

Automation of Variables Recording Process to Reduce Rework and Decrease Scripting Time

Jonataniel Arroyo Rivera
Master of Engineering in Manufacturing Engineering
Advisor: Rafael Nieves, PharmD
Industrial and Systems Engineering Department
Polytechnic University of Puerto Rico

Abstract — *The companies of aerospace services need to maintain the highest quality of their product. Therefore, this project will focus in the improvement of a process when verifying and validating system level requirements. For these requirements, an environment must be designed to in which these system levels will be tested. The designs are programed in a script. These scripts contain the signals used to validate the requirements. Therefore, this project will measure and analyze the process of recording these signals. Furthermore, an implementation of a new tool to record these signals will allow to automate the process yielding in a high quality of testing, reduce cost of man-hours and rework.*

Key Terms — *Automation, Control Charts, DMAIC, Parameters, Process Improvement, Recording, Scripting, Six Sigma.*

PROBLEM STATEMENT

Our company provides aerospace services associated with the software development life cycle. Part of the tasks performed is the verification and validation of software utilizing test scripts. The employees work with system level requirements given by the customer. These requirements contain expectations on how the electrical system should behave given a certain scenario. The electrical system is consisting of a main computer and sensors installed around the airplane. These sensors provide a live status of its readings and the integrity of the system.

Performing a test, the employee is responsible to create a script in which it will design a specific scenario in where the requirements will be put to test. These requirements are verified with the signals coming from the sensors. Furthermore, these signals

will provide a status of the electrical system in the engine.

Depending on what kind of test is about to be validated, the numbers of signal to be recorded when scripting can vary. That is, for some test can vary from 5 to 10, while for others, range between 10 and 20 signals. In addition, before recording the signals, it is important to know from which processor of the system is the signal coming from. For this, the signal is evaluated on a tool individually to know from which processor comes from.

Research Description

The study of this process is to get an insight on how the employee interacts with the tool when scripting. That is, the number of test to be verify and the number of signals per test will indicate the time it takes for an employee to record the variables repeatedly on the script.

Research Objectives

The analysis of this process will identify the current time of the actual process. An evaluation of number of parameters to be recorded against the time it takes to record them will be studied. Design of an automated tool to record variables minimizing human error while scripting and reduction of delivery time in a test. Creation of standard work for implementation and sustaining of the new process.

Research Contributions

This research will contribute to the improvement of the process' quality. The automation of this process will result in an error proof system. The employee will avoid doing rework due to incorrect recording of variables. In turn, this will reflect a reduction in the cost of man-hours and an increase of the test delivered. Furthermore, it will also facilitate the work of the

review since the reviewer won't have to worry about this part of the process.

LITERATURE REVIEW

Verification and validation composed a great part of employee duties in Pratt & Whitney Puerto Rico. Some of these responsibilities are analyzing data, plots, scripting scenarios in which requirements are to be tested. Throughout the process, mistakes arise due to human errors, network problems, tools misconfigurations, etc. The purpose of this project is to reduce the human errors automating the process of scripting. Moreover, the scenarios in which the requirements are to be tested are created in the script. This script contains commands that, when executed, control the engine to specific behavior. Before starting of the test, it is necessary to record parameters that are going to be tested against the requirements. Depending on the test to be verified and validated, these parameters can be a few and extend to a great variety.

There are two types of processor in the electric software system of the engine. Throughout the software you can find some of the parameters in the Processor A and some parameters Processor B. To record these parameters, the employee needs to know from which processor the parameter is coming from to record it with the appropriated format. The actual process to identify from which processor the parameter is coming from is to evaluate it, independently, in a tool. This tool is where test is verified and validated. Now, if a test contains a great number of parameters, it's almost certain that human errors will be present. These human errors mostly are missing parameters, typos and wrong identification of the processor. Sometimes these scripts were worked by others employee and errors are dragged over time meaning that, without previous verification, the employee could be missing data or recording wrong data which leads to rework.

“Six Sigma is a rigorous, focused and highly effective implementation of proven quality principles and techniques. Incorporating elements from the work of many quality pioneers, Six Sigma

aims for virtually error-free business performance.” [1]. Hence, applying Six Sigma to the actual process can reduce the human errors and the employee will avoid doing rework due to incorrect recording of variables.

In this project some of the implementation tools to improve the process are the DMAIC model. DMAIC stands for: Define- Measure- Analyze- Improve- Control.

