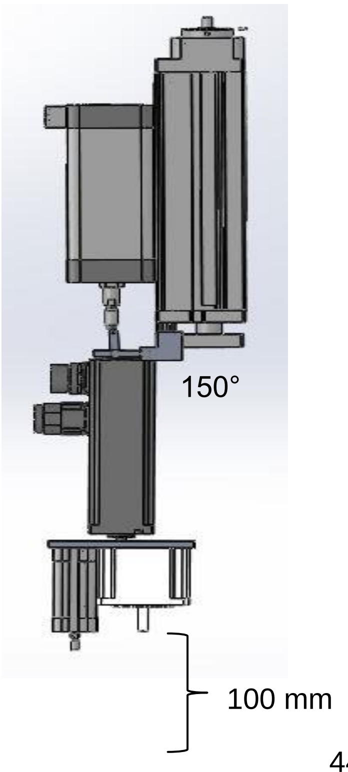


Figure 29. Vertical range of concept I.

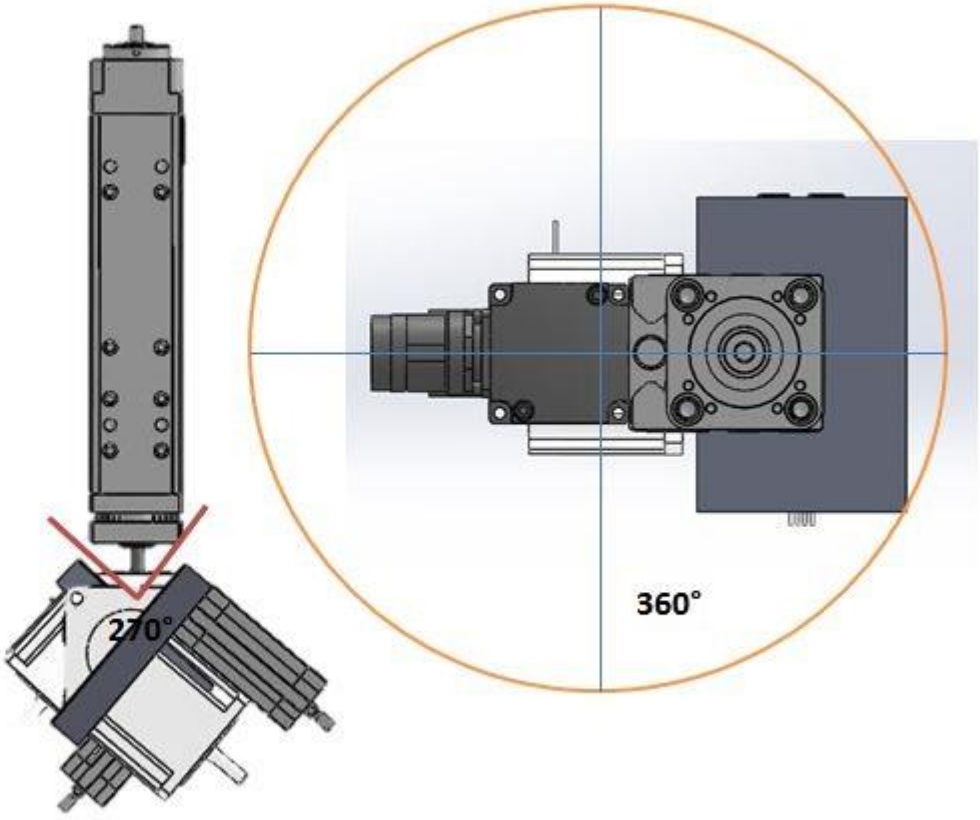


Figure 30. Angle and horizontal range of concept II.

Solution nr 2 has a greater range in angle than solution nr 1 In Figure 30 the left drawing shows the side look of the part and possible angles of testing endings whilst the right visualises the range of mobility from above. Figure 31 shows the vertical movement.

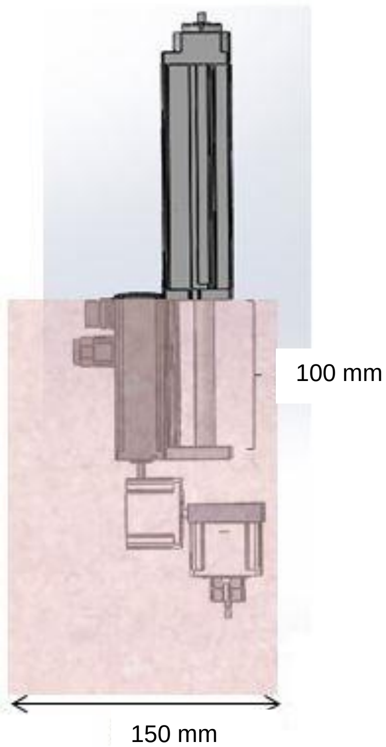
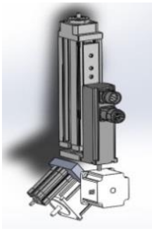
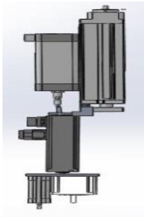


Figure 31. Range of mobility in vertical direction.

Table 14. Comparison of concepts.

Driver	CONCEPT II 	CONCEPT I 	Explanation
Reliability	***	****	Concept II has less components that's why it is more reliable.
Safety	***	***	Both constructions are fulfil the safety requirements.
Maintainability	***	****	Both constructions can work at least 10 years without failure, but considering the number of components it could be more difficult to maintain concept nr I.
Availability	**	**	Working 24h/7days a week for 2 years.
Cost	**	***	Concept II cheaper because of usage of electric actuator instead of servo motor. Additional, concept I needs a thrust ball bearing.
Innovation	****	**	Concept II is shorter than concept I which gives more space for placing the product.
Functionality	****	**	Concept I has a much larger angle range (270° instead of 150°)
Robustness	****	***	Concept nr I is more compact which makes it more robust.
Total:	25	23	**Winner solution: Concept II**
****	Excelent		
***	Very good		
**	Good		
*	Sufficient		

Also, a comparison regarding the main key drivers has been made. The resulting conclusions are shown in Table 15 and 16.

Table 15. Main key driver analysis concept I.

Driver	Verification +	Verification -	Verification value
Reliability	Resistant (servo motors lasting min to 18000 hours) Because of the actuator and stiffener part construction more massive Usage of servo motor and electric actuator - easy programmable & reliable Doesn't need regular service The components will work properly afer a long term of no usage The whole construction is linear - more stability	Support of rotating element - Z- actuator carries the burden - additional element	0,86
Safety	Safety cases are preserved, all standards are included, an 'safety button' is provided	-	1
Maintainability	Parts can be exchanged easily The construction allows product updates All components are prepared for long usage	-	1
Operability	To be operated easily by user No need for supervising Easy movable construction Just a short workshop needed to show the usage and different capabilities of the machine	Less flexible than solution I (inclination just in one way)	0,67
Availability	18000 hours - cheaper option (sufficient)	-	1
Cost	In comparison to Solution II cheaper (instead of servo motor, electric actuator) *http://www.apollovalves.com/_literature/plist_ACPL9000_2011.pdf*	65 EUR thrust bearing *http://www.skf.com/binary/28-153040/SKF-ERP-2014.pdf* 207 EUR *http://www.apollovalves.com/_literature/plist_ACPL9000_2011.pdf*	0,5
Innovation/ Appearance/ Design	Whole construction linear - professional appearance Ability to measure in angles - innovation Usage of servo motor and electric actuator - easy programmable & reliable	-	0,75
Functionality	Supports all of the functional requirements	-	1

Table 16. Main key driver analysis concept II.

Driver	Verification +	Verification -	Verification value
Reliability	Resistant (servo motors lasting up min to 30000 hours)	Support of rotating element - Z- actuator carries the burden - additional element	0,57
	The construction is able to carry all the weight - material selection.	Insertion can occur - stability of lower rotation motor needed?	
	Construction doesn't need a systematic service	Part that rotates placed on the side - less stable than solution I	
	The servo motors work properly while not being turned on for a long period of time		
Safety	Safety cases are preserved, all standards are included, an 'safety button' is provided	-	1
Maintaina - bility	Parts are easy exchangable	The exchange of parts can be time consuming	0,75
	The actuators and servomechanisms needs to be exchanged (but the period of time when it's needed to be exchanged is satisfying).		
	The construction allows product updates		
Operability	Because of the servo motors is easy programmable	The time used to undergo one testing is more time consuming than solution nr I	0,8
	No supervisor needed to operate the machine		
	Just a short workshop needed to show the usage and different capabilities of the machine		
	Device is easily movable		
Availability	30000 hours minimum (sufficient)	-	1
Cost	dependent on the material and components - to be discussed	65 EUR thrust bearing (*http://www.skf.com/binary/28-153040/SKF-ERP-2014.pdf*)	0,4
		645 EUR per piece for 30000hours, we need the half so cheaper (*http://hundtech.en.alibaba.com/product/60230045034-800968131/Servo_motor_planetary_gearbox_with_30_000_hours_life_time.html*),	
Innovation/ Appearance/ Design	Ability to measure in angles - innovation	Part that rotates placed on the side - no symetric; worse appearance	0,75
	Usage of servo motors - easy programmable & reliable		
	improved design		
Functionality	Supports all of the functional requirements	-	1

3.3.3. Lower part selection

First, the main idea has been chosen. According to Chapter 3.2.3. there was a selection among the already existing EVOLEO Technologies solution and the innovative solution using springs. The construction have been analysed in accordance to the chosen key drivers shown in Table 1 (See Chapter 2.1.1. Considering these values radar graphs have been created to compare the solutions. The diagrams are based on proportions of positive and negative aspects that have been noticed. The whole amount of factors equals 1. An percentage of the positive features has been calculated to create graphs (positioned on the left side of each table). Then key drivers have been chosen and values have been added to it concerning its importance for the construction. Table 1 shows the conclusion. Later on, multiplying the percentage with the values, other diagrams were created so to get the wanted conclusion. The Tables 17 and 18 show the path, the analysis was going through, whilst Table 19 shows the resultant Diagram.

Table 17. Lower part spring solution analysis.

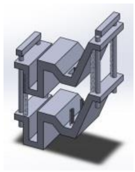
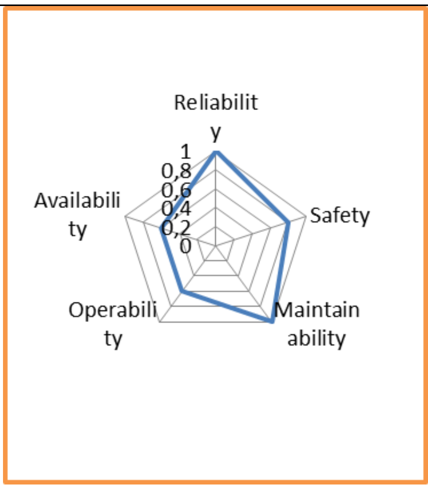
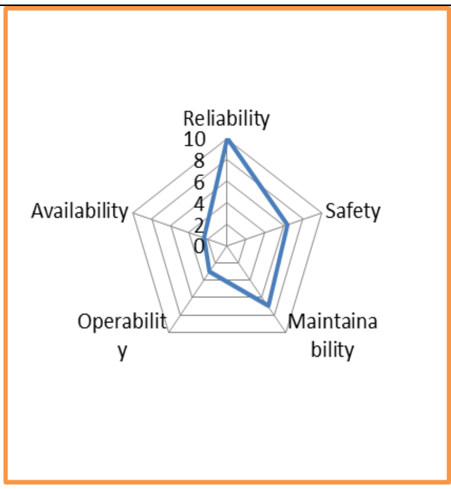
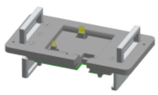
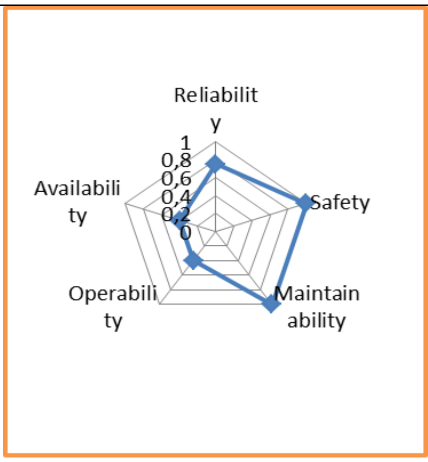
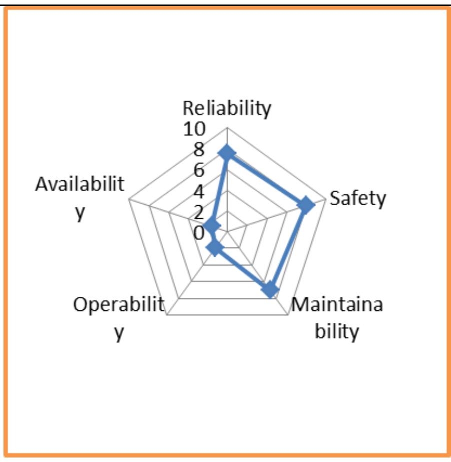
Driver	Verification +	Verification -	Verification value
Reliability	Base fits perfectly with the products shape - individual for each new product	-	1
	Construction stable in every case, can hold desired weight		
	Lateral stabilizators protect against bending of whole construction.		
Safety	Safety cases are preserved, all standards are included, an 'safety button' is provided	-	1
Maintainability	The construction allows product updates	Springs wear off	0,8
	All components are prepared for long usage		
Operability	Easily and fast exchangable due to springs used	-	1
	Needle pad connected with part responsible for placing the product helps exchanging the part quickly		
	Simple construction - easy to replace parts		
	Just a short workshop needed to show the usage and different capabilities of the machine		
	No need for supervising		
Availability	No limits	-	1
Cost	Lower cost than older solution (no need to use electric actuator to pull the needle pad up)	-	0,6
Innovation	Needs less components - simple design	-	0,6
Functionality	Supports all of the functional requirements	-	1

Table 18. Lower part solution with actuator analysis.

Driver	Verification +	Verification -	Verification value
Reliability	Base fits perfectly with the products shape - individual for each new product	Additional part (electric actuator) equals less reliability than spring solution	0,75
	Construction stable in every case, can hold desired weight		
	Product placed very accurate because of a form corresponding with the products shape		
Safety	Safety cases are preserved, all standards are included, an 'safety button' is provided	-	1
Maintainability	The construction allows product updates	-	1
	All components are prepared for long usage		
Operability	Easily and fast exchangable	-	1
	Needle pad connected with part responsible for placing the product helps exchanging the part quickly		
	Just a short workshop needed to show the usage and different capabilities of the machine		
	No need for supervising		
	Simple construction - easy to replace parts		
Availability	No limits	-	1
Cost	-	More expensive in comparison to solution using springs	0,4
Innovation/ Appearance/ Design	-	More components - complex design	0,4
Functionality	Supports all of the functional requirements		1

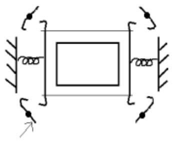
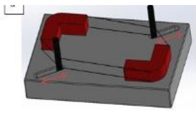
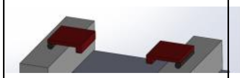
Assuming that the values for Safety, Availability and Functionality must be equal 1 (otherwise the machine would not make any sense) , radial diagrams have been created not containing them.

Table 19. Radial diagram comparison of lower parts.

	Before weight summary	After weight summary
 Spring part		
 Actuator part		

After choosing the main idea it was necessary to emerge the best concept for the product's fixture. Therefore a SWOT analysis of the different concepts has been made. Table 20 shows the winner solution – concept IV. It is because the most important criteria was the reliability factor of the device.

Table 20. SWOT analysis of holding part.

	Concept I 	Concept II 	Concept III 	Concept IV 
Strengths	No need for a lot of space	Fast exchange of components	Exchangeable endings – fitting to each product	Simple construction/ easy operating Just two actuators needed for solution to work
Weaknesses	A mechanism needed to stand up against the springs which hold the edges of the product Additional elements needed to move the clips	Trouble with placing the product in the exact middle Issue with non - streamline items (tape tearing apart)	Tapes wear off Few components equals less reliability	-
Opportunities	-	-	New invention on the market => opportunities for the company to evolve	Solving problem with cheap outcome
Threads	Amount of components – complicated construction	Tapes wear off (on the corners of the package) Possible time influence on tape extension	Possible time influence on tape extension	Placement of testing area
+	1	1	2	3
-	3	4	3	1
SUM	-2	-3	-1	2

3.4. Developing the main idea

3.4.1. Upper part development

The Upper part (EXCM XY – Table) from Festo company was put into the whole assembly in order to show the different movement dependencies of the different parts. Each component of the XY Table was given a new appearance (colour) in order to highlight the number of components it is composed of. The XY – Table is shown in Figure.

