Industrial and Systems Engineering

Implementation of Lean Methods in Special Problem Management at Lockheed Martin

Project Final Report

Productivity and Performance Improvement in Organization

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Abstract

Our team has chosen to pursue Lockheed Martin Corporation (LM) as the company we worked with for our final project to identify a process with a set of problems and implement an improvement method for. With a set of Lockheed Martin engineers on our team, we were able to gain firsthand insight on processes and implementation access. After detailed discussion, our team was able to narrow a small LM process down to work on, known as the Special Problems (SP) process, which we believe to have been a solid foundation to our project. Our team was able to apply eight out of the fourteen Toyota Production System (TPS) principles to the SP process to discover flaws and make improvements to this LM process.

1.0 Introduction – Special Problems Process

Lockheed Martin has labs that serve the sole purpose of testing the systems of fighter jets for the customer to be capable of testing in a simulated environment before testing through flying the actual aircraft itself. These labs are made up of all the systems of the jet and can often be very complex since Lockheed outsources most of their aircraft systems. As LM Systems Engineers, it is our job to make these systems work together collectively to make the lab perform to the best of its ability, synergy. With these different systems, the lab often has some problems that occur within the lab, in which we refer to as Special Problems (SP). As previously mentioned, Special Problems are common to our labs, so as Systems Engineers (SE) these SP are found by another LM team, the Test Engineers (TE), and reported to the Systems Engineering team as Special Problems as shown in Figure 1. Part of the job as a systems engineer is to investigate the SPs that occur within the lab by verifying the problem exists, writing documentation about the specific problem looking into a possible workaround so that the test engineers can continue their testing even with the SP being resolved, then working on solutions to fixing the SP. Some SPs are more severe than others, and our team always has an average of fifty SPs open per month. The SE team has their engineers constantly working on closing out as many SPs a month as possible, but for some reason closing out these SP always take a lot longer than expected and the SE team can never seem to get the average number of SP down. In conclusion, we have chosen to focus on the flawed process of Special Problems that takes place daily in the labs at Lockheed Martin.