Table 1
Overview of DMAIC [1, Figure 5.1]

D	Define the goals of the improvement activity and incorporate into a Project Charter. Obtain sponsorship and assemble team.
M	Measure the existing system. Establish valid and reliable metrics to help monitor progress toward the goals(s) defined at the previous step. Establish current process baseline performance using metric.
A	Analyze the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal. Use exploratory and descriptive data analysis to help you understand the data. Use statistical tools to guide the analysis.
I	Improve the system. Be creative in finding new ways to do things better, cheaper, or faster. Use project management and other planning and management tools to implement the new approach. Use statistical methods to validate the improvement.
C	Control the new system. Institutionalize the improved system by modifying compensation and incentive systems, policies, procedures, MRP, budgets, operating instructions and other management systems. You may wish to utilize standardization such as ISO 9000 to ensure that documentation is correct. Use statistical tools to monitor stability of the new systems.

DMAIC is a powerful tool to find the root of the problem. Defining the problem, process and resources will allow a clear vision on what it's going to be worked. Then, measuring the actual process with statistical control charts, will identify how off is the process and step backs. Analyzing the data measured will determine how much of the process is in control and allow the establishment of the goal to be accomplished. Improving the system will be the automation of the new process and the measured of the new process time. The control phase will be the

standardization of this new process with work instructions.

METHODOLOGY

To accomplish the objectives proposed for this design project, the DMAIC model must be developed. The Define phase of this project will clarify the objectives and what it's expected of it. Therefore, the first step is to create a Project Charter. "The Project Charter is a contract between the project team and its sponsor" [2]. The purpose of the Project Charter is to define the problem statement, it will mention the project objective or purposes, establishment of the deliverables or output, etc. [2]. Once this preliminary information is collected the next step is the breakdown of the problem statement. To breakdown the problem statement, a fish-bone diagram will be use. The fish-bone diagram allows to visualize what variables or connections there is to the problem. For this project, the output of the fish-bone will be the parameter recording rework. Once established, the next step is the measure phase.

For the measure phase, a previously determine test will be created. This test will consist of different sets of parameters. The subjects will be provided with these parameters. The objective of this test is for subjects to record them as they would normally when scripting. This exercise will show the relation between the numbers of variable to be recorded and the time it takes. The subjects will be coworkers at the company.

The analyze phase will consist in gathering the data collected to determine how in control is the process. To do this, the use of control charts of X and R will be implemented. These charts, also called average charts, are "statistical tools used to evaluate the central tendency of a process over time" [3]. These charts are useful when the sample size is not too big and will allow to determine the average time of the process and the range of that time.

The improvement phase will consist of the automation of the process. The automation tool will be created by another coworker. The idea is to use a database in which each parameter is located with the

information of the processor its coming from. Once the tool is finished, the user will insert the list of parameters he or she wishes to know its location, and the tools will print back every parameter with its specific location. In addition, once the new automated process is completed, the measure phase will be repeated, only now, it will record how much time it takes the tool to generate the list, taking in consideration the number of parameters to be recorded.

Finally, the control phase will be implemented. The control phase will consist of the standardization of the process. A work instruction or manual will be created for the subject to ensure the proper use.

RESULTS AND DISCUSSION

For the DMAIC methodology, it is needed to define the problem. That is, to have a clear understanding of the problem statement, scope, objectives and deliverables a Project Charter was created. "The official plan and authorization for the project is summarized in the Six Sigma Project Charter. The Project Charter is a contract between the project team and its sponsor" [2].

As the summary given in the Project Charter, the process needs to be defined, that is, company wise speaking. Therefore, to clearly visualize the process a SIPOC diagram is use in Fig 1.

For this process, the supplier and customer are the same people, Pratt & Whitney peers. The employees receive system level requirements to validate and verify them. The process is defined by creating a script in which it will be used to create a scenario in which the system level requirement will be tested. Once the script is done, the script is run in a tool to have the results. These results are validated and verified using logs and plots for each test run. If the data is an expected one, the next step is to document these results in a specific format. This documentation will be step for the output, which will be, the system level requirements validated and verified. The final step is the delivery of these requirements to the Pratt & Whitney peers.

For the Measure phase, the first step is to define the actual process. As mention above, once the system level requirements are assigned, the following step is to create a script.

The employee must have the parameters he or she wishes to record. Once they have the parameter, each parameter must be evaluated using a tool to determine from which processor is coming from.