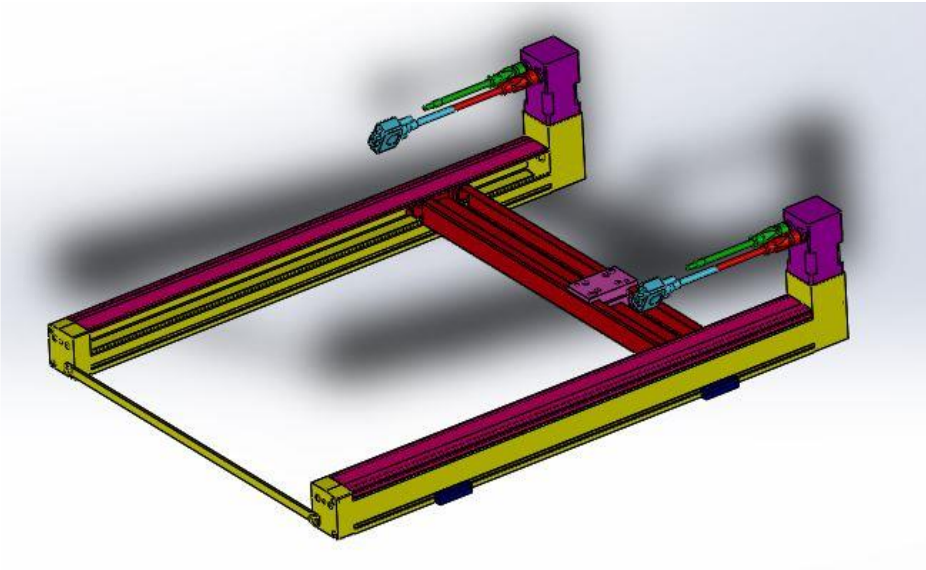


Figure 32. EXCM XY – Table produced by Festo company (*https://www.festo.com/cms/nl-be_be/21917.htm*).

The exploded view of the XY – Table is shown in Figure 32. It consists of 13 main parts, four holding parts and few screws. The part marked as I is sliding on the surface of part II, enabling horizontal movement. The part II on the other hand slides on part III allowing vertical movement. Part marked as V is responsible for holding part II into the splint of part III. The components marked as VI are parts to be connected with the motor causing the tables movement. Composition IV is used four times in this assembly. It is responsible for placing the whole XY – Table onto a rigid, robust structure.

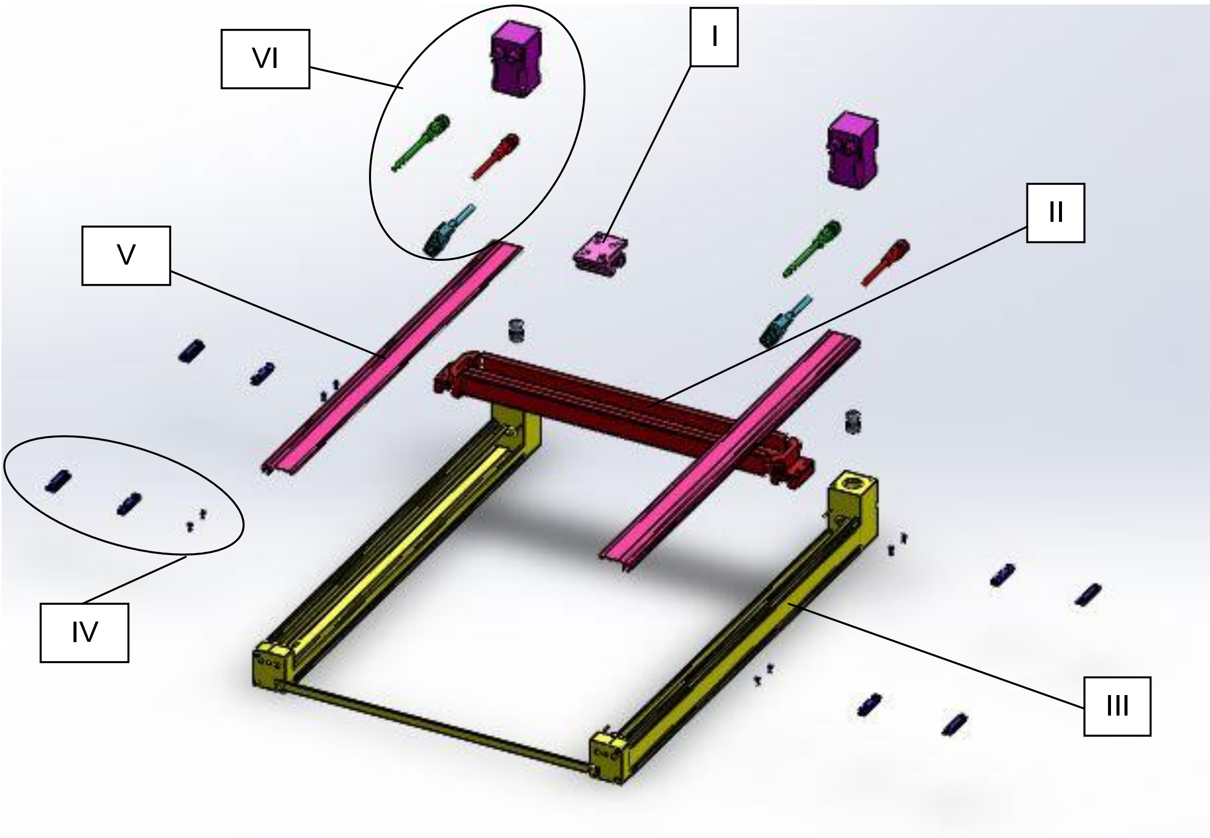


Figure 33. Exploaded view of XY – Table.

3.4.2. Middle part development

Strength calculations have been made in order to verify if the chosen parts fulfil all desired criteria. Optimization processes have been undergone in order to minimize the construction by simultaneous maintenance of all requirements. Because of that process some parts have been exchanged.

STRENGHT CALCULATIONS FOR EMMS-AS-40-S-LS-SRB SERVO MOTOR PLACED ABOVE TESTING ENDINGS

The attached pneumatic actuator responsible for moving the endings can work under pressure up to 6 bar which at this point is causing the theoretical force of 68 N [9]. Out of a linear proportion it is possible to count the force at 3 and 4 bar (values used by EVOLEO Technology). Because the maximum force used by the company is desired, the force is counted at 4 bar.

$$\begin{cases} 68 = 6\,a + b \\ 34 = 3\,a + b \end{cases}$$

$34 = 3\,a \ \rightarrow a = 11,(3), b = 0$

$y = 11,(3)\,x$

$F\,(4\,bar) = 11,(3) \cdot 4 \ \approx 45(3)\,N$

To check if this value is counted properly the underneath equation can be used:

$$p = \frac{F}{S} \rightarrow F = p \cdot S \qquad [5]$$

Knowing that 1 bar = 10^5 Pa, the diameter of the servos shaft = 12 mm and that the servo motor will work under max. pressure 4 bar:

$F = 4 \cdot 10^5 \cdot \pi \cdot 0{,}006^2 \ \left[Pa \cdot m^2 = \frac{N}{\cancel{m^2}} \cdot \cancel{m^2}\right] \approx$ 45 N

It needs to be considered that the pneumatic actuator while pushing a button applies that force, which causes reaction force at the same amount. That is why this maximum force is considered during calculating the torque which the servo motor responsible for rotation of the table attached to the testing endings. Now it is important to count the distance from the centre of the mass on which the force is applied. That is the distance between the shaft of the discussed servo motor and the shaft of the pneumatic actuator. Knowing the dimensions of all the components and their weights it is possible to define the centre of mass.

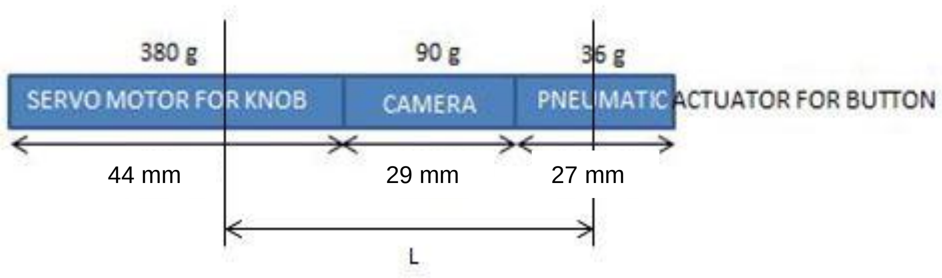


Figure 34. Explanation drawing.

The maximum weight the chosen servo motor must stand is 509 g. Assuming even weight distribution the centroid should be placed in a position where on both sides there is 254,5g. Knowing that the servo motor is responsible for rotating the suction cup weights 380g through proportion it is possible to calculate the centroid.

$380\ g - 44\ mm$

$254{,}5\ g - x\ mm$

$$x = \frac{254{,}5\cancel{g} \cdot 44\ mm}{380\ \cancel{g}} \approx 29{,}5\ mm$$

Now, knowing that the actuation part of the pneumatic actuator responsible for pushing the button is placed in the middle of the actuator it is possible to calculate the distance between the shaft of the servo motor and the shaft of the pneumatic actuator.

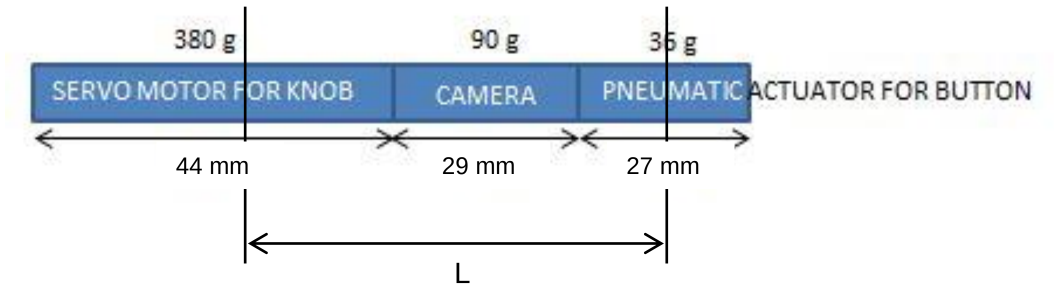


Figure 35. Explanation drawing.

$$L = (44 - 29{,}5)\ mm + 29\ mm + \left(\frac{27}{2}\right)\ mm = 57\ mm$$

The torque that the side set servo motor needs to stand is calculated using the underneath equation:

$$\boldsymbol{T = M_O = F \cdot L} \qquad \textbf{[6]}$$

$T = 45{,}3\ N \cdot 0{,}057\ m \approx 2{,}58\ Nm$

The selected servo motor EMMS-AS-40-S-LS-SRB turned out to be inadequate because of a too small torque. That is why the need occur to change this component. The part was exchanged into a stepper motor from Parker (LVHV341-01). This unit is able to provide a movement of 1,8° per impulse. It is possible for the stepper motor to perform so called 'half steps' in order to get a rotation of 0,9° per impulse.

STRENGTH CALCULATIONS FOR EMMS-AS-40-S-LS-SRB SERVO MOTOR ATTACHED TO Z - ACTUATOR

BENDING AND TORQUE ANALYSIS

The selected servo motor has to overcome bending produced by the weight of the testing endings together with its mounting (drawing b), the weight of the LVHV341-01 stepper motor and also bending and torque caused by the reaction force of the pneumatic actuator (drawing a).

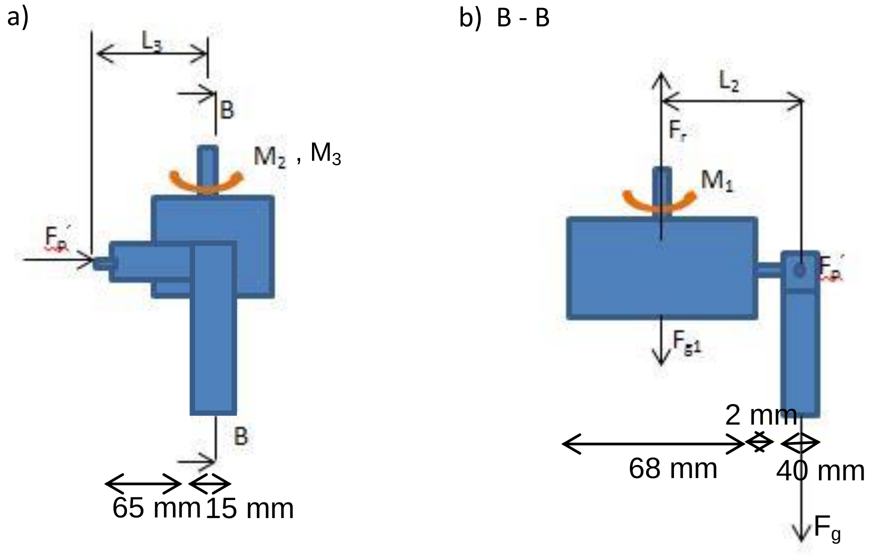


Figure 36. Explanation drawing.

From a) bending caused by the weight of the testing endings is calculated:

$$\boldsymbol{M_1 = F_{g1} \cdot x + F_{g2} \cdot L_2} \qquad \textbf{[7]}$$

$because\, x = 0: \quad M_1 = F_{g2} \cdot L_2$

$L_2 = \left(\frac{68}{2}\right) mm + 2\, mm + \left(\frac{40}{2}\right) mm = 56\, mm$

$M_1 = \left(0{,}506\, kg \cdot 9{,}81\, \frac{m}{s^2}\right) \cdot 0{,}056\, m \approx 0{,}28\, Nm$

From b) It is considered that the table with actuators is situated under an angle of 90°. The force from the pneumatic actuator causes torsion as well as bending:

$$\boldsymbol{M_2 = F_g{}' \cdot L_2} \qquad \textbf{[8]}$$

$M_2 = 45\, N \cdot 0{,}056\, m = 2{,}52\, Nm$

$$M_3 = T = {F_g}' \cdot L_3 \qquad [9]$$

$$L_2 = 65\,mm + \left(\frac{15}{2}\right) mm = 72{,}5\,mm$$

$$T = 45\,N \cdot 0{,}0725\,mm \approx 72{,}5\,mm$$

Radial forces that the selected servo motor should be able to stand 51,28N:

$$F = F_{g1} + F_{g2} + F_p \qquad [10]$$

$$F = 17{,}17\,N + 4{,}96\,N + 45\,N = 67{,}13\,N$$

Also, it has to overcome a torque of T = 3,26 Nm.

The above mentioned requirements are fulfilled by the servo motor EMMS-AS-70-SK-LS-RSB from Festo company, which stands 78 N radial forces and 7,75 Nm of torque [8].

$$F = 67{,}13\,N < 78\,N$$

$$T = 3{,}26\,Nm < 7{,}75\,Nm$$

The requirements are fulfilled.

STRENGHT CALCULATIONS FOR Z – ACTUATOR

The Z-actuator needs to stand the total weight of the construction and the torque produced by the reaction force of the pneumatic actuator.

$$F_{gt} = (2{,}3 + 0{,}175 + 0{,}039 + 0{,}38 + 0{,}09)\,kg \cdot 9{,}81\,\frac{m}{s^2} = 29{,}27\text{ N}$$

$$T = 3{,}26\,Nm$$

An actuator that fulfils the above mentioned requirements is EGSL-BS-45-100-3P from Festo company. The documentation proves that the Z-actuator is able to carry 631N and stand a torque up to 16,3Nm.

$$F = 29{,}27\,N < 631\,N$$

$T = 3{,}26\ Nm < 16{,}3\ Nm$

The requirements are fulfilled.

Strength calculations showed that some of the parts needed to be exchanged. The final element list is visible in Table 21. The final algorithm of the NSCU 2.0 Testing Machine Is shown in Figure 37.

Table 21. Final elements list of middle part.

Device	**Weight [g]**
Z actuator [EGSL-BS-45-100-3P, Festo] [5]	2700
Servo motor [EMMS-AS-70-SK-LS-RSB, Festo] [8]	2300
Servo motor [LVHV341-01, Parker] [7]	1750
Pneumatic actuator [ADN-12-30-A-P-A, Festo] [9]	77
Servo motor [EMMS-ST-28-L-SEB-W, Festo] [10]	380
Camera [ACA1300-60gc, Basler] [11]	90
51104 Thrust ball bearing, NSK [12]	37
TOTAL:	**7334**

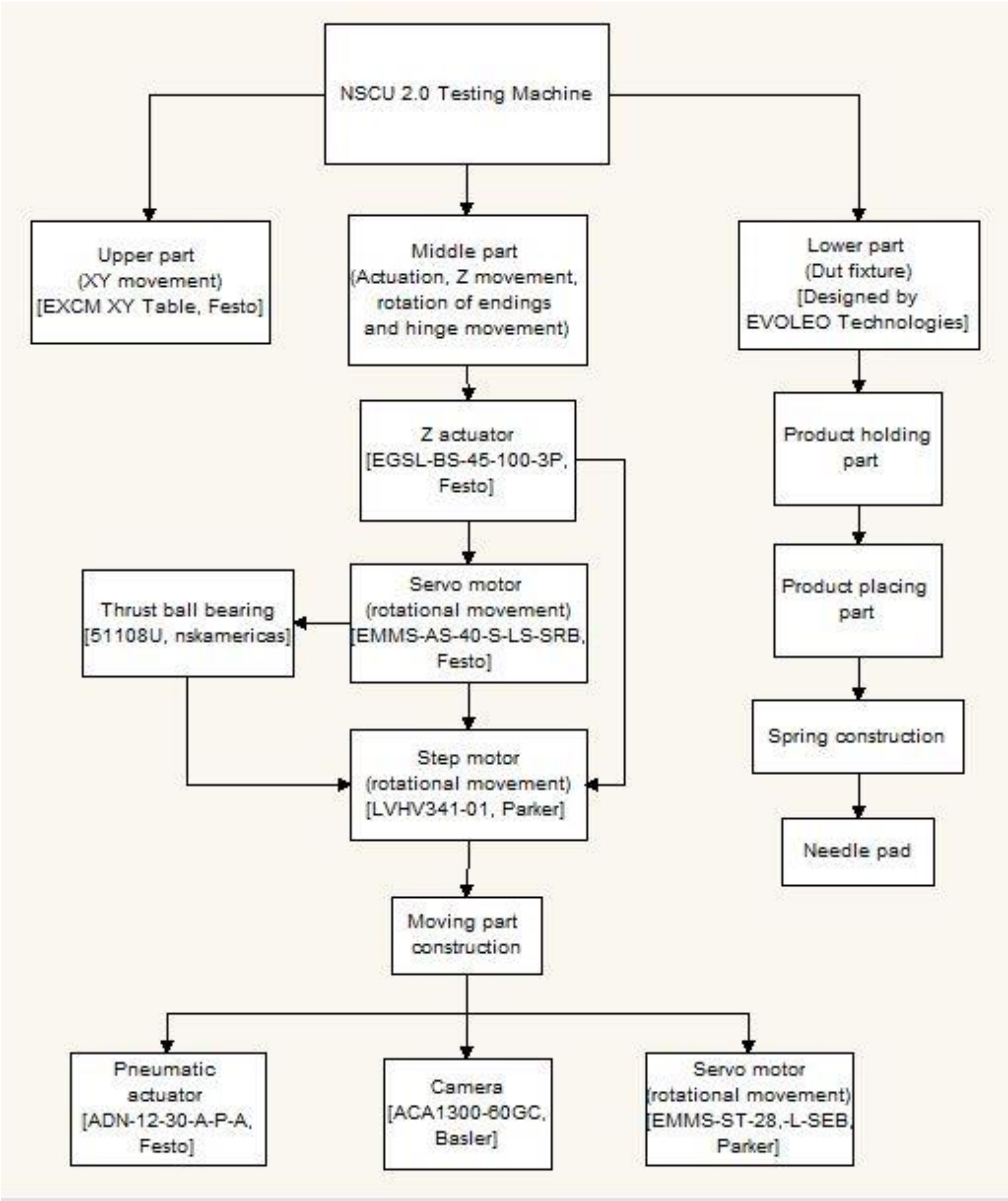


Figure 37. Final algorithm of NSCU 2.0. Testing Machine.