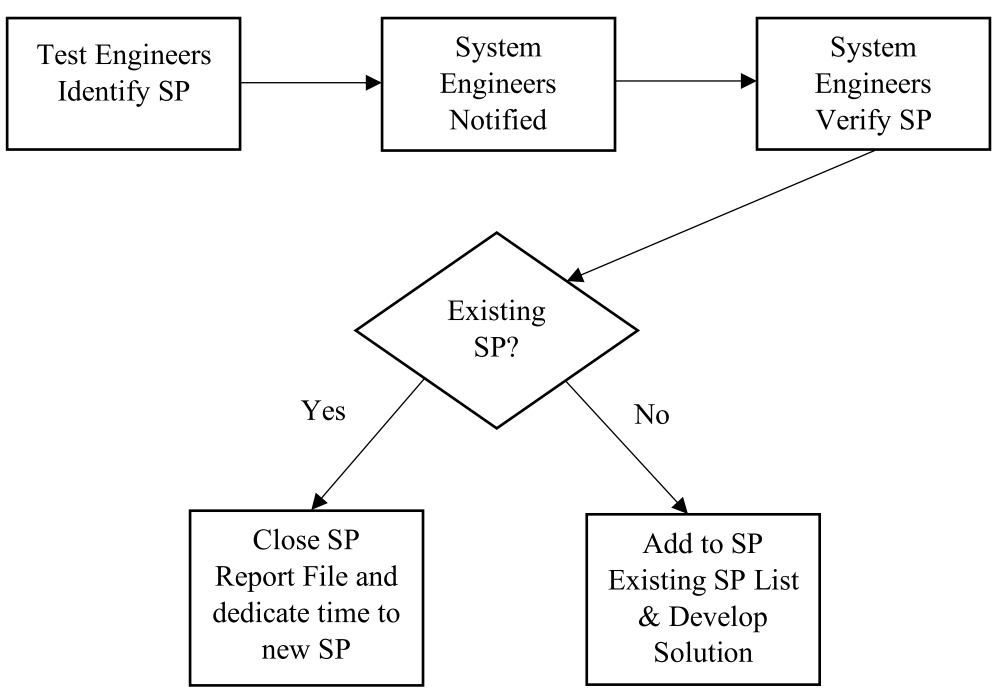

Figure 1. SP Process Flow Diagram

1.1 Initial Problems Identified in the SP Process

After looking deeper into the issue of why we are not able to get the average number of SP down, it really began to make more sense to our team. Seeing how the SP process works at LM, we were able to identify multiple flaws within the SP process. The main issue with the current process is that there is no quick way to identify if an SP has already been reported. This causes delays by having the test engineers go start a report for an SP, submit the SP and increase the number of SPs reported per month. Only for the system engineer to later find out it has already been reported and is in the works of finding a solution for. The F-35 is one of the most advanced technological advancements with multiple cameras, sensors, and systems all working together. It is common to have multiple issues come up constantly. Having our engineers go over issues that have already been reported, it is a waste of time, money, and resources. Another flaw we have identified with the process is a lack of communication. It is easy to lose communication with other teams when your team is constantly busy trying to resolve issues. There must be another way to also begin to resolve the SP faster.

1.2 Lean Organizational Process in SP Process

Lean method is all about reducing waste and adding value to products and processes by encouraging the lean thinking/lean mindset throughout the organization. It focuses on improving productivity and achieving better quality. This methodology involves people from all levels of the organization. We have chosen to implement the lean method to make improvements at LM lab to get over the existing problems of the SP process. We find this approach best suited for this process, as systems engineers at LM lab have to keep track of the SP and work on that to eliminate it. There are many SP which are being worked on already and still the test engineers constantly notify and repeatedly report the same SPs to systems engineers, which creates confusion among the teams, and they end up wasting valuable time to find the SP which is already being worked on. So here we found scope to implement a few TPS principles to improve the LM SP process overall.

The reason we have chosen to implement the Lean approach at LM and not the other approaches have to do with some key differences in the methodologies and the problems we intend to solve at LM. A key difference is that Lean and Six Sigma focus more on the customer while Theory of Constraint does not. Theory of Constraint focuses on determining what the goal is and identifying constraints and bottlenecks that prevent us from achieving the goal and providing solutions to reduce these constraints. While Lean and Six Sigma methodologies both work on eliminating waste and improving processes, they take different approaches on achieving this task. This is because they view the causes of waste differently, that is they identify root cause differently. Also, Lean focuses more on ways to increase flow in the production process while Six Sigma uses techniques to reduce the rate of defects. Due to the nature and complexities of the systems in the labs at LM which results in a miscommunication problem and flow between the systems engineers and test engineers, Lean is most suitable as we would attempt to analyze the workflow to reduce lead time and eliminate waste by focusing on 7 Deadly Wastes as identified in Lean. Six Sigma on the other hand defines waste more on defects, anything that does not meet customer expectation and uses DMAIC approach to eliminate dissatisfaction in customer experience and achieve consistent results. Lean also uses the Toyota Production Systems principles which encourage brainstorming, teamwork and respect for partners or suppliers, this encourages better communication among the parties involved in the process for better understanding and timely resolution of special problems.

1.3 Objectives

As a team, we came up with a set of goals to help us stay on track throughout the course of our project. Listed below are the goals our team discussed:

- Reduce the amount of repeated SP reported daily down to 0.
- Increase the amount of SP closed daily.
- Improve the communication between system engineers and test engineers.
- Level out the workload amongst the team for most efficient results.