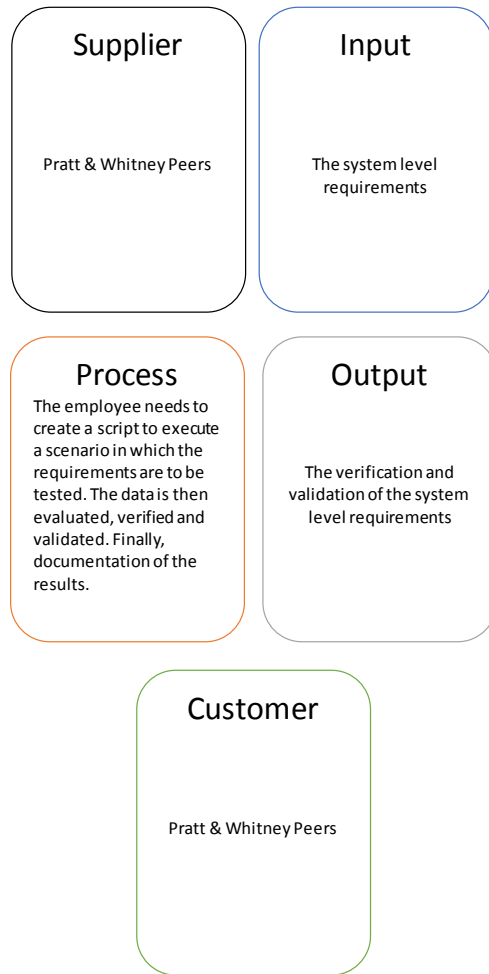


Figure 1
SIPOC Diagram

The employee needs to know from which processor the parameter is coming from to record it in its proper format. Failing to identify the processor will show an error in the results and the data for that parameter in specific will not be shown. Furthermore, the employee will have to re-run the test again, once the recording format is fixed, which represents rework and a waste of time.

For more insight of the process, a scenario will be created so that each employee has to record a number of parameters and the time it takes will be measured. The first measuring will be a case in which the employee has to record eight parameters. The second measuring will be a case in which the employee has to record sixteen parameters. Finally, the last case is the recording of parameters taken from a special format of documentation (SFD). Each case will be replicated twice to account for variance in the process. Five subjects were chosen randomly for this process. The results are show in Table 2, 3 and 4, respectively.

Table 2
Old Process Recording of 8 Parameters

Observation Using 8 Parameters				
Subject	Replicate #1	Replicate #2	X-bar	R
1	2.42	2.65	2.535	0.23
2	2.03	1.75	1.89	0.28
3	4.38	3.52	3.95	0.86
4	1.13	0.98	1.055	0.15
5	2.6	2.25	2.425	0.35

Table 3
Old Process Recording of 16 Parameters

Observation Using 16 Parameters				
Subject	Replicate #1	Replicate #2	X-bar	R
1	3.68	3.33	3.505	0.35
2	3.28	3.18	3.23	0.1
3	4.98	5.77	5.375	0.79
4	1.45	1.1	1.275	0.35
5	4.03	3.45	3.74	0.58

Table 4
Old Process Recording using SFD

Observation Using SFD				
Subject	Replicate #1	Replicate #2	X-bar	R
1	11.23	10.83	11.03	0.4
2	9.93	10.28	10.105	0.35
3	11.08	10.65	10.865	0.43
4	6.35	6.12	6.235	0.23
5	11.47	11.38	11.425	0.09

The Analyze will evaluate the data of the current process. The measurements units are given in minutes. To determine how in control is the process, the X and R chart are used. Each observation is evaluated individually. First, the process control charts of recording eight parameters are shown in Fig 2 and Fig 3.

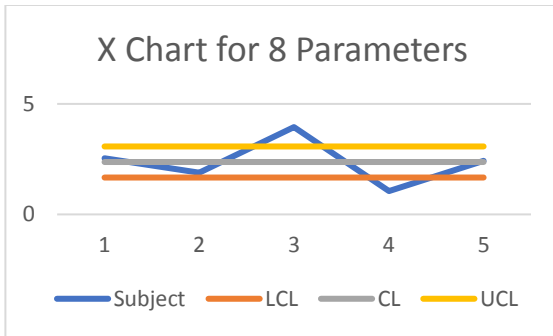


Figure 2

X Chart for Recording Eight Parameters

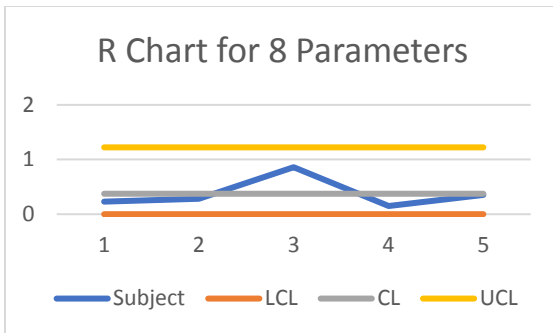


Figure 3

R Chart for Recording Eight Parameters

It is seen that for the actual process, there are some points that fell outside of the control lines. This implies that the process is not robust and can fluctuate depending on the performance of the subject. Finding the overall capability of this process shows that has a value of 0.23, which implies a sigma level of $\sigma=0.69$. This is shown in Fig 4.