MATERIAL SELECTION

In order to select an adequate material for the customized parts it was essential that these parts would be resistant against pressure applied from all components. For this a situation is considered in which each of the parts apply the highest possible force on the smallest possible area. This area belongs to the shaft 341-01 parker servo actuator. The force Is a summary of the force coming from the components situated below the servo and the force applied by the EMMS-ST-28 pneumatic actuator.

$$F = \{[(1{,}75 + 0{,}039 + 0{,}38 + 0{,}09) \cdot 9{,}81] + 45{,}3\}N = \quad 65{,}36\ \mathrm{N}$$

$S = 3{,}14 \cdot 0{,}00635^2 = 0{,}0001266\ m^2$

$$p = \frac{F}{S} \qquad [11]$$

$$p = \frac{65{,}36}{0{,}0001266} = 516277{,}96\ Pa = 516\ kPa$$

The chosen material must stand stress at minimum 516 kPa. Since the construction should also be light, aluminium alloy 5052-0 has been chosen [23, 24, 25]. It has a good workability, is easy to machine, is corrosion resistant and is used in sheet metals.

FIXTURE OF COMPONENTS

The 341-01 Parker stepper motor is a 1,8 degree stepper, so it needs 200 steps to make a full revolution. Considering the longest testing actuator used (EMMS-ST-28), the distance between the servo shaft and the end of the actuator has been calculated. That procedure was made in order to examine the arc length which the actuator needs to overcome at a 1,8° displacement. The distance between the 341-01 Parker shaft centre and the actuator ending equals 141,65mm. From the equation [12] the arc length has been calculated.

$$l = \frac{\alpha \cdot 2\pi r}{360^\circ} \qquad [12]$$

$$l = \frac{1{,}8^\circ \cdot 2 \cdot 3{,}14 \cdot 141{,}65}{360^\circ} \approx 4{,}45\ \text{mm}$$

This parameters are sufficient for the NSCU 2.0 Testing Machine.

In order to get a better operability of the testing endings the whole lower situated construction that is rotatable was being placed higher. Because of that the distance between the 341-01 Parker stepper motor shaft and the ending was lowered to 101.27 mm, which resulted in shortening the arc length of the testing endings to 3.18 mm. Due to the possibility of programming the stepper motor for performing ‘half steps’ (every 0,9°), the operating arc length per pulse equals 3.18/2 = 1.59 mm.

FINAL CONCEPT - CONSTRUCTION

Changes to the previous concepts have been made in order to improve the design, compactness, weight and reliability. The resulting appearance of the middle part is shown in Figure 38.

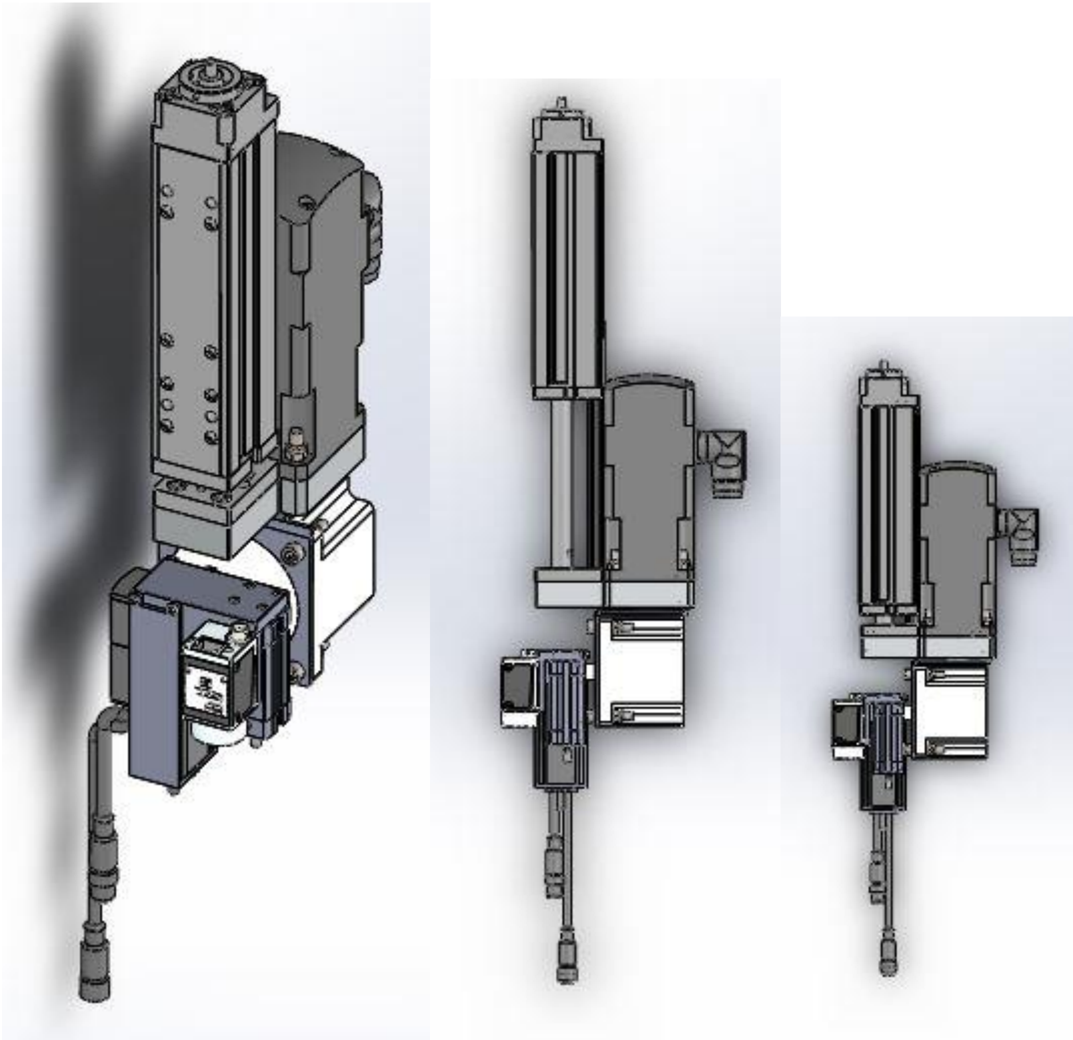


Figure 38. Final concept of middle part. (1. maximum elongation, 2. maximum reduction of component)

The pictures below explain how each individual part is situated in the assembly.
The EGSL-BS-45-100-3P actuator is connected to the EMMS-AS-70 servo motor through an purpose-built element shown in Figure 39. It presses against the 51104 thrust bearing in order to cause load transfer to the Z - actuator. Inside the bearing there is a bush, which ending is wider than the bearing so it can move easily on the surface of the balls inside the thrust ball bearing.

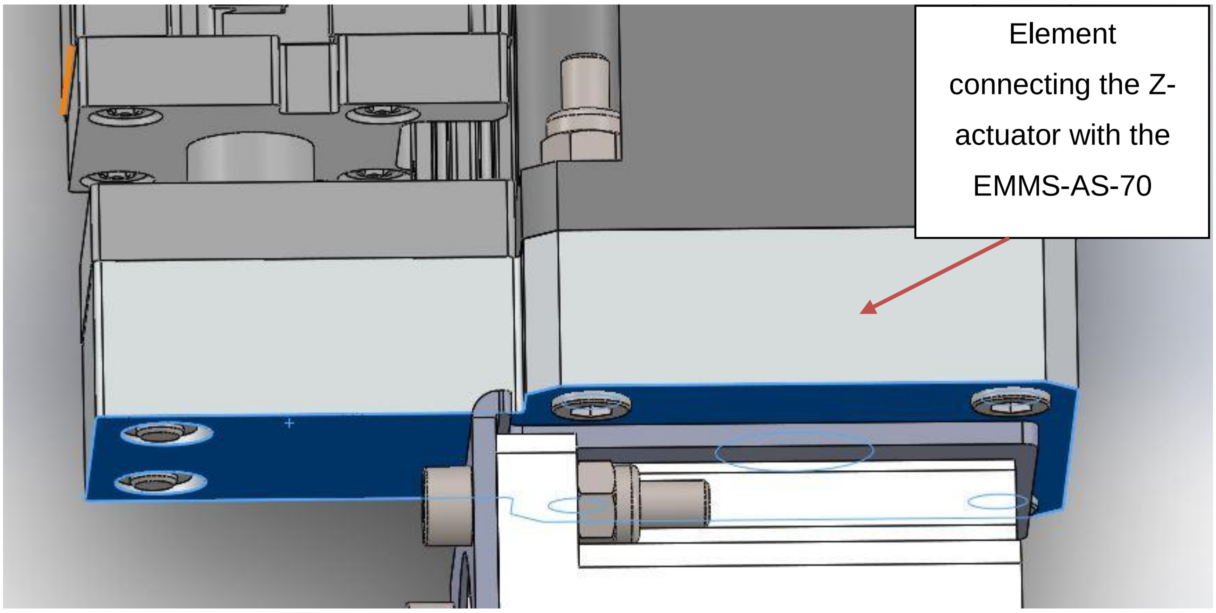


Figure 39. Z - actuator to EMMS-AS-70 servo motor fixture.

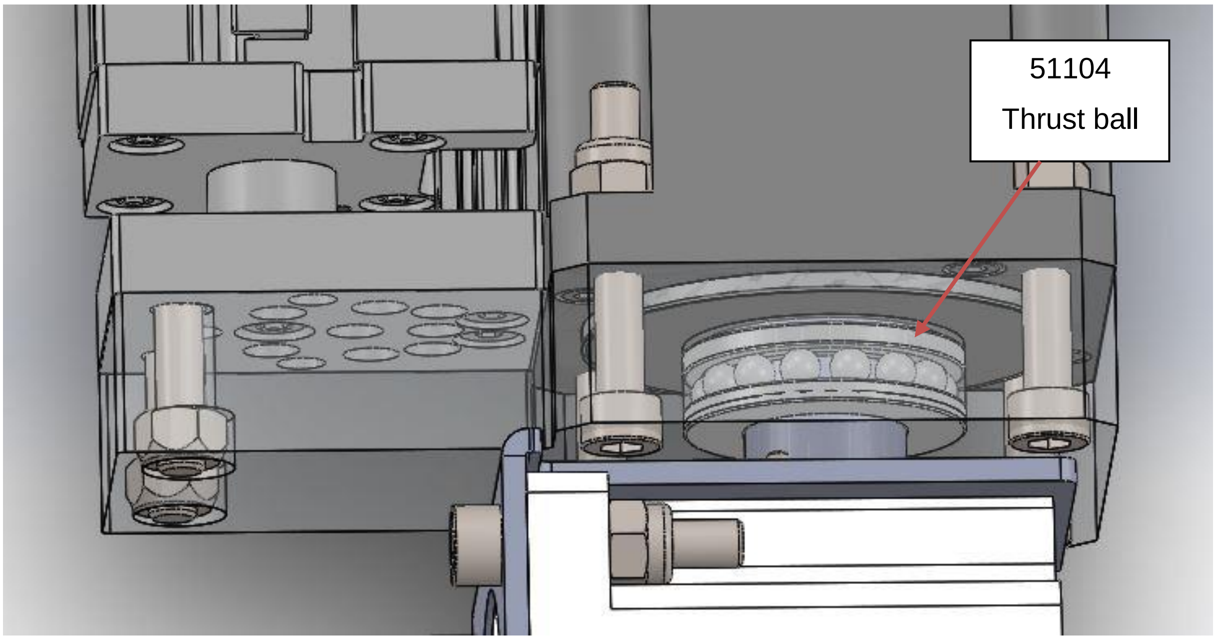


Figure 40. Interior visualization of element connecting Z - actuator with EMMS-AS-70 servo motor.

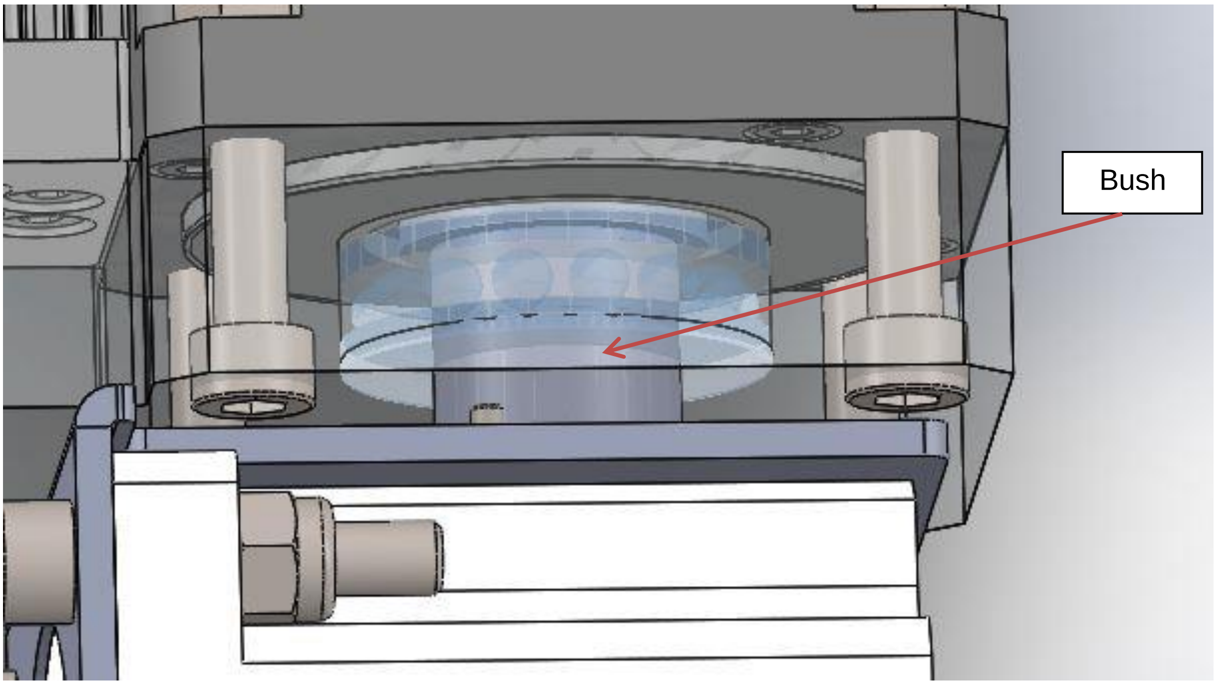


Figure 41. Bush inside thrust ball bearing.

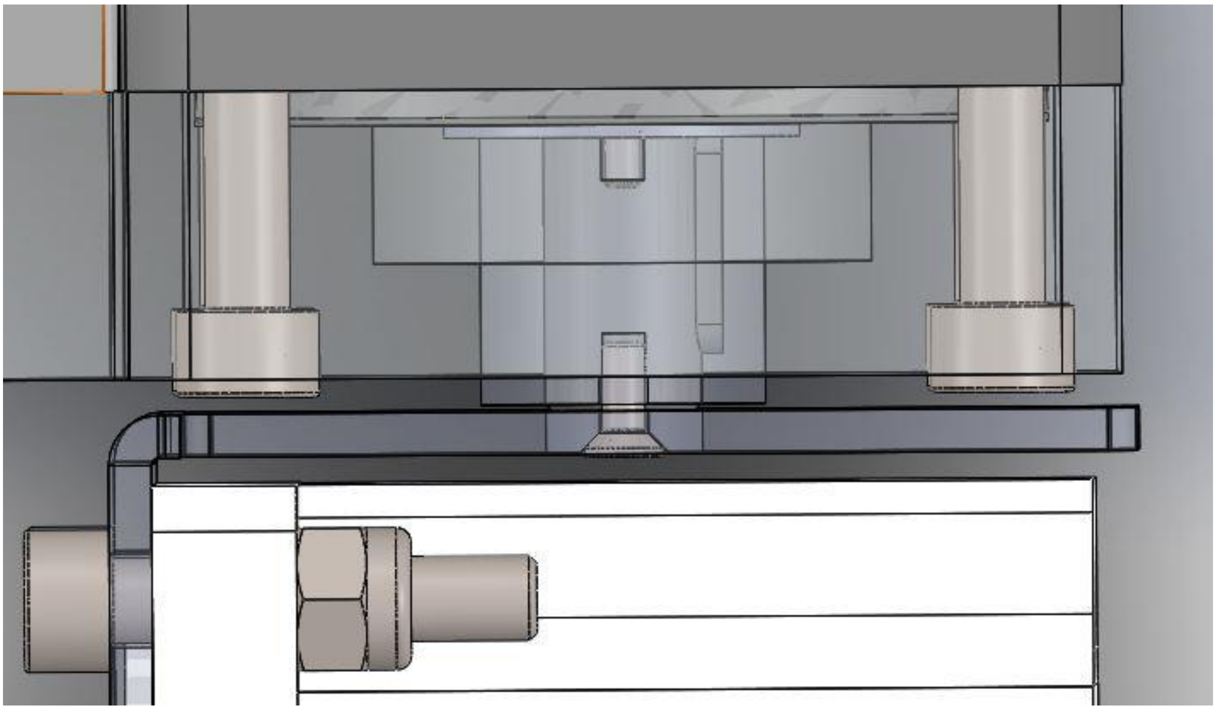


Figure 42. Fixture of bush.