2 TPS Principles Applied to SP Process

Our team took the time to deeply analyze each of the fourteen principles in Toyota Production System and consider which of these principles would apply to our smaller SP process at Lockheed Martin. We found that eight out of the fourteen principles of TPS we were able to apply and implement to our process. Following, we were unable to apply all fourteen principles to our process because TPS focuses more on production and bigger processes. For example, Principle 3 in which states, “Use “Pull” system to avoid overproduction”, in our small process, we are not producing anything, but rather solving issues in the lab environment. Therefore, we were able to implement the following principles listed below:

2.1 Principle 4

Principle 4 of TPS states, "Level out the workload (heijunka). ('Work like a tortoise, not the hare')" (Liker, 2004). Our team was able to extract data from LM SP Process that identified the average SP each level of system engineers (1-4) was working on a weekly basis. For our first three weeks of raw data, we noticed that the workload was not levelled out evenly amongst engineers. One of our teammates was able to meet with the project lead who assigns SPs to get more input as to how she assigns SP to different engineers. This is when our team came to find out that she did not have any specific method of assigning SPs, and just did so at random. With this information, our teammate was able to take the time to sit with her and come up with methods of levelling out the workload. In continuation, we did not just implement equaling out the number of SP amongst all engineers, but we also analyzed all teammate strengths and weaknesses and assessed who would be able to close out a specific SP at a faster pace, based on their knowledge base and skillset.

2.2 Principle 6

Standardizing tasks helps keep all the engineers stay on the same page. Working on SP if we can standardize specific tasks such as sending emails every other morning for the test engineers to know what SP are already open and have been reported, this in turn could save time and money. Something as small as an email will hopefully prevent double work and double submissions of SP. The email is a minimal standard task that has made a dramatic change. There is already a template created for the email and it is extremely simple to update before sending. Another approach we took in hopes of assisting with standardizing tasks was creating a word document with step-by-step details of the SP process. This word document makes it easier to teach new hires what are the steps and actions that should be taken. This document also keeps the experienced engineers in check to make sure no steps were missed.

2.3 Principle 7

When producing ideas for Principle 7 which discusses "use visual controls", was more challenging than expected. Mainly because we do most of our work inside a classified area. Working in such an area prevents us from taking information in or out, as well as specific items. This really limits us in what ideas we can integrate. Luckily, we came up with the idea of using colored index cards. Each color is tied to a certain subsystem or specific part of the lab. These index cards have a brief description of specifics SP that are open already. An example of what the index card can say is "GPS loses connection with internal core processor during test." Each index card is then placed in front of where that subsystem is located. Providing the test engineer with a brief visual cue of what SP has been identified and reported. The main goal of visual controls is to expose any problems that are hidden, and these color-coded index cards are our solution.

In relation to the colored index cards, we also used a binder in which we keep in the lab that goes into further detail regarding the SP already open and the specific work-around to be implemented for every SP. This binder also includes a step-by-step instruction for the SP Process. This visual control is to be used by the test engineers in the lab, when they run into an SP, they first resort to checking the index cards in which list every SP that is currently open. Once they verify if the SP, they ran into is already open then they can refer to the binder the find the specific work around. If the SP they found is not listed on the index card related to their specific system, then they know this SP has not been reported and they can create a report themselves. Like the index cards, the binder is color coded by system and specifies the needed details in regard to all the existing SP.

2.4 Principle 10

Develop people and teams, teamwork can only flourish and help the company if there is respect for one another. At LM we implemented this principle by identifying the teams in the process i.e., Systems Engineers, Testing Engineers and supporting staff, and created a culture of having periodic meeting where all the members were involved, it helped everyone to know about the challenges the teams are facing, and how they are dependent on one another's work. This created a sense of teamwork, respect among all and it improved the quality of the work done. Due to these periodic meetings, we were able to get feedback from the team members and accordingly the changes were made in the processes with immediate effect, this benefited our process overall, as we achieved better quality of work, results, process got effective and fast as everyone was having the respect and understating for other team and they understood how curial and important their work is for the other team's performance.

2.5 Principle 11

Respect the outside forces, having respect for the partner and suppliers and treating them as an extension of the company. Valuing them and challenging them to grow and develop by setting targets. At LM in our process external factors like stakeholders, suppliers, etc. are not involved directly but we do have internal factors and teams on which our process of attending SPs is dependent upon. At our lab, the SPs are reported by the test engineers and those are the ones who are the supplier for our work, we created a sense of respect among the test engineers and systems engineers by appreciating test engineer's efforts for identifying and reporting the SPs and systems engineers treated every SP as equally important and worked on it without delay. The systems engineers also kept test engineers updated with all the improvements and work done on the SPs. This minor change helped us to achieve respect among the teams, and keeping them updated with the current SPs improvement nullified the repeated reporting of the same SP. Also, as a systems engineer we set a challenge for ourselves to work on SPs with no delay and keeping the open time of SP as less as possible, this improvement challenged the test engineers to work more efficiently and find SPs for us to work on. This overall made us achieve a better quality of work and respect within the organization.