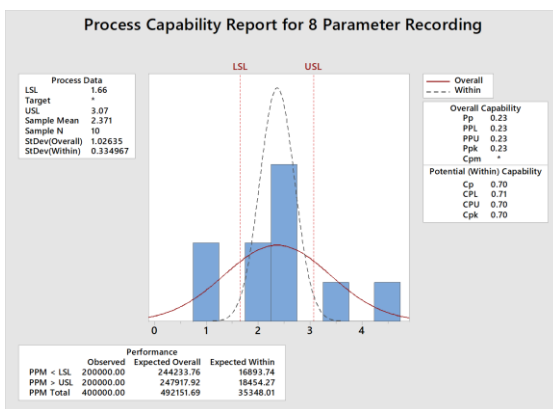


Figure 4

Capability Analysis for 8 Parameter Recording

Second, the process control charts of recording 16 parameters are shown in Fig 5 and Fig 6. Again, some of the points fell outside of the control lines.

As expected, the time it takes to record 16 parameters is greater than 8 parameters.

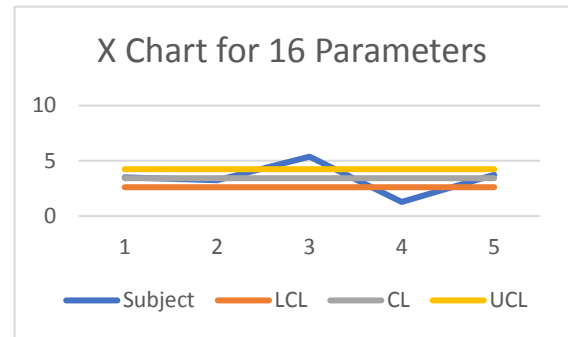


Figure 5

X Chart for Recording 16 Parameters

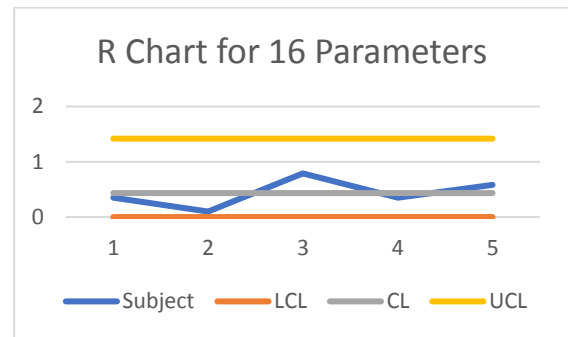


Figure 6

R Chart for Recording 16 Parameters

On the other hand, having more signals to record increase the probabilities of having typos, missed signals or wrongly choosing the correct processor. The overall capability of this process is 0.19, corresponding to a sigma level of $\sigma=0.57$. This is shown in Figure 7.

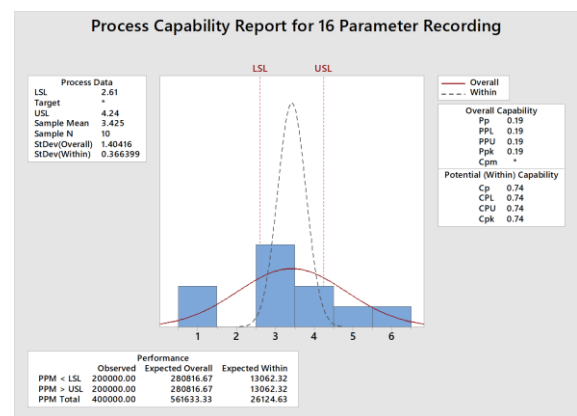


Figure 7

Capability Analysis for 16 Parameter Recording

Finally, the same evaluation process was done for the SFD. The control charts are shown in Fig 8 and Fig 9. As shown, this format is longer than the previous process. In addition, is a more accurate scenario than the previous one. That is, usually when a test is assigned, the documentation is already in SFD. However, if is not in SFD, one of the employee responsibilities is to modify to comply with the documentation procedure. There are test in which the requirements to verify are a few. However, there are test that can have hundreds of requirements to verify.

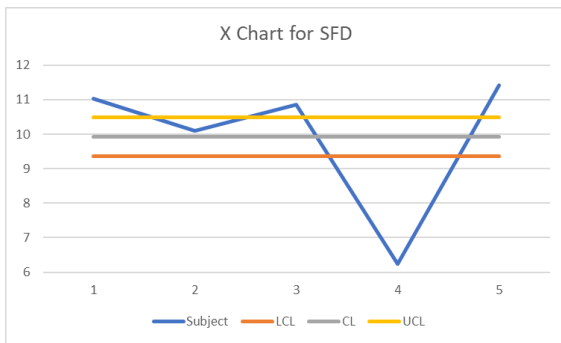


Figure 8
X Chart for Recording in SFD

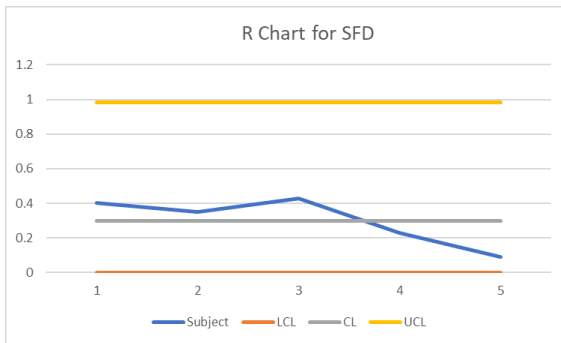


Figure 9
R Chart for Recording in SFD

The capability analysis for this process, shown in Fig 10, shows a value of 0.09, corresponding to a sigma level of $\sigma=0.27$.