The 341-01 Parker stepper motor is fixed through an element shown in Figure 42.

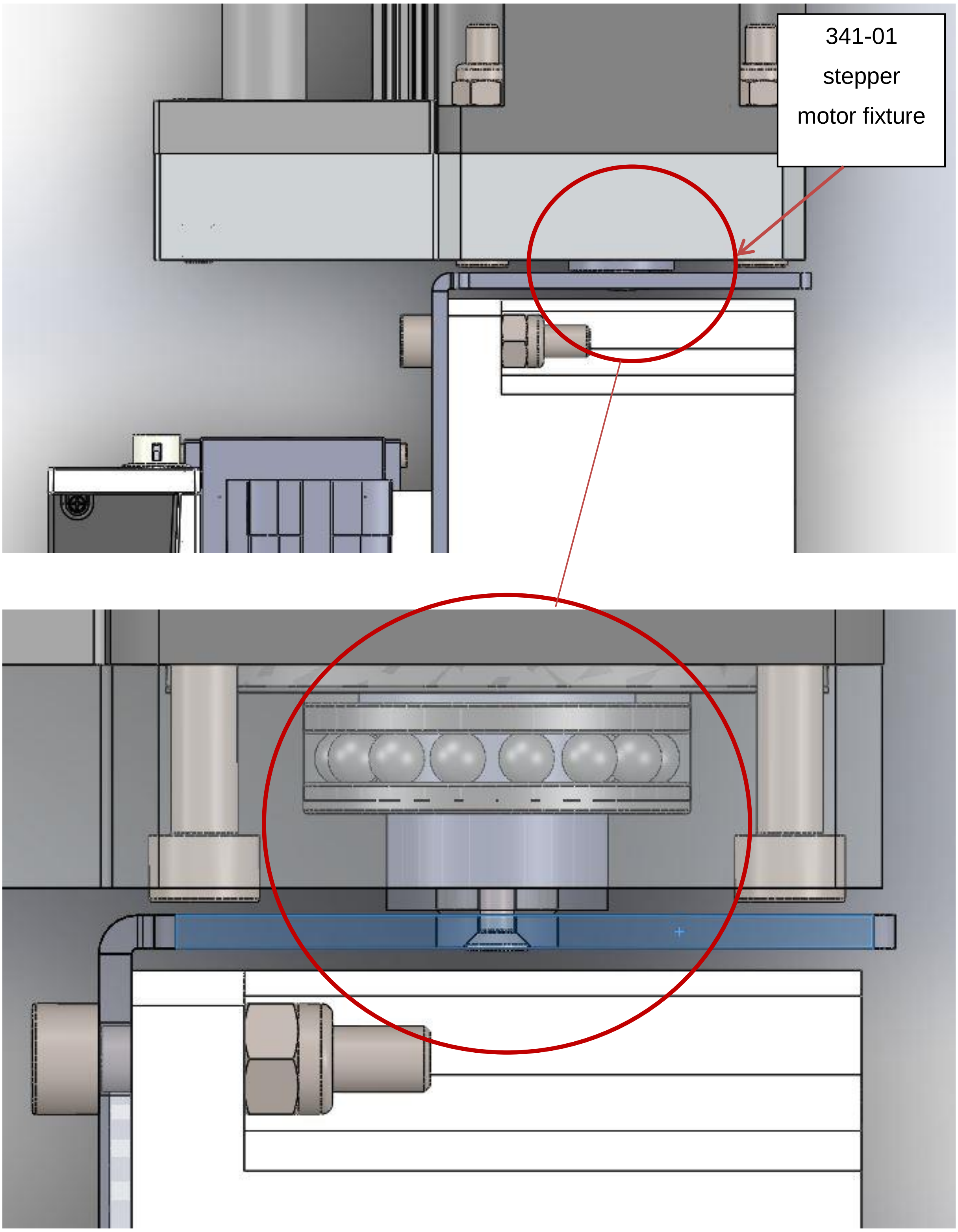


Figure 43. 341-01 Parker step motor fixture.

The stepper motor 341-01 is attached to an element holding the testing endings (Figure 43).

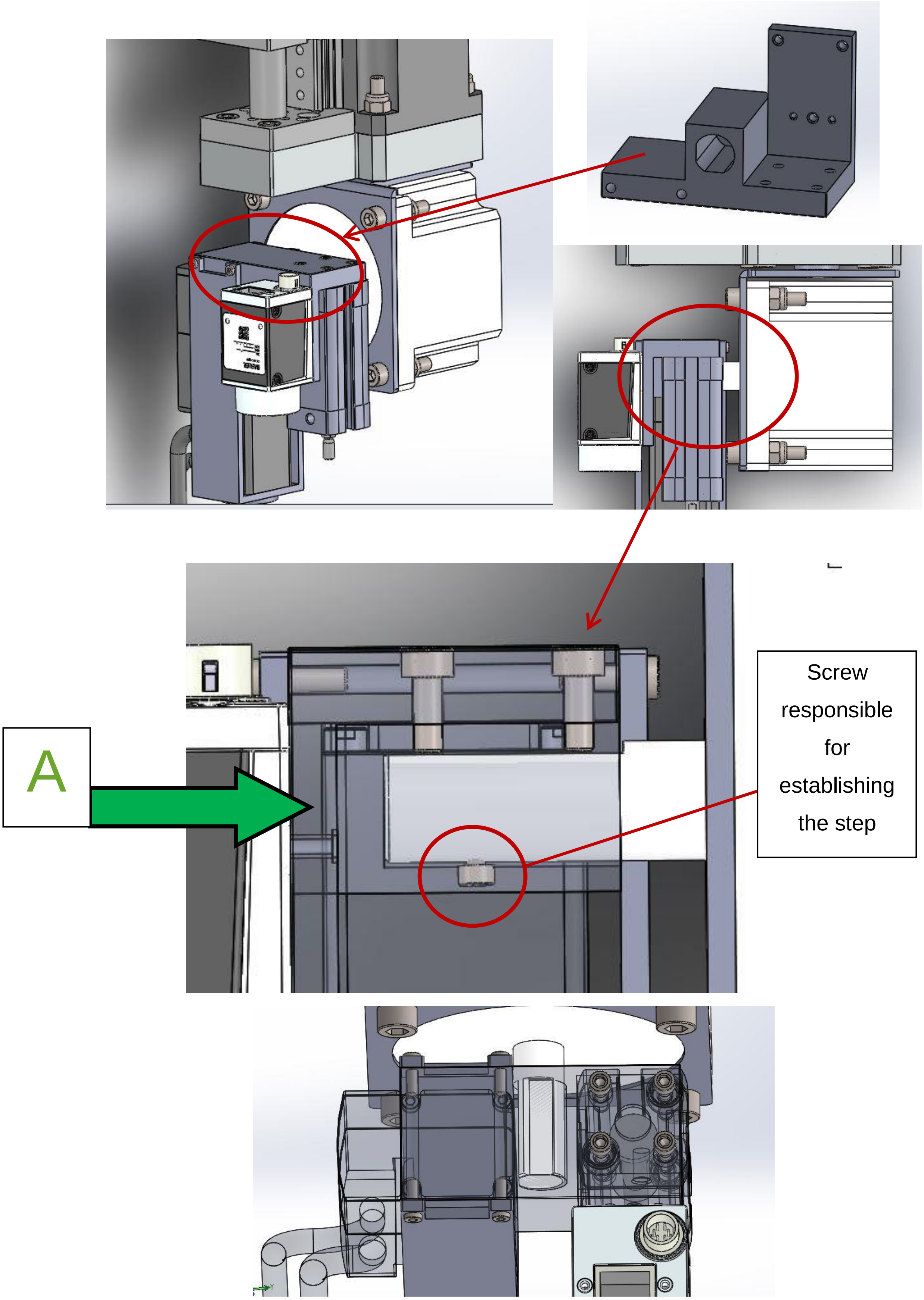


Figure 44. Expansed views of middle part.

The front view of the above shown elements is presented in Figure 44.

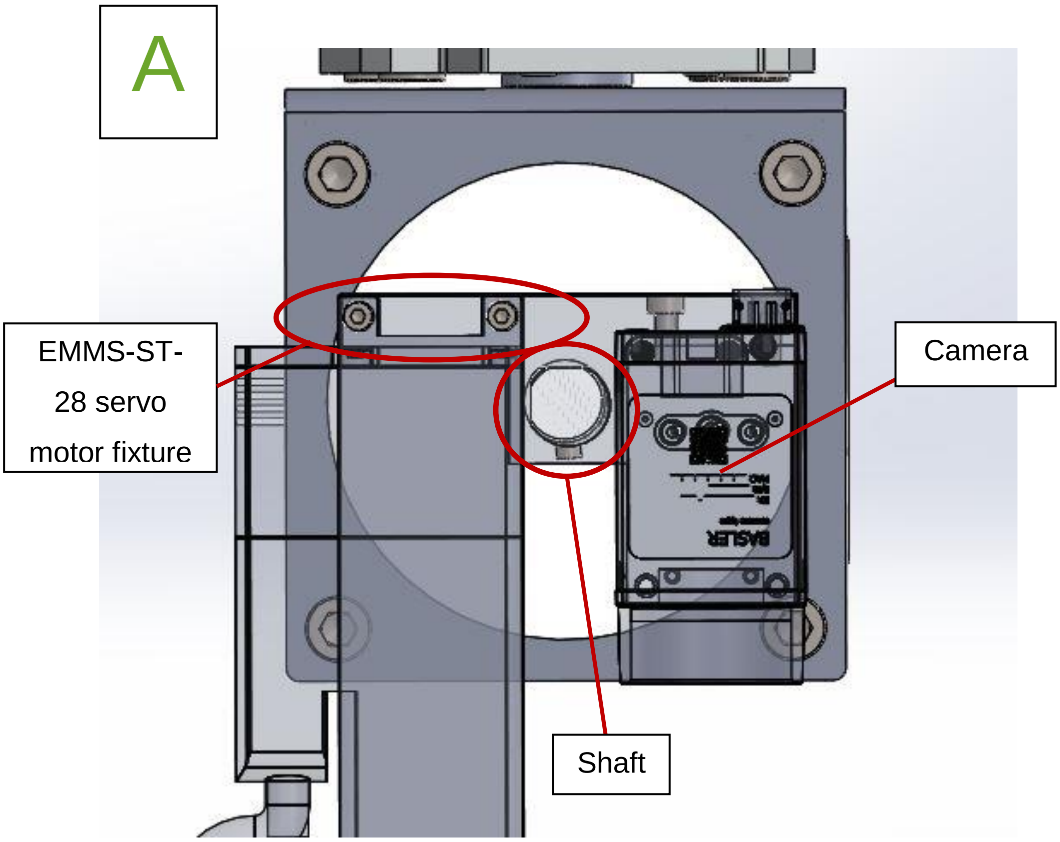


Figure 45. Front view of middle part.

The AND-30-P pneumatic actuator is connected to the rotatable platform through four screws. The EMMS-ST-28 servo motor (left) and camera (right) fixture is shown in Figure 46.

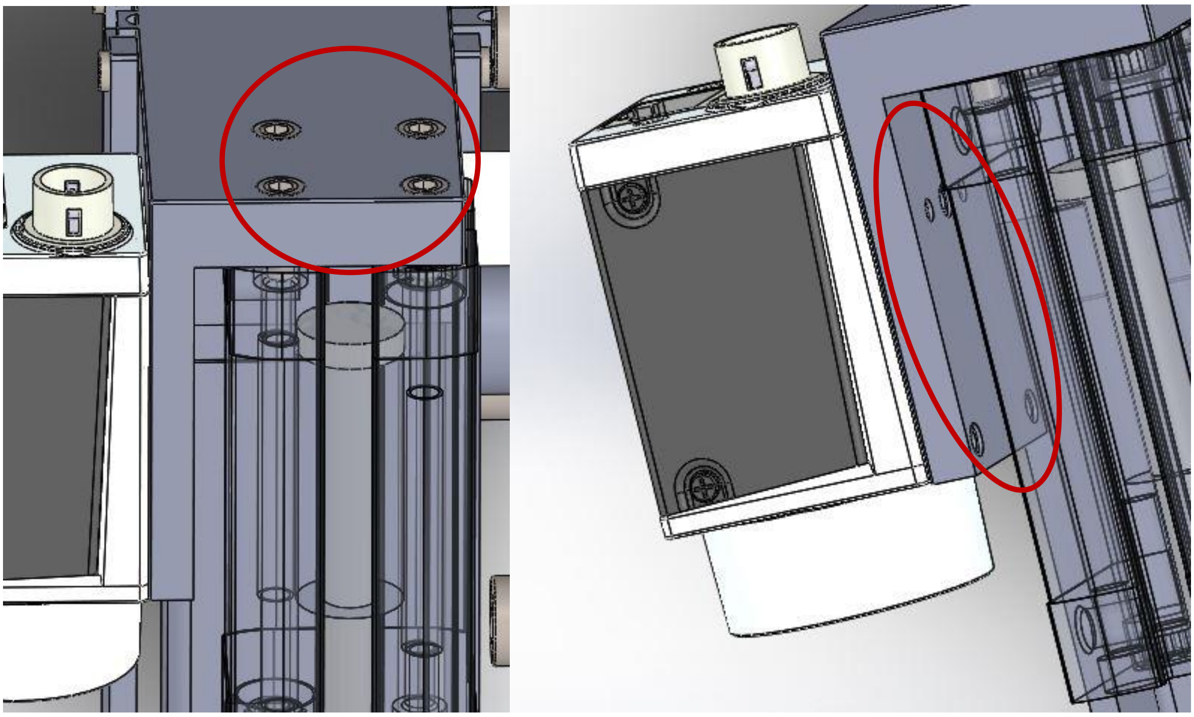


Figure 46. Fixture of pneumatic actuator and camera.

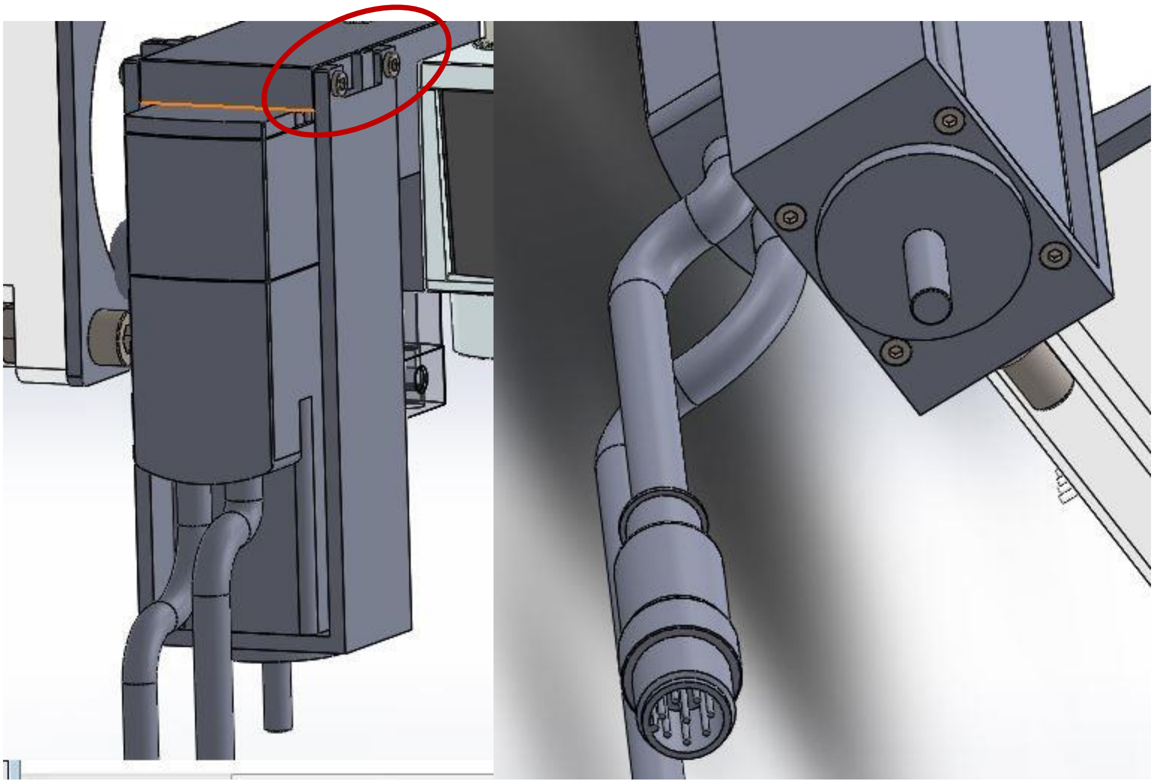


Figure 47. EMMS-ST-28 servo motor fixture

The exploded view of the middle part is shown in Figure 48. The middle part is composed of 7 main units (see Table 22 and Figure 42). All parts that are not mentioned were customized especially for the need of this project. 27 screws have been used to connect all the parts together. Mostly it have been socket head cup screws at various sizes.