2.6 Principle 12

Principle 12 explains that rather than solving problems by trying to improve the design or repeating the process, it is beneficial to go to the actual source of the problem to resolve it.

"Genchi Genbutsu – Go and see for yourself to thoroughly understand the situation" (Liker, 2004).

One of the problems faced by the SEs at LM is the report process of SPs, when in some instances they were repeatedly reported by the TE's at the lab. By adapting principle 12, we assigned a member on the project team who visited the lab to observe the TEs process of reporting an SP. As a result of this we uncovered certain facts on how they log their report and the resources that was available to them to make such judgement calls.

We also observed the level of workload assigned to each SE. This we did by getting the team lead who assigns SPs to the SE's after they have been reported more involved in the lab. We observed that SP were assigned randomly in no order or rank which made it difficult for some SEs with little experience to resolve. This further led to delays in resolution, increased lead-time, increased number of unresolved SPs and SPs being repeatedly reported. We were only able to achieve this after applying '5 Why's' by asking leading questions from previous answers given. After determining the root cause, we narrowed the data source we needed to collect, analyzed, and gained a meaningful overview of how to apply the process of improvement. Data collection involved retrospective samples and weekly future data to check if there was a significant change in the process during and after lean implementation.

2.7 Principle 13

This principle goes over the responsibility that we should take the time to think and analyze the data and after deciding, we do not hold back. As a team, we must act and clear our minds from any doubt because we ought to have considered all the alternatives available before choosing a particular option. It is also time-consuming and once a decision is made, implement it rapidly. Nemawashi means building consensus, is the process of discussing the problems and potential solutions with all of those affected to collect their ideas, opinions and make an agreement on a path forward.

At LM, after we gathered and analyzed the retrospective sample data, we had brief weekly meetings with SEs and TEs to build consensus on what we intended to implement. By doing this, we got the buy-in from the members of both teams, listened to their contributions and reservations to clear any doubts and carefully explain areas of concern. As part of the consensus, we made use of efficient communication tools like A3-report, questionnaires, email notification of meeting times with precise objectives of what we intend to achieve during the meetings. We also had kaizen events which included 2 members of the project team, the team leads, and supervisors of SEs and TEs to focus on the workflow process and document a standardized procedure on how to approach task and reporting SPs. A copy of the A3 Report is shown in Section 6.4 of the Appendix.

2.8 Principle 14

Principle 14 of becoming a learning organization through relentless reflection (hansei) and continuous improvements (Kaizen), was implemented during the twice-a-week meetings hosted by the involved team members with the system and test engineering managers. As part of these meetings, changes to the system were reflected upon to assess if they were truly beneficial to the process of reducing repeatedly reported SPs. If the change was deemed unhelpful after continuous improvements were made, then that change was removed, and other alternatives were pursued. This process of reflection and continuous improvements was made possible by the wholehearted collaboration of all stakeholders to reduce the repeatedly reported SPs. Additionally, a feedback survey was administered to all team members during the last week of data collection to evaluate the receptiveness and effectiveness of the implemented changes; the results of the feedback surveys will be discussed in Section 3.3 of this report.

3 Results of Implementing TPS to the SP Process

3.1 Data Before TPS

The Lockheed Martin engineers on our team collected three weeks of SP data and statistics before any of our TPS implementations and solutions were made to the lab. In reference to the weekly statistics, Tables 1-6, a few common trends that can be identified is that the number of SPs closed weekly is significantly less than the amount open weekly. Hence, why the number of SPs within the lab environment never seem to go down. Following, there is a handful of SPs that are repeated SPs that have already been reported. Those repeated SPs waste the time of the systems engineers who are trying to get these SP closed since the team is doing double the work on these repeats.