When errors occur while recording, this means that rework will have to be done. Rework in this process means that the test needs to be run again. However, to run the test the employee uses a specific tool. Furthermore, sometimes there are only 3 to 5 of this tool to be used by a lot of employees. In other words, the employee has to get in queue in order to

use the tool. The etiquette of the tool is that each employee uses it for exactly one hour. However, there are employees that stay longer. The best-case scenario is that finding an error and fixing it could take about one hour. The worst-case scenario is that you have to get in queue again to run the test and, if there are other employees on queue, it could take hours to fix that error. Therefore, it is a good practice to determine the variables and contributing factor that yield in error. Hence, a fish-bone diagram is used in Figure 11 for a cause and effect analysis.

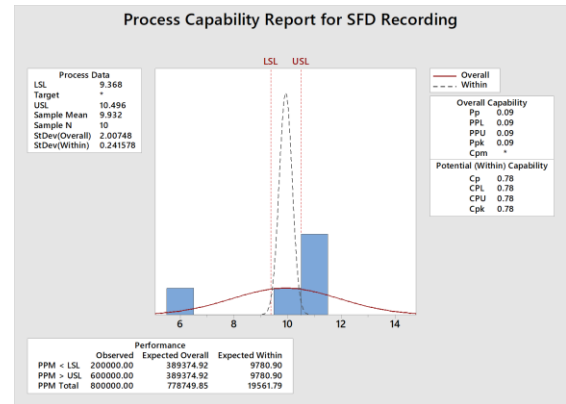


Figure 10
Capability Analysis for SFD Recording

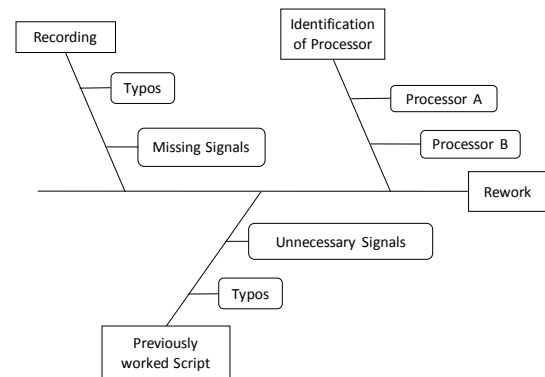


Figure 11
Fish-bone Diagram

As part of the analysis, questions were asked to the employees about the common mistakes they encountered while recording parameters. They were asked that out of 10 scripts, how many scripts they had to re-run because of missing signals, typos or wrong processor format? The results are shown in table 5.

Table 5
Reasons for Rework

Reasons for rework	
Missing signals	8
Typos	1
Wrong Processor	1

These results were translated it to a Pareto Chart in Fig 12. Notice that from the mistakes or errors that causes rework, the main contributor is the missing signals. Most of the time the requirements to be tested have a script done by another employee. Knowing that, the test is run only to find out that some of the signals to be verified are missing. The errors of typos or wrong processor are not that common while scripting, but still they are encountered throughout the process.

To decrease the errors while recording parameters, and for the Implementation phase, a tool was created. Each of the signals to be recorded has a specific format. Therefore, using this specific format it was possible to develop the program. The program was created in excel using Visual Basic.

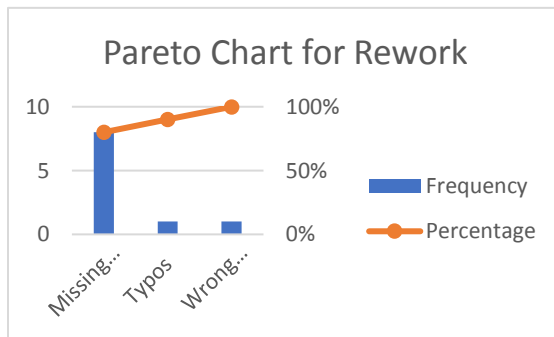


Figure 12
Pareto Chart

Furthermore, using excel allowed a more user-friendly interface for the employees. When the recording tool is opened, it allows the user to select the sheet in which he or she would like to work on. That is, the SFD format or List format. For the SFD format, the user needs to provide the text where the signals are. Then, once the text is copy and pasted it to the tool, the tool provides a button of Start. When

pressed, the new window appears which allow you to select the engine program you are working. At the bottom of that window, there is a button that says SFD and another that says List. Since the user is working with the SFD format, he or she needs to press the button of SFD. Then the tool will find all the parameters in the text and it will print them in other column in the excel with their respective processors. On the other hand, when the user is not working in the SFD format, the tool expects that the user provides the list of parameters. Once the list is provided, the process of determining the signals' processors is the same as the SFD format.