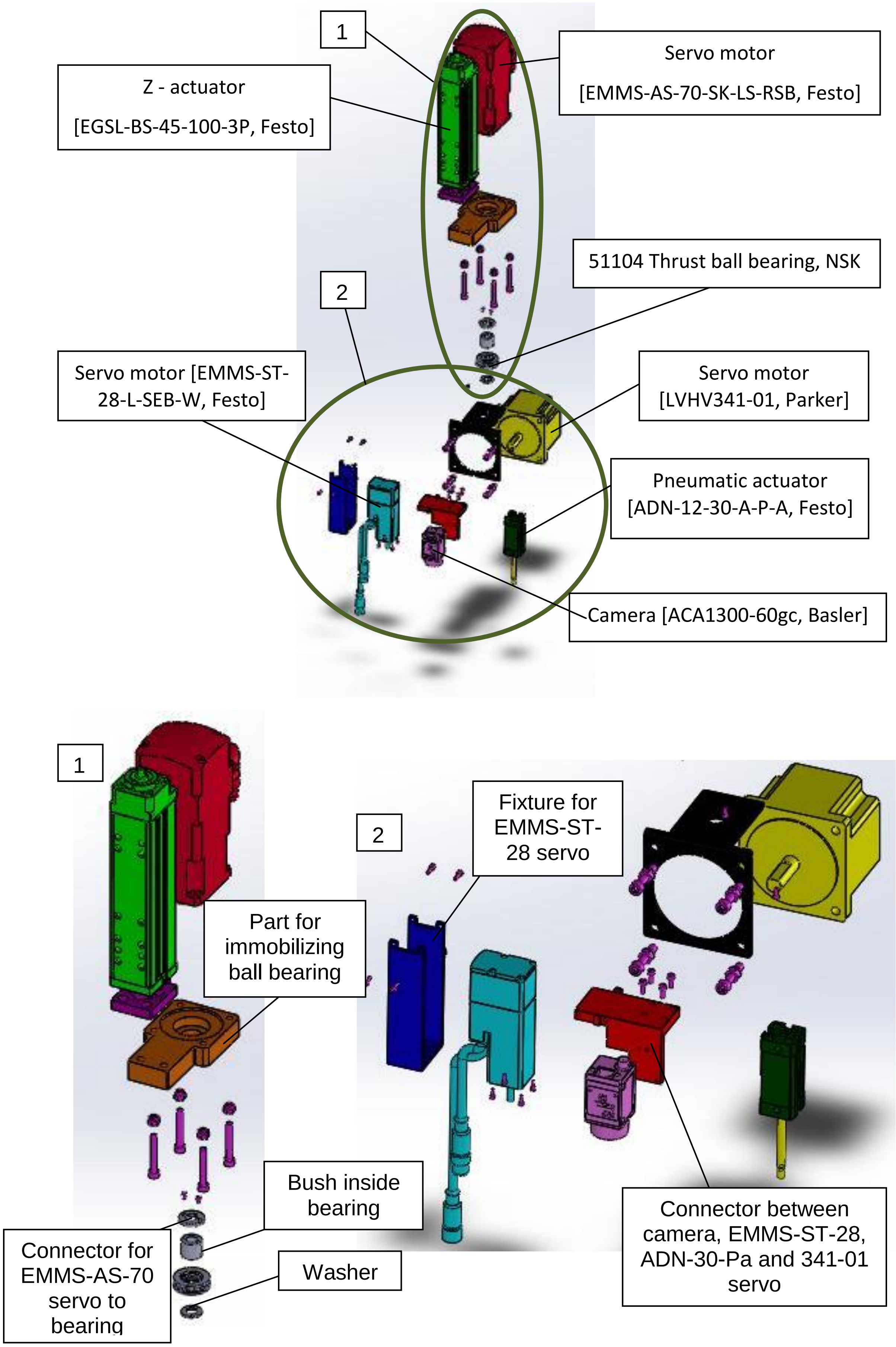


Figure 48. Exploded views of middle part.

3.4.3. Lower part development

Since the Preliminary Design phase of the project, the Lower part has been improved. It was to be assumed that in order to improve the machine, some of the older versions need to be lowered in the number of components. That is why the mechanism, which was used to connect and disconnect the DUT fixture with the needle pad differs completely from the new, innovative solution. In order to reduce the number of elements the connection and disconnection is realized by an opening door flap as shown in Figure 50. The Lower part consists of 27 units shown in Figure 49. All components of which the Lower part consists are customized units.

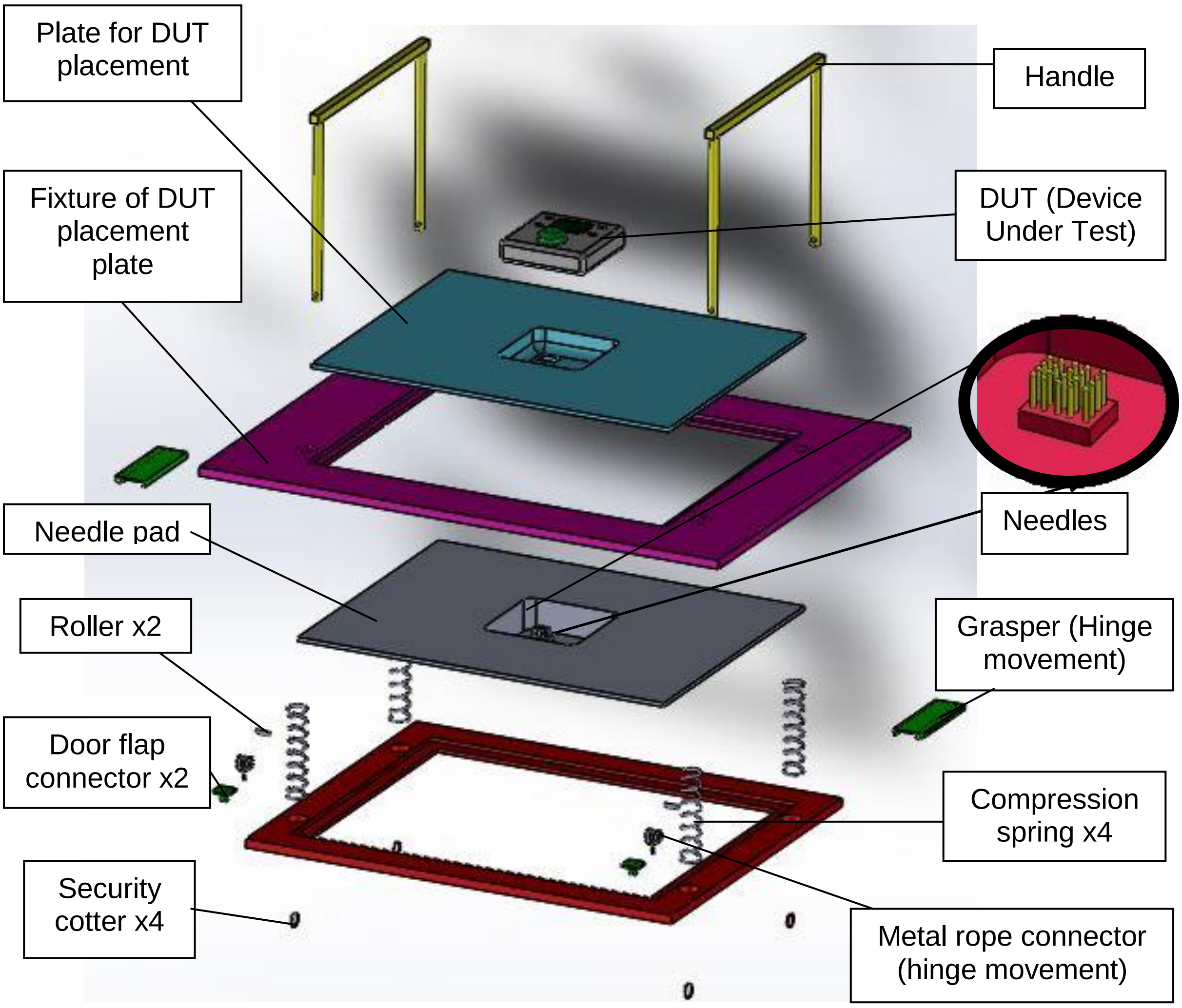


Figure 49. Exploded view of Lower part.

The final, improved Universal Functional Tester is shown in Figure 50. It is composed of five different sub – assemblies: so called Upper part, Middle part, Lower part, Structure (corps) and movable door which is responsible for the closure mechanism of the DUT fixture and needle pad.

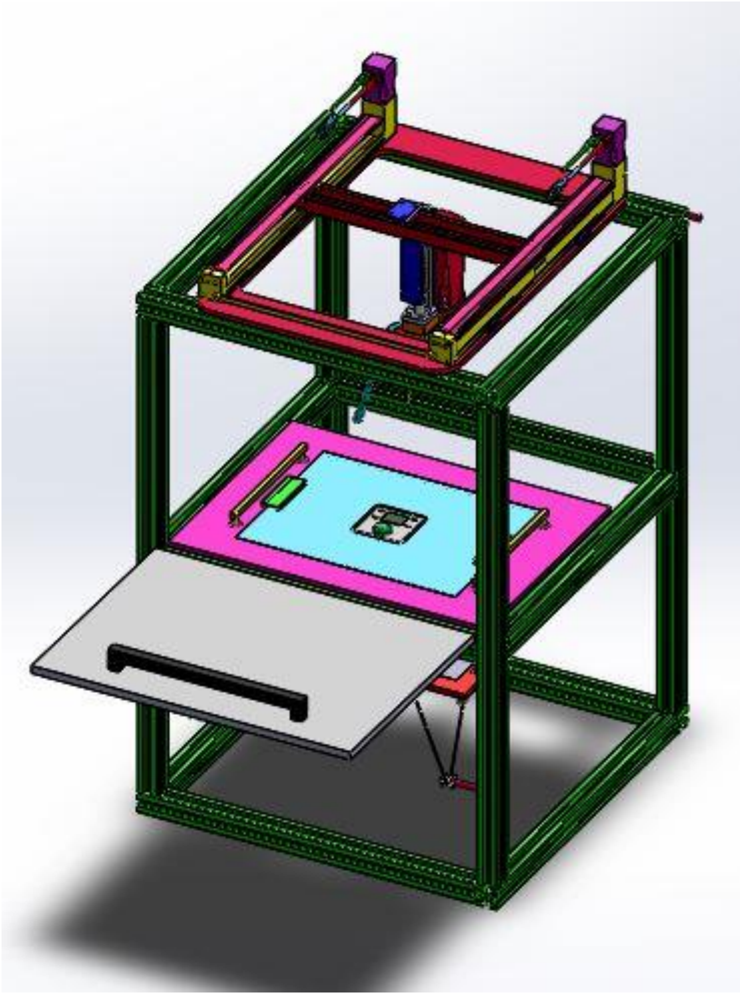


Figure 50. Final appearance of the optimised Universal Functional Tester.

The machines corps is a solid structure composed of aluminium profiles that have a special shape allowing its connection without any effort and being very reliable at the same time. The profile is shown in Figure 51.

Figure 51. Aluminium profiles cross – section.

The different sections of the Machine are shown in Figure 52. It is possible to see the different sub – sets which have been discussed before.

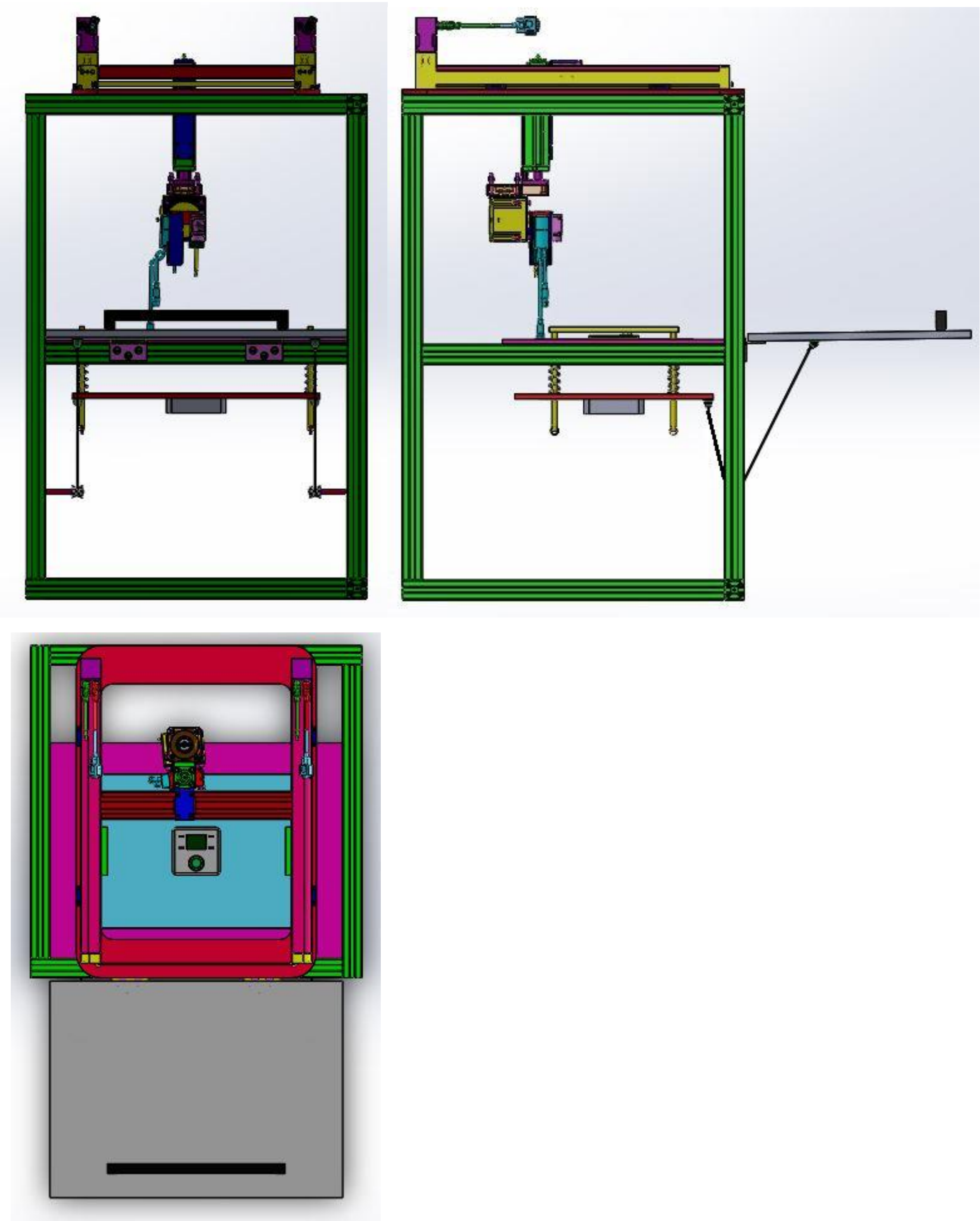


Figure 52. Section views of improved Universal Functional Tester.

In order to visualise the different sub – assemblies Figures below are being showed.

1) Structure

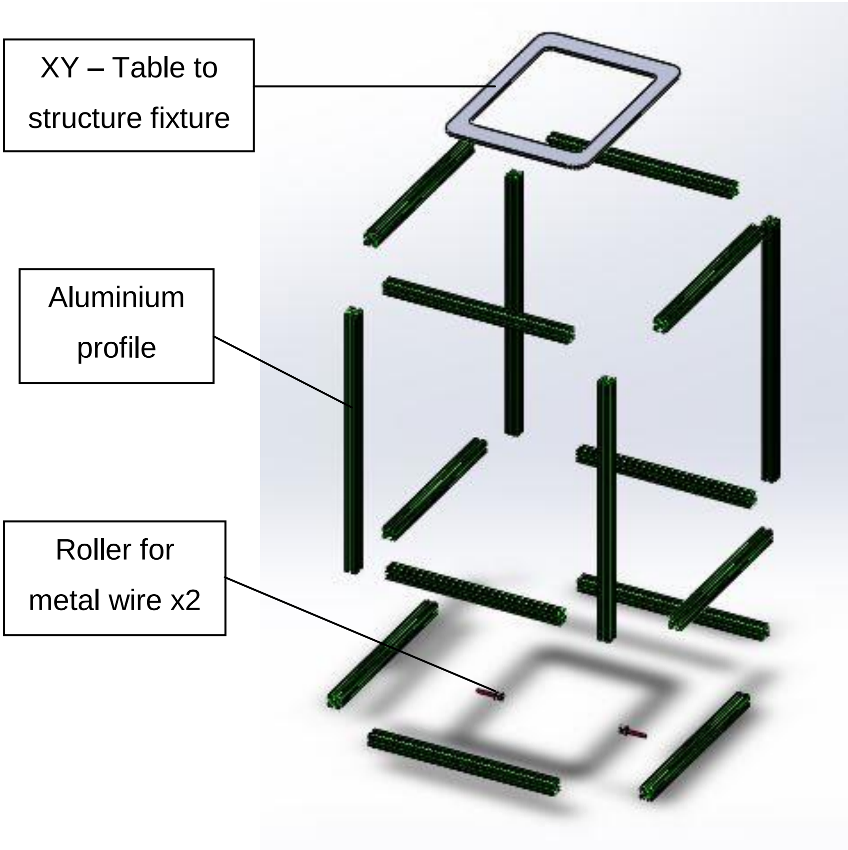


Figure 53. Aluminium profile structure (exploded view).