When the tool was finished, new measures were taken to determine if the tool actually improve the process. For this, the same scenario as the measure phase was used. This way allows a better comparison. Again, the employee needed to record certain signals to determine the time it takes, but this time using the tool. The same five employees were used for this measurement. Each measurement was replicated two times. The first measurement consisted in recording 8 parameters in the form of list. Likewise, the second measurement consisted in recording 16 parameters in the form of list. Finally, the last measurement consisted in recording signals using the SFD. The results are presented below in Table 6, 7 and 8. The units of each measure are given in minutes.

Table 6
New Process Recording of 8 Parameters

Observation Using 8 Parameters				
Subject	Replicate #1	Replicate #2	X-bar	R
1	0.13	0.15	0.14	0.02
2	0.23	0.12	0.175	0.11
3	0.13	0.18	0.155	0.05
4	0.17	0.13	0.15	0.04
5	0.22	0.2	0.21	0.02

Table 7
New Process Recording of 16 Parameters

Observation Using 16 Parameters				
Subject	Replicate #1	Replicate #2	X-bar	R
1	0.13	0.2	0.165	0.07
2	0.12	0.13	0.125	0.01
3	0.13	0.13	0.13	0
4	0.13	0.12	0.125	0.01
5	0.12	0.15	0.135	0.03

Table 8
New Process Recording using the SFD

Observation Using SFD				
Subject	Replicate #1	Replicate #2	X-bar	R
1	0.2	0.13	0.165	0.07
2	0.22	0.15	0.185	0.07
3	0.12	0.08	0.1	0.04
4	0.12	0.17	0.145	0.05
5	0.27	0.18	0.225	0.09

In comparison of the data in the measure phase, it is noted that the time it took to record the parameters dropped considerably. To determine how in control is the new process, the X and R chart are used. Each observation is evaluated individually. First, the process control charts of recording eight parameters are shown in Fig 13 and Fig 14.

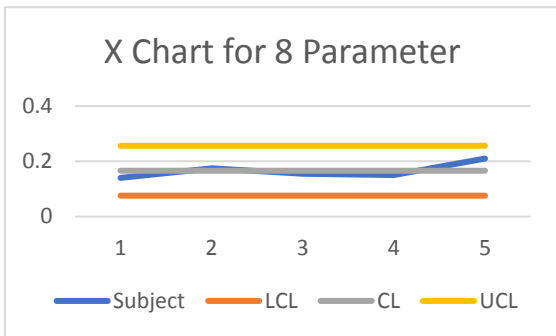


Figure 13

X Chart for Recording Eight Parameters

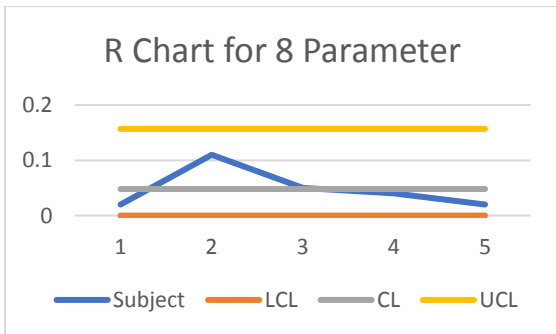


Figure 14

R Chart for Recording Eight Parameters

It is seen that for the new process, all of the points that fell inside of the control lines. This implies that the process is now in control since it does not depend on the performance of the subject. Finding the overall capability of this process shows that has a value of 0.69, which implies a sigma level of $\sigma=2$. This is shown in Fig 15.

Second, the process control charts of recording 16 parameters are shown in Fig 16 and Fig 17. Again, all of the points fell inside of the control lines.

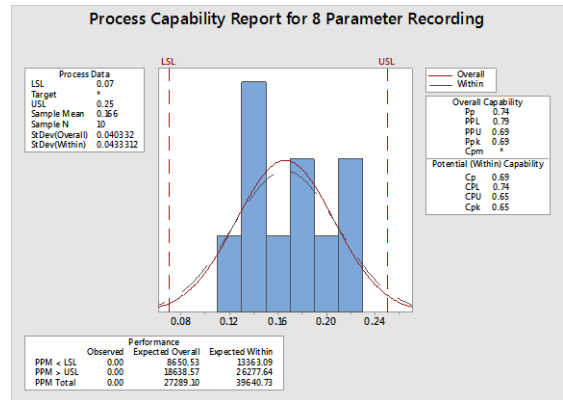


Figure 15

Capability Analysis for 8 Parameter Recording

In contrast of the measure phase where the time it takes to record 16 parameters is greater than 8 parameters, now is more normalized since it does not depend on the performance of the employee.

The overall capability of this process is 0.61, corresponding to a sigma level of $\sigma=1.83$. This is shown in Fig 18.

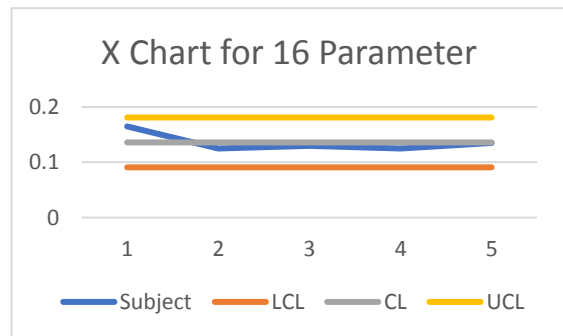


Figure 16

X Chart for Recording 16 Parameters

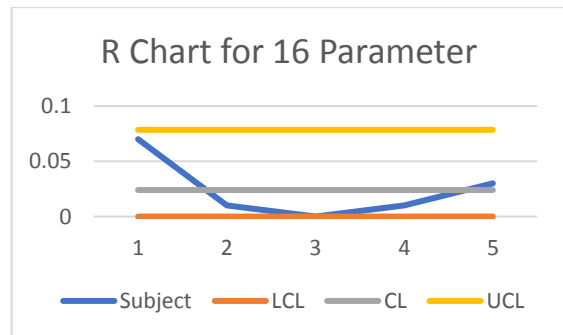


Figure 17

R Chart for Recording 16 Parameters

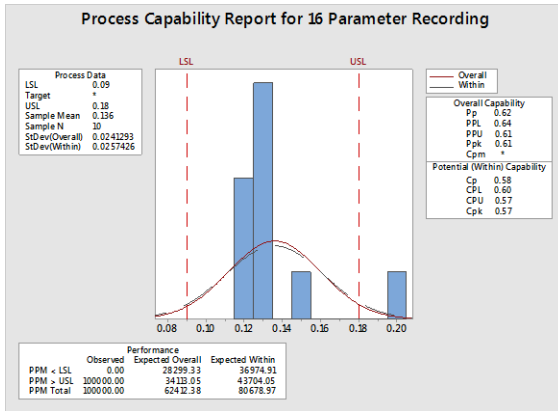


Figure 18
Capability Analysis for 16 Parameter Recording

Finally, the same evaluation process was done for the SFD. The control charts are shown in Fig 19 and Fig 20. Remember that in the measure phase, this was the longest process. However, with the new process the time was reduced considerably. This is a more accurate scenario than the previous one since the employee normally work with the SFD.

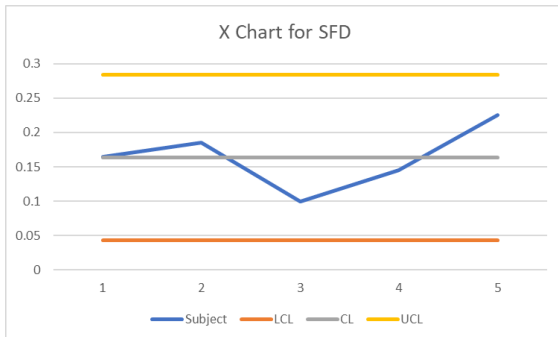


Figure 19
X Chart for Recording in SFD

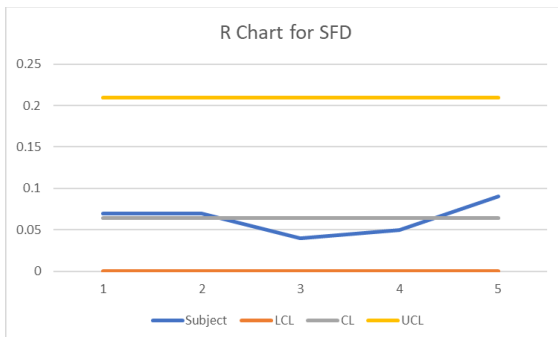


Figure 20
R Chart for Recording in SFD

Notice that all points fell inside the control lines. The overall capability analysis for the new process

is shown in Fig 21. This figure shows a value of 0.69, corresponding to a sigma level of $\sigma = 2$.