2) Upper part

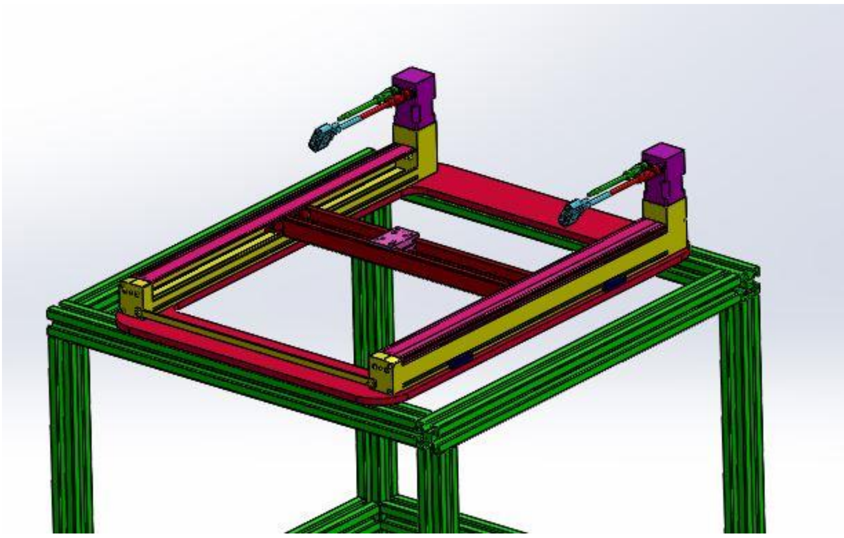


Figure 54. Upper part sub – assembly: XY – Table.

3) Middle part

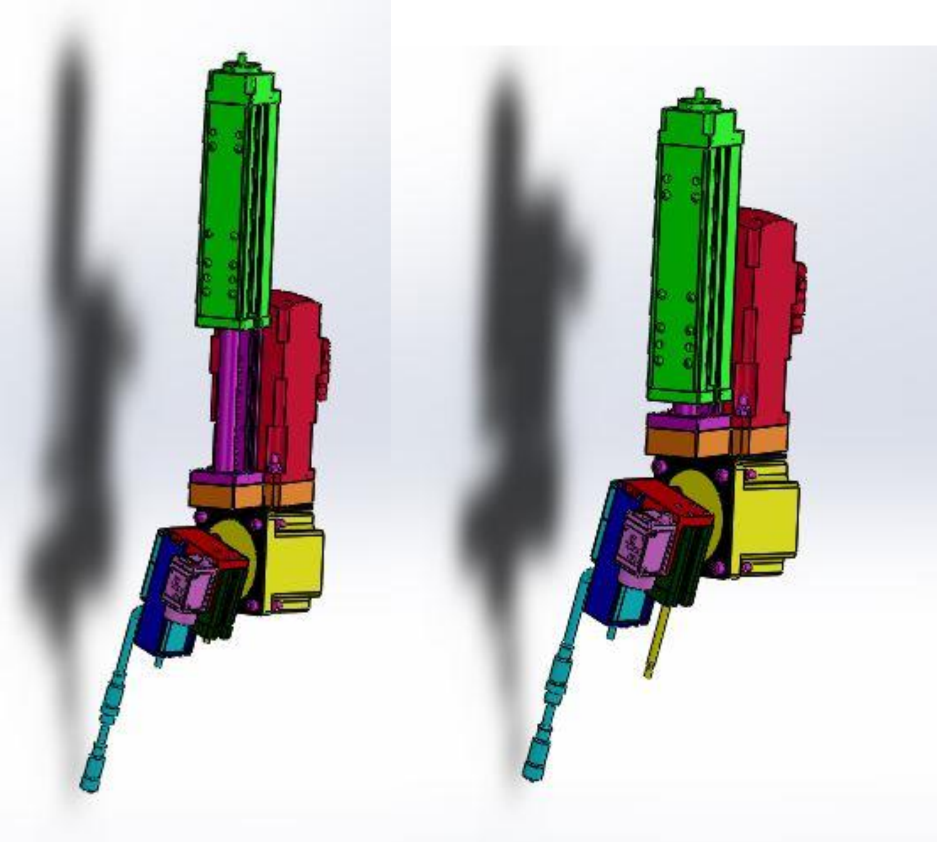


Figure 55. Middle part sub – assembly .

4) Lower part

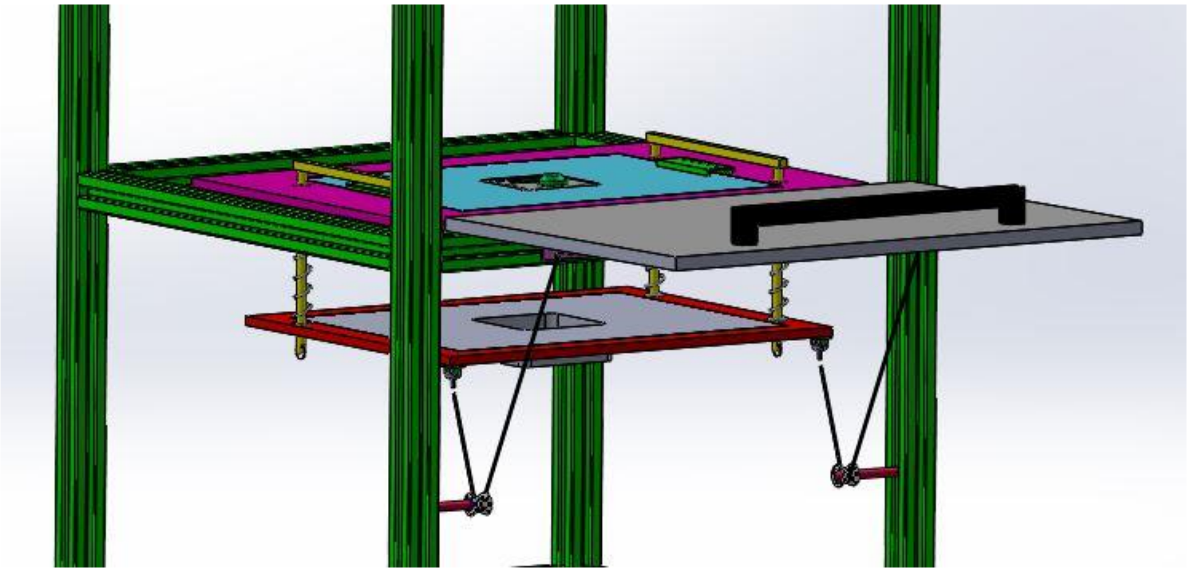


Figure 56. Lower part sub – assembly with movable door flap.

5) Movable door

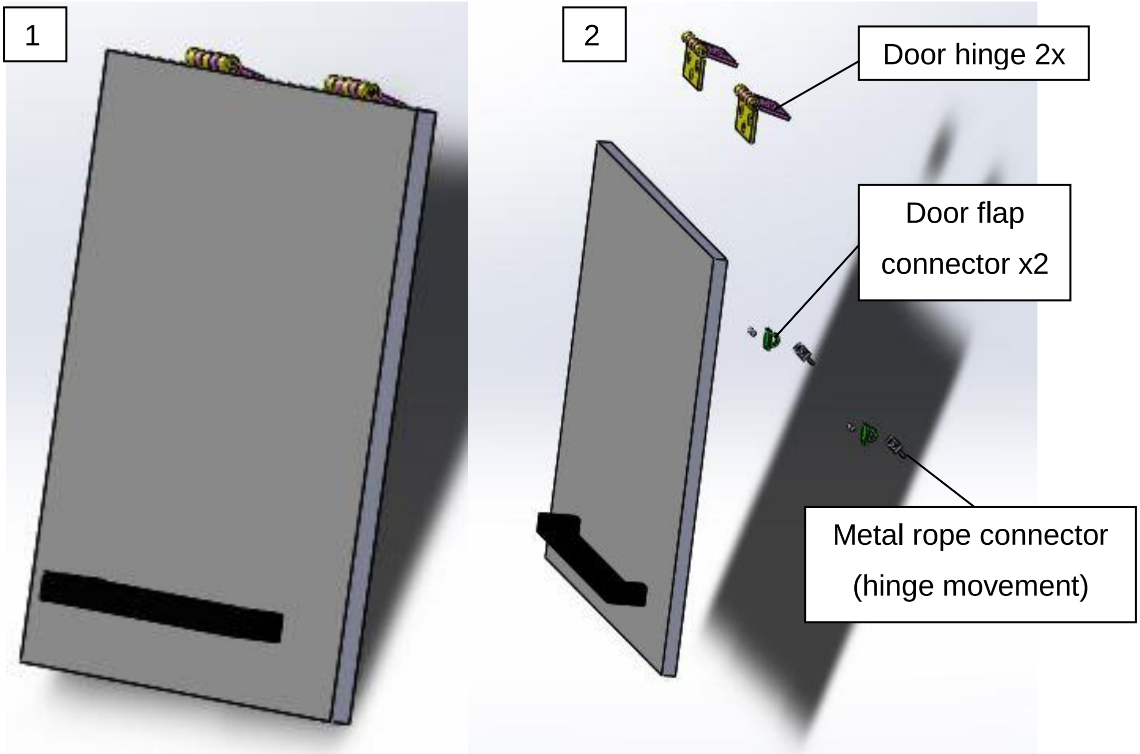


Figure 57. Door sub - assembly (1 - normal view, 2 - exploaded view).

A set of illustrations has been made (Figure 58) in order to show the following steps of placing the DUT into the desired position as well as connecting the DUT fixture with the needle pad.

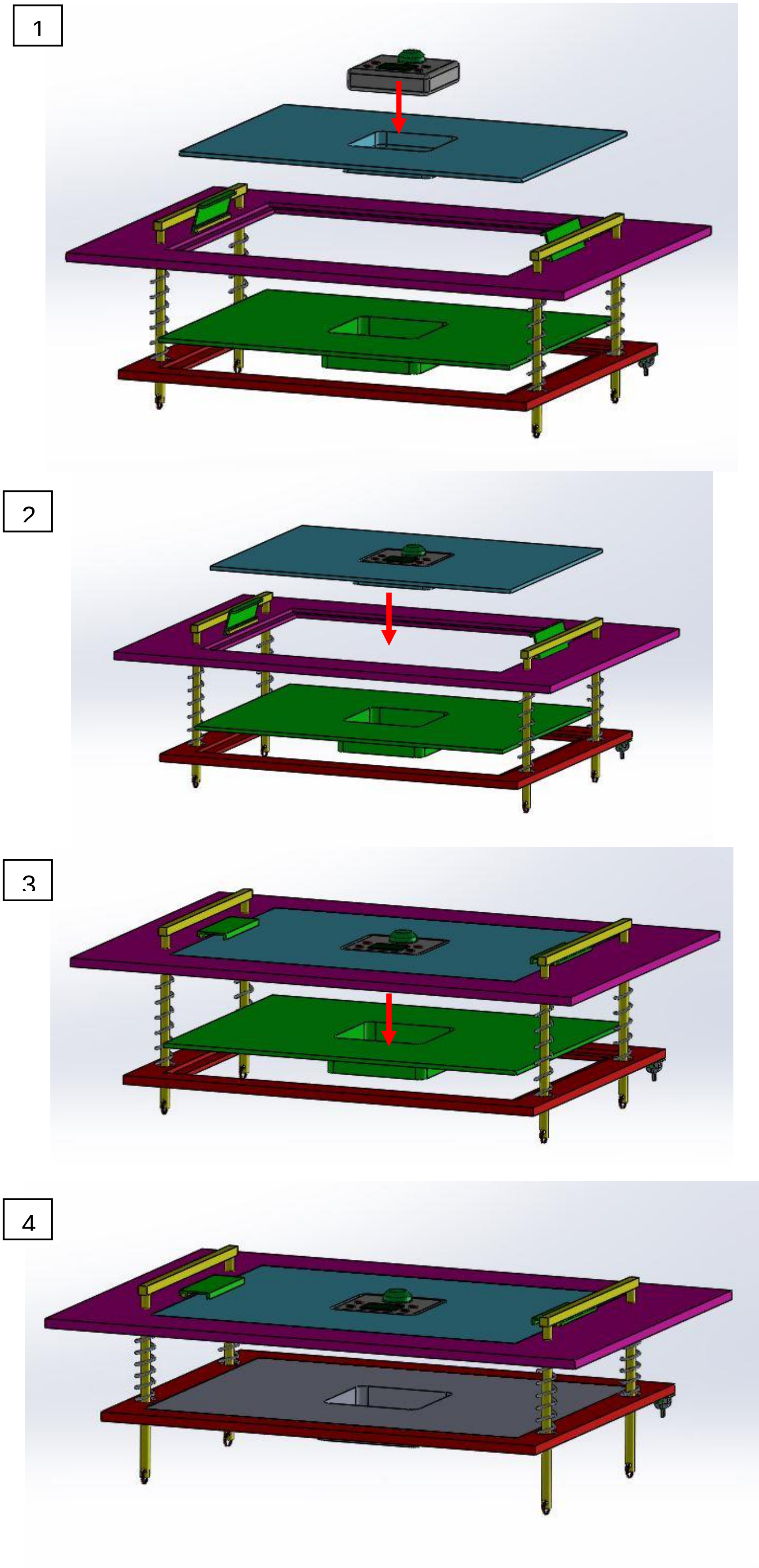


Figure 58. Consecutive steps while positioning the DUT.

Special holes have been designed for the spring to hide while being compressed.

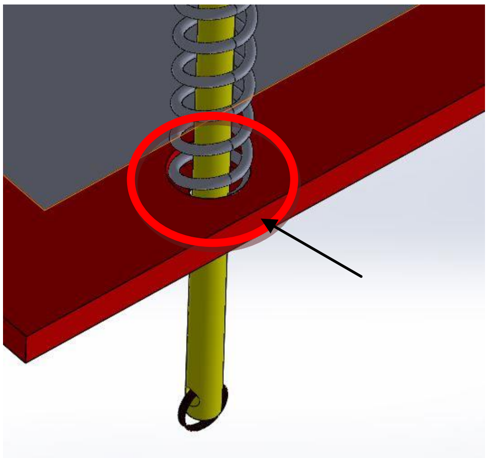
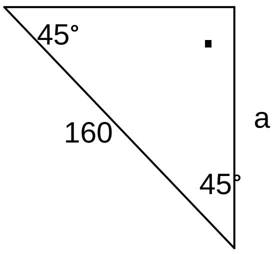


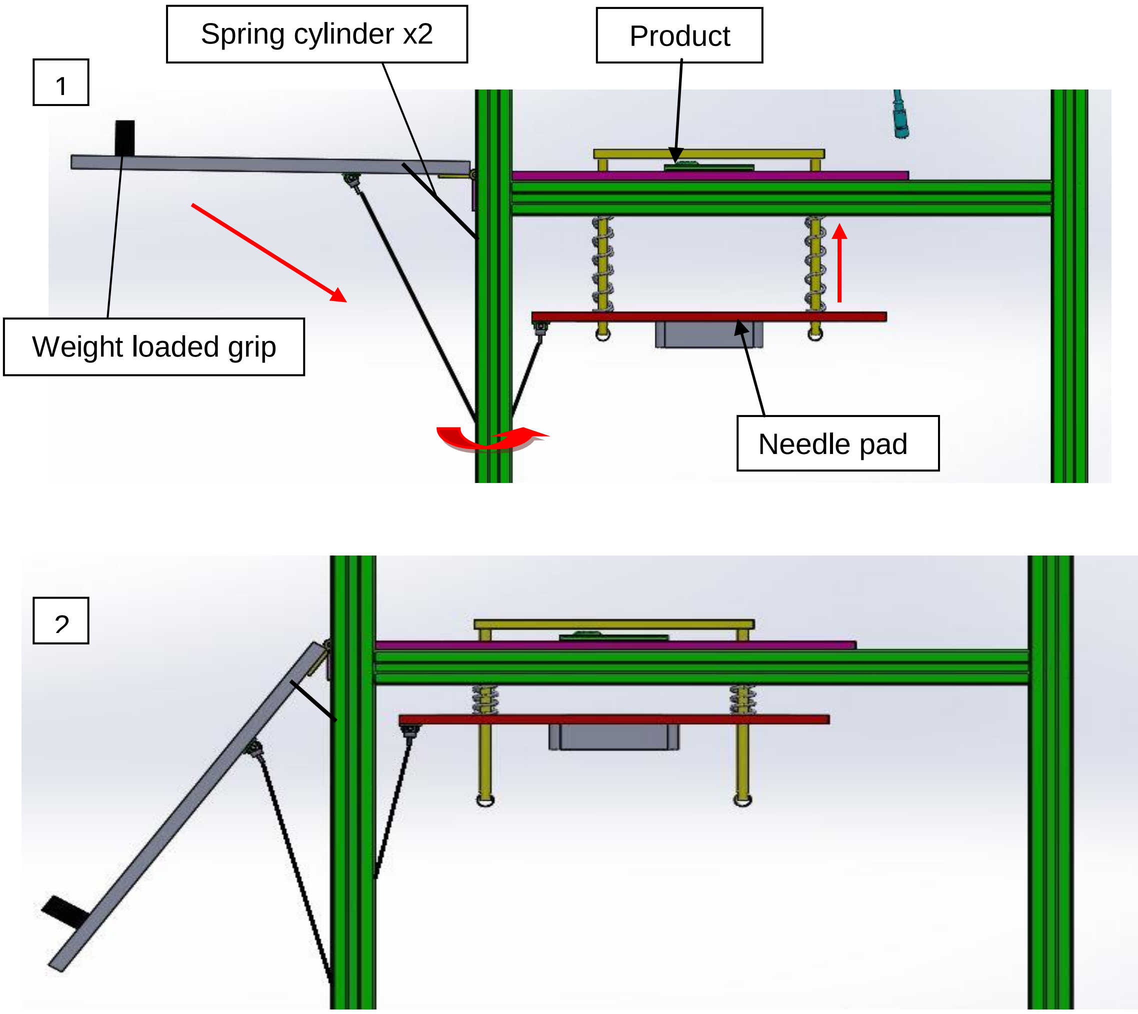
Figure 59. Holes responsible for covering the compressed springs while connecting DUT fixture with needle pad.