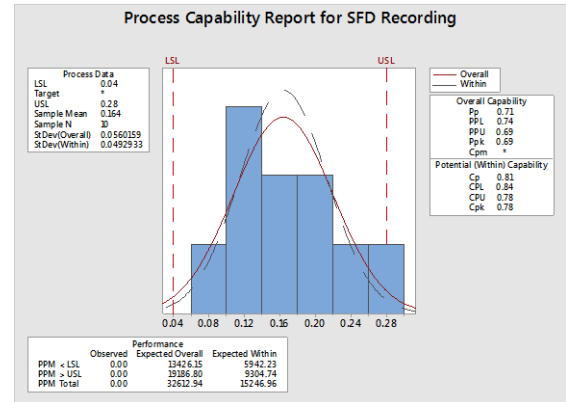


Figure 21
Capability Analysis for SFD Recording

In the table 9, 10 and 11 below is a comparison between the old and new process for each observation.

Table 9
Comparison between Processes for 8 Parameters Recording

Old Process 8 Parameters Recording			New Process 8 Parameters Recording		
Process Capability	Sigma Level	Average Time (mins)	Process Capability	Sigma Level	Average Time (mins)
0.23	0.69	2.371	0.69	2	0.166

Table 10
Comparison between Processes for 16 Parameters Recording

Old Process 16 Parameters Recording			New Process 16 Parameters Recording		
Process Capability	Sigma Level	Average Time (mins)	Process Capability	Sigma Level	Average Time (mins)
0.19	0.57	3.425	0.61	1.83	0.136

Table 11
Comparison between Processes for SFD Recording

Old Process SFD Recording			New Process SFD Recording		
Process Capability	Sigma Level	Average Time (mins)	Process Capability	Sigma Level	Average Time (mins)
0.09	0.27	9.932	0.69	2	0.164

The employee that were used to takes these measures were very satisfied. They recognize that the old process produced a lot of rework. In turn, this can be tiring since they have to wait in turn to use the tool to run the test again.

For the Control phase, a guideline document was created showing how to set up the tool. In addition, guidelines were created to instruct how to

use the recording tool properly. This is shown in Fig 22 and Fig 23, respectively.

How to set up the tool?

- Create a folder in your D drive with the name of **Recording Tool Schedulers**
- Inside that folder create 5 folders with the Engine Programs
 - Engine 1
 - Engine 2
 - Engine 3
 - Engine 4
 - Engine 5
- Download the schedulers of each respective engine program inside their respective folder

Figure 22
Guideline to Set up the Recording Tool

CONCLUSION

Observing the data and the process, it can be said that the project's objectives were met. The measurement of the old process allowed to identify what was the common mistakes and how much time it was taking.

How does the tool work?

Once the tool is open follow the instruction below:

SFD Format

- Export to an excel file the VTPs of the test you will be working
- Copy all the VTPs
- In the recording tool, select the SFD sheet
- In column B, under the name SFD Text, paste the VTPs copied
- Press Start button
- Select the Engine Program you will be working
- Press the SFD Button
- In column C, under the name of List Results, will be printed the parameters with their respective processor.

List Format

- Create the list of parameters
- Copy that list
- In the recording tool, select the List sheet
- In column B, under the name List Text, paste the VTPs copied
- Press Start button
- Select the Engine Program you will be working
- Press the List Button
- In column C, under the name of List Results, will be printed the parameters with their respective processor.

Figure 23
Guideline on How to Use the Recording Tool

Once these details were identified, a solution for this problem was tackled creating a tool to automate the process. This tool allowed not only reducing the time considerably, but also it eliminated the human errors. In turn, this will avoid rework due to this process. Therefore, the man-hours invested in scripting are reduced since the process avoids errors that produced hours of rework. Moreover, the process avoids costs, not just of the process, but of the rework too, which ultimately represents the higher cost.

The employees are very satisfied with the new tool. They know that the old process, depending on

the test, could be extent and tiring. Furthermore, the idea of rework is frustrating because, like stated above, could take several hours to use the tool to run the test depending on the queue of other employees waiting to use it.

Finally, as part as future work, the employees feel more confident and have a better idea on how they can keep improving the process. They were asked to keep identifying areas of opportunities to keep increasing the quality and reducing the time of our work. In turn, this will be reflected in more tests delivered given a specific time. Although the scripting process as a whole can't be automated, just because it will always need some engineering knowledge, it can be automated up to 80% of the process.

REFERENCES

- [1] T. Pyzdek, and P. Keller, "What is Six Sigma?" in *The Six Sigma Handbook*, 4th ed., McGraw Hill Education, 2014, ch. 1, pp. 3.
- [2] T. Pyzdek, and P. Keller. "The Define Phase," in *The Six Sigma Handbook*, 4th ed., McGraw Hill Education, 2014, ch. 6, pp. 245.
- [3] T. Pyzdek, and P. Keller. "Process Behavior," in *The Six Sigma Handbook*, 4th ed., McGraw Hill Education, 2014, ch. 8, pp. 311.