The mechanism causing connection of the DUT with the needle pad is presented below. It is to be mentioned that regarding the fact that potential users could slam the door (resulting with problems occurring at the needle connection part) a safety system is used to prevent too fast door shut closure. The end of the door is equipped into spring cylinders that smoothen the closure of the door in case of slumming it. Additional, the black grip visible in Figure 60 is laden with weight so to help the ordinary user by dealing with the doors weight. When the door is placed in a position exceeding 90° it automatically goes up and holds itself in the air. On the other hand, when the door is positioned below 90° it helps the user to easy close the door. Also, It needed to be calculated at which position the steel wire should be mounted. Knowing that the best possible option is to have a isosceles triangle (45°) and that the distance between the DUT fixture and needle pad while being disconnected equals 160, a simple calculation has been made in order to get best distance for mounting the wire.



$a\sqrt{2} = 160 \rightarrow a = \frac{160\sqrt{2}}{2} =$ 113,14 mm

While the door is being pushed down, the metal wire causes rotation on the roller which indicates the movement of the needle pad construction.



The whole movement is resulting with the closure of two components – the needle pad and the product.

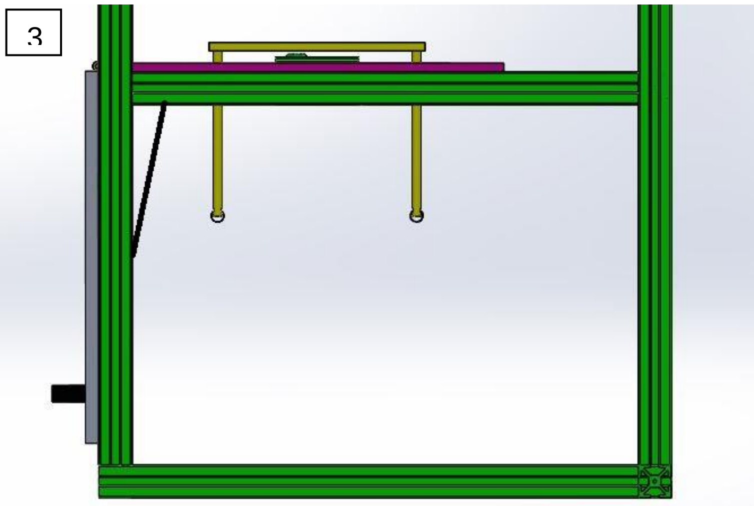
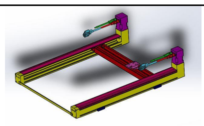
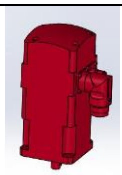
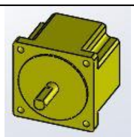
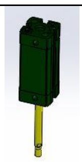
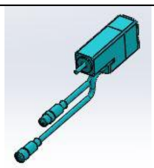


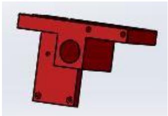
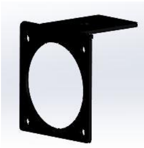
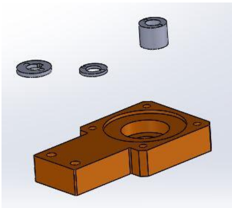
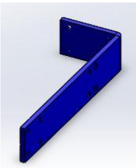
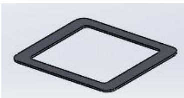
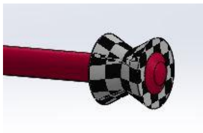
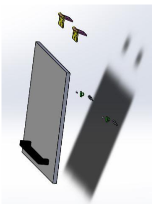
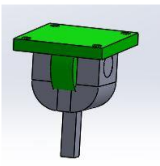
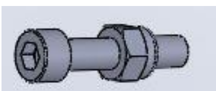
Figure 60. DUT fixture to needle pad connection mechanism.

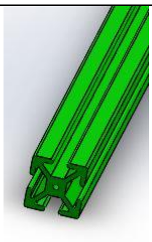
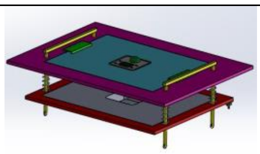
3.5. Budgeting

All components have been summarized below (Table 22) in order to receive a demonstrative price list. Some of the prices have been taken from websites of the producers, others have been approximated by the knowledge of employees working at EVOLEO Technologies.

Table 22. Price list of NSCU 2.0 Universal Functional Tester.

	Device	**Quantity**	**Cost (euro)**
	XY – Table [EXCM, Festo]	1	1500,00**
	Z actuator [EGSL-BS-45-100-3P, Festo] [10]	1	1065,00*
	Servo motor [EMMS-AS-70-SK-LS-RSB, Festo] [8]	1	792,40*
	Servo motor [LVHV341-01, Parker] [7]	1	271,70*
	Pneumatic actuator [ADN-12-30-A-P-A, Festo] [9]	1	115,40*
	Servo motor [EMMS-ST-28-L-SEB-W, Festo] [13]	1	142,35*
	Camera [ACA1300-60gc, Basler] [14]	1	440,00*
	51104 Thrust ball bearing, NSK [15]	1	10,50*

	Customized units: Connector for 341 – 01 servo to testing endings	1	
			
	Fixture for EMMS – ST – 28 servo	1	
	Fixture for 341 – 01 servo	1	
	Unit for immobilizing thrust ball bearing Bush inside bearing Washer Connector for EMMS-AS-70 servo to thrust ball bearing	1 1 1 1	
	Sheet metal (Middle part fixture)	1	500*
	XY – Table to structure fixture	1	
	Steel wire	2	
	Roller	2	
	Door with hinges	1x2	
	Needle pad fixture to steel wire connector Door to steel wire connector	2 2	

	Screws and nuts	1 package (100)	
	Aluminium profile (10pcs 600mm +10pcs 650mm+ 4pcs L730mm) [16]	20	54,44* (price for 20)
	DUT fixture and needle pad connector mechanism cassette	1	1000**
	Additional costs: work payment (employees), production, new design, additional elements, electrical devices, motors etc.		30000*
TOTAL:			**35891,79**

*Currency conversion from pounds to euros
**price taken from consultation with EVOLEO Technologies employees

The overall cost of NSCU2.0 (including components, new design and production) equals **35891,79 euro.** The NSCU1.0 (previous Universal Functional Tester) oscillated around 40,000 euros.

3.6. Critical analysis and prospects for improvement

Summing up the whole work process I think that regarding the fact that this was the first time I had to deal with a project, the results achieved are satisfying. Two completely new parts have been created, it was possible to make the machine measure in angles and the DUT fixture to needle pad connection mechanism was being improved. That is, I would say, a good outcome. If I would start the project again I would definitely distinguish which concepts are possible to realise and which ones are almost impossible to achieve. My knowledge about the technical aspects expanded a lot and for sure the next project would take a shorter time to being brought into reality.

If I was asked about improving the project in present I could only think about the DUT fixture and needle pad connecting mechanism improvement (which equalize with a cost rise). Instead of using rollers upon which steel wires that connect the door with the needle pad holding are placed, double - acting hydraulic cylinders could be used. As the door would be closing, the liquid would move actuating the needle pad fixture to connect with the DUT. On the other hand, while opening the door the exact opposite situation would take place – the mentioned devices would be disconnected.

3.7. Equipment instructions manual

Since the work was based on improving the already existing NSCU1.0 Universal Functional Tester and regarding that a few components have been exchanged, others have remained, the Manual Instruction guide was not changed. No important changes (from the view of the user) have been implemented. For more information about the content of the Manual it is necessary to reach for the Equipment Instructions Manual NSCU *Descrição da operação do Sistema.*

3.8. Maintenance Guidelines

Table of Contents

Introduction

This document was created in order to explain processes that are necessary for maintaining the equipment of the NSCU 2.0 Testing Machine.

The NSCU 2.0 Testing Machine is composed of a universal platform used to test the buttons, rotary switches and displays of different devices. Figure 1 shows the machine.

Figure 1. NSCU Functional Tester.

Testing and solving problems

This section is dedicated to problem solving of errors that could occur during the usage of NSCU 2.0 Functional Tester.

In each situation it is to be assumed that errors from the site of the software may occur. That is why it is to be assured that the problem does not results from the failure of the software.

Before proceeding with the problem solving it is to be assured that all pneumatic actuators are blocked in order not to cause harm to the user.

Table 1. Dealing with errors.

Procedure	Respond	Solution
1. The Machine does not turn on		
Check if the integrated switches X1, X2, X3 are switched on	YES NO	Proceed to next step Switch on the switches
Check if all the cables are plugged in properly	YES NO	Proceed to next step Plug in all cables
Check if the UPS is connected	YES	Proceed to next step

	NO	Connect the UPS
Check if the ON/OFF switch is damaged. To do so remove the panel that contains the switch. Place the switch in a device that verifies if there is communication between all pins.	YES NO	Exchange the switch Contact the service for assistance.
2. The vision system does not work		
Open the MAX software and verify if the camera is connected	YES NO	Proceed to next step Connect the camera
Use a button to verify if the camera is showing the desired image correctly	YES NO	Verify if the camera is corresponding to the MAX software Proceed to next step
Check if the Ethernet cable between the computer and the camera is plugged in correctly	YES NO	Proceed to next step Plug in the cable
Verify if the lens is placed onto the camera	YES NO	Contact the service for assistance. Put the lens onto the camera
3. The DUT does not fit		
Check if anything is in-between the DUT and the connection part	YES NO	Pull out the colliding element Proceed to next step
Use the special prepared system responsible for verifying if the part is reacting correctly.	YES NO	Proceed to next step Check if the DUT's pins are reacting (Yes - Proceed to next step, No – exchange the damaged pin)

Check if the system is sending an information about the connected voltage (proper values: 2V, 3.3V)	YES NO	Contact the service for assistance. Write an command including the desired voltage
	4. XY – Table does not work	
Connect the software of FESTO in order to verify if controllers are working properly	YES NO	Contact the service for assistance. Exchange

Conservating/ cleaning

The cleaning process should be done under the strict shut down of the equipment. The areas that should be cleaned are the needle pad part – placed onto the DUT and the ventilation system which is located in the inner side part of the top panel. To do that it is recommended to exchange the attached filter.

List of components

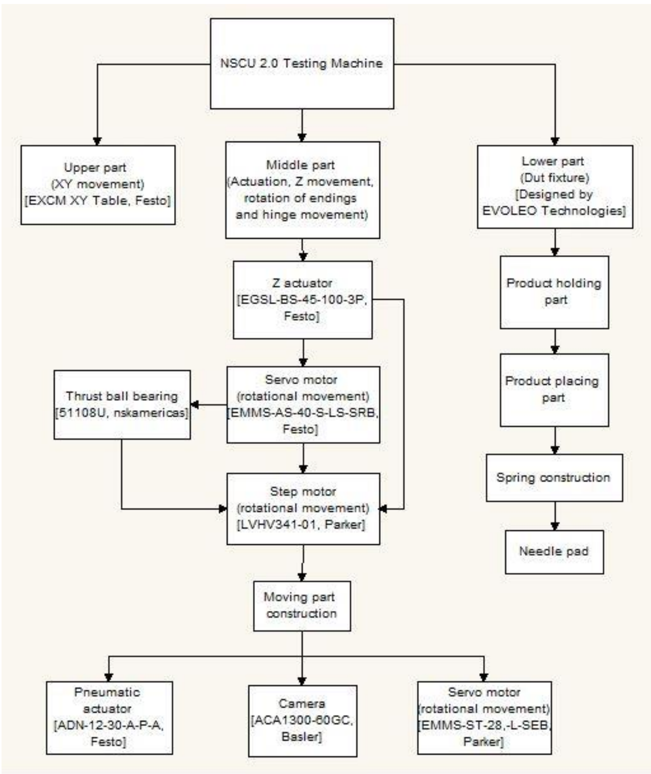


Figure 2. Components chart of NSCU 2.0 Testi ng Machine.

4. CONCLUDING REMARKS

4. Concluding remarks

The project being presented with this work was my first of that kind. That is why I have encountered a lot of problems which in the first place seemed to be very easy to solve. After writing this report I have realized that it is more difficult to optimize an already existing device than to build one from scratch. That is because while You are looking at a certain problem having already the previous results it is harder to think 'out of the box'. Previous designs seem to be ideal because everything was working as it should. Also, the computer - aided engineering software Solidworks was a new environment for me. Because of this I have spent a lot of time in tutorials rather than concentrating on the problem at the beginning (which was good for me because right now I can use this tool in a lot of aspects). After the time accommodating to the form of this project and also after familiarization with the Solidworks environment everything was easier. New concepts came into my mind very quickly and everything seemed more organised and clear. The achieved results in this project were satisfying, though. Two completely new parts have been created, it was possible to make the machine measure in angles and the DUT fixture with needle pad connection mechanism was being improved. That is, I would say, a good outcome. I have gained a lot of new skills, learning Solidworks, business language, different Product Development Processes, how to accommodate in a company etc.

It was the first time for me to work with Portuguese people, but I have to admit that it was a pleasure to be given a chance like that. Right away when I entered EVOLEO Technologies (the company I was realizing my project at) I was greeted with smiles and interest about my person. The first impression was great. The work also was very good. Always when I needed help someone was there to give me advices. I never encountered uncomfortable situations and I could easily talk about all my doubts or problems. The chefs are open for new ideas and are trying to do their best in order for everyone to be satisfied. Also, besides the job, me and my work colleagues went out several times. It was a great experience.

If it comes to the university, I have to say that being part of the ISEP Master Degree in Mechanical Engineering was the best thing that could actually happen to me. It was the first time I encountered that a department takes so much care about students. Since the arrival we were being welcomed with food and music, after that we got propositions to realize our Erasmus Projects in companies, what rises our attractiveness in the work life and gives us great experiences. Together with Professor Francisco J. G. Silva we have been having meetings in companies. The contact between us was great. Professor Silva answered our E – Mails very fast, always assured himself if everything was all right and was a really big help to all us Erasmus Students from Poland. We were glad to have him.

My Erasmus+ experience in Porto was amazing. The city is beautiful (I have been doing a lot of sightseeing through whole Portugal), the people are awesome (when I got lost somewhere there was always a person to help me find the way!), the food is different (cheese, wine and coffee are AMAZING!) and the weather is perfect. I made a lot of friendships which I hope to keep in the future. Also, from the educational aspect I have gained a lot. I have learnt new things about Management, Manufacturing Processes, Product Development, requirement factors and have managed to learn how to use different Solidworks tools. In my opinion this particular student exchange program was a huge success.

5. SOURCES OF INFORMATION

5. Bibliography and others sources of information

BOOKS:

Dietrich M., Podstawy Konstrukcji Maszyn, Tom 1, Wydawnictwo Naukowo – Techniczne, 1999

Mały Poradnik Mechanika, Tom 1, Wydawnictwa Naukowo Techniczne , 1999

Niezgodziński Michał E., Niezgodziński T., Wytrzymalość materiałówPWN, Warszawa, 2002.

WEBPAGES:

[1] http://evoleotech.com/company/

[2]http://www.businessdictionary.com/

[3]https://www.linkedin.com/pulse/what-do-we-know-design-who-envolved-here-james-pacala-capalar

[4]https://prezi.com/sd6bmkhqstld/untitled-prezi/

[5]https://www.festo.com/net/SupportPortal/Files/13541/Sicherheitstechnik%20135242%202013-03%20EN%20S.pdf p.12

[6]http://www.thomsonlinear.com/micro/conversion_eng/why-electric.html

[7]https://festo.direct/Pneumatic-drives/Linear-actuators/Compact-cylinder-ADN/p/536295

[8] https://www.festo.com/cat/pl_pl/data/doc_engb/PDF/EN/EMMS-AS_EN.PDF

[9]https://festo.direct/medias/PDF-EN-ADN EN.PDF?context=bWFzdGVyfGZlc3RvLWNhdGFsb2ctbWVkaWF8MTM3OTc4MXxhcHBsaWNhdGlvbi9wZGZ8ZmVzdG8tY2F0YWxvZy1tZWRpYS9oNTcvaDFkLzg3OTc3NjI3ODEyMTQucGRmfGM0YTc4ZTZmMzI3MGE3YjMzMTdmMjU0MGY4ZDRiNzQ4OGRjNDdiOTQ2YjlmNTM2MTU0YWMyMDkxMWRhOTBjYjM

[10]https://www.festo.com/net/SupportPortal/Files/212956/13_1-18%20-%20Stepper%20motors%20EMMS-ST_ENUS.PDF

[11] http://www.baslerweb.com/en/products/area-scan-cameras/ace/aca1300-60gc

[12]http://nsk-jp.partcommunity.com/portal/auth/portal/nsk-jp#!prjpathinfo=nsk_rb%2Froller_bearings%2Fthrust_bearings%2Fsingle_direction_tbb%2Fwith_flat_seet_asmtab.prj

[13] https://www.festo.com/cat/nl-be_be/data/doc_engb/PDF/EN/EGSL_EN.PDF

[14] https://graftek.biz/products/basler-aca1300-60gc-1-slash-1-dot-8-in-format-c-mount-1280-x-1024-60-fps-color-cmos-global-shutter-gige-vision-poe

[15] http://uk.rs-online.com/web/p/ball-bearings/4090877/

[16]http://www.aliexpress.com/item/8pcs-600mm-6pcs-650mm-4pcs-730mm-20x20-aluminium-profile/1301925744.html?spm=2114.40010508.4.67.Iah8qQ

6. APPENDIXES

6. Appendixes

Attachement 1. Requirement list - Universal Functional Tester 2.0.

Req-ID	Description	Verification method	Driver/Factor
REQ.001	The platform must have a vision system with controlled lighting (darkroom)	Visual verification	Functionality
REQ.002	The platform should have a pressor system allowing the mechanical performance of testing the products buttons.	Testing verification	Functionality
REQ.003	The vision and testing actuators systems should be programmable in space (x, y) whenever necessary to test another type of product	Testing verification	Functionality
REQ.004	The Test fixture / jig system should be quick-changed (<1 min).	Testing verification	Operatilibity
REQ.005	The platform must be equipped with an interconnection system between the measuring equipment and the test fixture / jig standard and modular.	Design Review	Functionality
REQ.006	The connection interface will be of Virginia Panel Mass Interconnect systems or equivalent and support at least : -300 Points for analogue and / or digital ; 50 points for coaxial (up to 50MHz) : -10 Points for DC power supply (0V - 60V 5A) -10 Points for AC power (230V max 5A) -10 Points optical fiber - 2 points for pneumatic - 4 USB points - 4 RJ- 45 points -4 Points DB9	Design Review	Functionality
REQ.007	The platform must be prepared to receive fixture / jig with dimensions enabling the product testing to (400 * 300 * 130).	Design Review	Functionality
REQ.008	The platform must have a 19" rack with a minimum capacity of 16U .	Design Review	Functionality
REQ.009	The platform should be mobile.	Design Review	Operatilibity
REQ.010	The Test fixture should be compatible with the platform.	Design Review	Functionality
REQ.011	The Test fixture should have a base capable of placing the product.	Design Review	Functionality
REQ.012	The test fixture should have a bed of needles in accordance with the product.	Design Review	Functionality
REQ.013	The platform should have a CPI computer with EC characteristics (Terms of Reference) .	Design Review	Functionality
REQ.014	The platform should have a UPS APC SMT1500RM12U (battery).	Design Review	Functionality
REQ.015	The platform should have a DC power supply, Agilent N6700B .	Design Review	Functionality
REQ.016	The platform should have a DC Power Module N6743B .	Design Review	Functionality
REQ.017	The platform must use a PG- FP5 programmer device from Renesas	Design Review	Functionality
REQ.018	The platform shall have a temperature sensor.	Design Review	Functionality
REQ.019	The platform should have a 2.4GHz band transceiver Model: ETRX357USB Man: Telegesis	Design Review	Functionality
REQ.020	The platform should have a Frequency Counter Rhode & Schwarz Mod: HM 8123 .	Design Review	Functionality
REQ.021	The platform must have a Printer: Brady BPR- 600 plus.	Design	Functionality
REQ.022	The platform should have a 19" Display.	Design Review	Functionality/ Operatibily
REQ.023	The platform must have mouse and keyboard.	Design Review	Functionality/ Operatibily
REQ.024	The platform should have a 2D Scanner.	Design Review	Functionality
REQ.025	The operating system must be Windows 7 Pro 32bit in English.	Testing verification	Operatilibity
REQ.026	The programming language shall be in NI LabVIEW 2013.	Design	Operatilibity
REQ.027	The Test Sequencer should be 2013 NI TestStand.	Design	Functionality
REQ.028	The maximum size of the JIG and / or equipment for placing the product is 90 (W) x 110 (H) x 80 (P) cm.	Design Review	Functionality
REQ.029	The platform should respect the BOSCH N62A Standard.	Design Review	Functionality
REQ.030	The platform should be provided with CE marking and the certificate issued in Portuguese.	Design Review, Testing verificatin	Functionality
REQ.031	The platform should follow the Bosch N55 standard and be supported by the N51M M24 . 	Design Review	Functionality

REQ.051	The following documents in Portuguese must be delivered to Bosch Security Systems, within 10 days after completion of delivery: -Description of the system; -Installation guide; -Manual Maintenance; -Schemats; -Plan Preventive maintenance ; -Materials list used in the system ; -Safety instructions; -EC Declaration.	Design Review	Operatilibity/ Functionality
REQ.052	The connecting interface must have : 2 x RJ45 Cat5e FTP; -2 X USB 2.0 Pneumatic -2 x (4mm w / check valve) -20 X coaxial lines (10x + 10x 50 Ohm 75 Ohm) -140 X 300V / 5A signal lines;	Design Review	Functionality
REQ.053	The platform must be equipped with a safety and security system for the user.	Design Review, Testing verificatin	Safety
REQ.054	The platform must use an Ember developer debug adapter ISA3.	Design Review	Functionality
REQ.055	The platform should permit interaction between user and product.	Design Review, Testing verificatin	Operability
REQ.056	The maximum weight of the cartridge while replacement must be imitated to a maximum of 10 kg.	Design Review, Testing verificatin	Reliability
REQ.057	The time of the test should be limited up to 3 minutes.	Design Review, Testing verificatin	Functionality
REQ.058	The system should be able to disconnect and connect the programmer lines to DUT.	Design Review, Testing verificatin	Functionality
REQ.059	All interfaces necessary to carry out functional test of the DUT must be guaranteed.	Design Review, Testing verificatin	Functionality
REQ.060	The test of the product shall include the steps listed in *TestSpec* file.	Testing verificatin	Operatilibity
REQ.061	The platform must have a rack with technical profile that allows equipment 19" with 12U.	Design Review	Functionality
REQ.062	Devices (Ember debug adapter ISA3 , PG- FP5 Renesas) , should be within the cassette.	Design Review	Functionality

REQ.032	A training in usage and maintenance of the machine for the Electrical Engineering group should be provided.	Formation	Operatilibity
REQ.033	During production of the first 100 pieces support by the contractor should be given (with the presence of a technician).	Support	Operatilibity
REQ.034	Before the final installation of the system tests for verification of the requirements will be performed.	Test verification	Reliability
REQ.035	The platform should be able to read voltages and currents.	Design Review	Functionality
REQ.036	The JIG should allow product updates.	Design Review	Maintainability/ Operatilibity
REQ.037	ProDeverá system should be used to automatically operate the buttons of the product.	Design Review, Testing verificatin	Functional
REQ.038	There should be an automatic visual test to the product's display.	Design Review, Testing verificatin	Functionality
REQ.039	There should be a test able to check if the overprints of the product appear correctly.	Design Review, Testing verificatin	Functionality
REQ.040	It should be possible to test the Display's Backlight.	Design Review, Testing verificatin	Functionality
REQ.041	It should be possible to verify the existence of all symbols of the display.	Design Review, Testing verificatin	Functionality
REQ.042	Programming EEPROM should be possible.	Design Review, Testing verificatin	Functionality
REQ.043	Reset of the product RTC should be possible.	Design Review, Testing verificatin	Functionality
REQ.044	It should be possible to verify that the product buttons have been actuated.	Design Review, Testing verificatin	Functionality
REQ.045	Comunication with the product should be possible (sending instructions to the product).	Design Review, Testing verificatin	Functionality
REQ.046	It should be possible to read the version of the product software.	Design Review, Testing verificatin	Functionality
REQ.047	It should be possible to compare the temperature of the product to the environment.	Design Review, Testing verificatin	Functionality
REQ.048	The switching on/off of the power supply should be possible.	Design Review, Testing verificatin	Functionality
REQ.049	The control panel for operators and all the labels in the system must be in Portuguese.	Design Review	Operatilibity
REQ.050	The test should be ready for production within 8 weeks after award.	Formation	Cost

REQ.063	Time intended for the test must be no more than 3 minutes.	Testing verificatin	Operatilibity
REQ.064	The platform must be prepared to receive fixture / jig allowing the dimensions with product testing to (400x300x100mm).	Design Review, Testing verificatin	Functionality
REQ.065	All lines of two devices (Ember debug adapter ISA3 , PG- FP5 Renesas) shall be made available for future connections.	Design Review	Functionality
REQ.066	The platform should permit the individual cutting of each of the lines 12 going to the connector x5002.	Design Review	Functionlity
REQ.067	The Odd , Even and Blacklight tests must be performed separately.	Testing verificatin	Functionlity
REQ.068	The platform must have some sort of output (hardware / software) in case of errors.	Design Review	Functionlity
REQ.069	The platform should allow the exchange of 20 Cassette 20 min.	Design Review, Testing verificatin	Operatibility
REQ.070	The platform must use a safety PLC whose software is certified to ISO 13849-1 standard.	Design Review	Safety
REQ.071	The platform must be prepared to hold the DUT test without being supported by a wall.	Design Review, Testing verificatin	Functionlity
REQ.072	The platform should be compatible with standard Bosch needles.	Design Review	Functionlity
REQ.073	The frequency meter signal lines must be less than 3 meters.	Design Review	Functionlity
REQ.074	At least 2 years working without failure.	Testing verificatin	Reliability
REQ.075	Placement of display used by operator at eye height.	Design Review	Functionality
REQ.076	Measurement possible in angles.	Design Review, Testing verificatin	Functionality
REQ.077	Availiability of machine 24 h/7days 365 days a year.	Testing verificatin	Availability
REQ.078	Lower cost in comparison to XY - Table.	Materials & Components list	Cost
REQ.079	Atracctive to clients design of machine.	Visual verification	Innovation

Planned action	Technical area	Source	Importance
The system will include a camera placed inside construction -> dark environment.	MEC	BOSH proposal	3 - very important
The system will include a system allowing the mechanical performance of testing the products buttons. Use of: -rotatable actuator with suction (vacuum) to allow the rotation of the rotary knob -linear actuator (vertical movement) to manipulate the placement of button testing ending	HWE	BOSH proposal	2 - important
Named testing equipment will be universal - reaching every desired location (x, y); camera attached to the testing element	MEC	BOSH proposal	3 - very important
exchange of tested products realized through operator; The JIG and test fixture together are a single block , being taken as an individual module . This facilitates the rapid exchange of JIG.	MEC	BOSH proposal	2 - important
The interconnection system between measuring equipment and the test fixture / jig consists of an interconnection panel Multi -Contact manufacturer. The panel is removable at a time , behaving as a single connector	MEC	BOSH proposal	2 - important
EVOLEO's proposal: 2 x RJ45 Cat5e FTP; -2 X USB 2.0 Pneumatic -2 x (4mm w / check valve) -20 X coaxial lines (10x + 10x 50 Ohm 75 Ohm) -60 X signal lines ; -20 X lines to 230V / 5A ;	MEC	BOSH proposal	1 - less important
Change to the current solution 400x300x100mm	MEC	BOSH proposal	2 - important
The platform will have a 19" rack with a minimum capacity of 16U.	MEC	BOSH proposal	2 - important
The mobility will be provided through wheels added to the construction.	MEC	BOSH proposal	2 - important
The Test fixture will be compatible with the platform, because it is designed to be working togehter.	MEC	BOSH proposal	3 - very important
The Test fixture will have a base capable of placing the product, because it is designed to be working togehter.	MEC	BOSH proposal	3 - very important

The part equipped in needles will be custommade to each new product.	MEC	BOSH proposal	2 - important
Equipment supplied by BOSCH .	HWE	BOSH proposal	1 - less important
Equipment supplied by BOSCH .	HWE	BOSH proposal	3 - very important
Equipment supplied by BOSCH .	HWE	BOSH proposal	3 - very important
Equipment supplied by BOSCH .	HWE	BOSH proposal	2 - important
Equipment supplied by BOSCH .	HWE	BOSH proposal	1 - less important
The sensor will be placed at the holding part of the device.	HWE	BOSH proposal	1 - less important
Equipment supplied by BOSCH .	HWE	BOSH proposal	1 - less important
Equipment supplied by BOSCH .	HWE	BOSH proposal	1 - less important
Printer (supplied by BOSH) placed away from the basic machine.	HWE	BOSH proposal	1 - less important
Iit will be equipped in a 19" monitor interacting with the user. The placement of the display must respect the norm N62A. Display placed at eye hight.	HWE	BOSH proposal	1 - less important
The platform will be equipped in mouse and keyboard for maintenance (great access). The placement of these devices must respect the norm N62A.	HWE	BOSH proposal	1 - less important
Equipment Supplied by BOSCH. Included in the construction.	HWE	BOSH proposal	2 - important
The operating system will be Windows 7 Pro 32bit in English. License -> BOSH	SW	BOSH proposal	1 - less important
The programming language will be NI LabVIEW 2013.	SW	BOSH proposal	1 - less important
This standard will be used.	SW	BOSH proposal	2 - important
To be considered during desing phase.	MEC	BOSH proposal	3 - very important
The machine is designed according to the Bosh standards.	MEC	BOSH proposal	3 - very important
The device will fulfil the CE norms.	PA	BOSH proposal	3 - very important
The machine is designed according to the Bosh standards.	HWE	BOSH proposal	3 - very important
Training will be provided.	MNG	BOSH proposal	1 - less important
Considered in the planning.	MNG	BOSH proposal	1 - less important
Test will be provided.	MNG	BOSH proposal	2 - important
The platform will be able to read voltages and currents, using the DMM to measure the current of the DUT.	FUNC	BOSH proposal	2 - important
The jig will allow product updates.	MEC	BOSH proposal	3 - very important
BOSH will provide the ProDeverá system?	FUNC	BOSH proposal	1 - less important
The user can follow the visual test on a screen placed at eye height.	FUNC	BOSH proposal	2 - important
Test realised through camera inserted inside the construction.	FUNC	BOSH proposal	2 - important
The platform must be isolated from the outside light. Artificial lighting should be placed on the platform so as to allow automatic screen overprints for visual inspection of the product.	FUNC	BOSH proposal	1 - less important
The software will be able to perform this function . A standard test will be performed.	SW	BOSH proposal	1 - less important
Equipment supplied by BOSCH .	SW	BOSH proposal	1 - less important
There will be a reset button.	HWE	BOSH proposal	3 - very important
There will be an interface provided.	FUNC	BOSH proposal	1 - less important
A touch monitor allows to communicate with the machine.	FUNC	BOSH proposal	3 - very important
The version of the product will be visible in the corner of the display.	FUNC	BOSH proposal	1 - less important
Due to the temperature sensor it will be possible to read the temp. of the product; a program will compare it with the environment temp. (thermometer)	SW	BOSH proposal	2 - important
There wil be a button for switching on/off the power supply (hardware commanded by software).	FUNC	BOSH proposal	3 - very important
Portuguese language will be provided for usage of the sytem.	NFUNC	Specification	2 - important
To be considered.	MNG	Specification	1 - less important

The documents will be delivered.	MNG	Specification	1 - less important
These lines will be used.	HWE	PDR with client	1 - less important
There will be a safety button.	FUNC		3 - very important
Equipment will be supplied by BOSCH. The binding of ISA3 with the PC programmer is done via USB.	HWE	PDR with client	1 - less important
All parts related to the machine are to interact with user (display, keypad + mouse, software inside individual devices - interaction).	FUNC	PDR with client	3 - very important
To be considered during desing phase.	MEC	PDR with client	2 - important
To be considered during testing desing.	SW	PDR with client	3 - very important
The disconnection and connection of the programmer lines to DUT will be possible.	HWE	PDR with client	1 - less important
All DUT test will be provided.	FUNC	PDR with client	2 - important
The test of the product will include the steps listed in TestSpec file.	SW	PDR with client	1 - less important
Rack with technical profile that allows equipment 19" with 12U will be used.	MEC		2 - important
The listed devices will be placed in the cassette (onsidered during design phase)	HWE	CDR EVO-NSCU-MN-068-1	1 - less important
Time limit will be considered.	SW	CDR EVO-NSCU-MN-068-1	3 - very important
It will be considered in the design phase.	MEC	CDR EVO-NSCU-MN-068-1	2 - important
It will be considered in the design phase.	HWE	CDR EVO-NSCU-MN-068-1	3 - very important
It will be considered in the design phase.	HWE	CDR EVO-NSCU-MN-068-1	1 - less important
It will be considered in the design phase.	HWE	CDR EVO-NSCU-MN-068-1	1 - less important
The control PLC will be provided with Ethernet to enable communication and records will be sent for this purpose.	SW	CDR EVO-NSCU-MN-068-1	2 - important
Considering change of exchange time.	FUNC	DELTA CDR EVO-NSCU-MN-087-1	3 - very important
Safety ISO 13849-1 standards will be provided.	HWE	DELTA CDR EVO-NSCU-MN-087-1	3 - very important
Construction equipped in wheels with lock function to allow movement.	HWE	DELTA CDR EVO-NSCU-MN-092-1	2 - important
Needles to be used: 75mils (1.8mm) -> BOSH standart.	HWE	DELTA CDR EVO-NSCU-MN-092-1	3 - very important
To be considered.	HWE		1 - less important
Tests will be carried out in order to prove the resistance of the machine.	FUNC	Proposal SL	3 - very important
The display will be placed at eye height.	MEC	Proposal SL	2 - important
The construction of testing element will allow testing in angles.	FUNC	Proposal SL	1 - less important
Tests will be carried out in order to prove the availiability of the machine.	FUNC	Proposal SL	3 - very important
Cost estimation will be made.	MEC	Proposal SL	1 - less important
The design will be improved.	MEC	Proposal SL	1 - less important