Our team was able to extract data from LM SP Process that identified the average SP each level of system engineers (1-4) was working on a weekly basis. After conversation with the project lead, we came to find out that there was no specific method to assigning out SP. Therefore, we investigated how we could apply Principle 4 of TPS in order to spread out the SP workload more evenly taking into consideration every employee's System of Interest (SOI).

Table 1. Week 1 SP Data

	Special Problem Daily			
	Week 1 Statistics			
	Opened	Closed	Repeated SP Reported < 1	Non-Repeated SP Reported < 1
10/11/21	3	0	2	1
10/12/21	3	0	3	0
10/13/21	1	1	1	0
10/14/21	1	1	0	1
Totals:	**8**	**2**	**6**	**2**

Table 2. Week 1 Average SP Per Engineering Level

Average SP Per Employee by Level	
Level 1	6
Level 2	9
Level 3	6
Level 4	3

Table 3. Week 2 SP Data

	Special Problem Daily			
	Week 2 Statistics			
	Opened	Closed	Repeated SP Reported < 1	Non-Repeated SP Reported < 1
10/18/21	3	0	2	1
10/19/21	1	2	1	0
10/20/21	2	1	1	1
10/21/21	1	1	1	0
Totals:	**7**	**4**	**5**	**2**

Table 4. Week 2 Average SP Per Engineering Level

Average SP Per Employee by Level:	
Level 1	5
Level 2	8
Level 3	7
Level 4	2

Table 5. Week 3 SP Data

	Special Problem Daily			
	Week 3 Statistics			
	Opened	Closed	Repeated SP Reported < 1	Non-Repeated SP Reported < 1
10/25/21	1	1	1	0
10/26/21	4	1	2	2
10/27/21	0	1	0	0
10/28/21	1	1	1	0
Totals:	**6**	**4**	**4**	**2**

Table 6. Week 3 Average SP Per Engineering Level

Average SP Per Employee by Level:	
Level 1	4
Level 2	6
Level 3	6
Level 4	2

3.2 Data After TPS

After our three weeks of implementing our TPS solutions, the Lockheed Martin engineers on our team collected three weeks of SP data. Tables 7 through 12 display the data collected after our teams TPS implementations to the LM lab. On the first week we can already see we hit a new record of SP closed in comparison to the previous three weeks. The progress does not stop there, we also hit a new low when it comes to repeated SP reported. Luckily for us this was not an outlier, the following week the data continues to show the improvement made with the new implementations. In reference to table 11, our data hit another all-time high of SPs closed! Since there was no specific way of assigning out SP, we were able to take advantage of having a more balanced approach. Table 8 shows the average SP per employee by level. After implementing Principle 4 by spreading the workload to have a more balanced number of SP per employee, the SE team really began to take advantage of our more knowledgeable engineers. There was some pushback from some of the more experienced engineers because they are getting more work and they are already busy as it is. However, since they have had that experience, we believed this would not be a problem for them. Fortunately, they agreed and if at any point they were feeling overloaded we would revert to having them work less SP. But with the whole team seeing the progress and continuous improvements of the SP data, we have not gotten much pushback from engineers since they are able to see how effective applying TPS principles have been to the SP process.

Table 7. Week 4 SP Data

	Special Problem Daily			
	Week 4 Statistics			
	Opened	Closed	Repeated SP Reported < 1	Non-Repeated SP Reported < 1
11/1/21	1	1	1	0
11/2/21	3	2	0	3
11/3/21	1	2	1	0
11/4/21	2	2	0	2
Totals:	**7**	**7**	**2**	**5**

Table 8. Week 4 Average SP Per Engineering Level

Average SP Per Employee by Level	
Level 1	4
Level 2	5
Level 3	6
Level 4	6

Table 9. Week 5 SP Data

	Special Problem Daily			
	Week 5 Statistics			
	Opened	Closed	Repeated SP Reported < 1	Non-Repeated SP Reported < 1
11/8/21	2	0	0	2
11/9/21	1	2	1	0
11/10/21	0	4	0	0
11/11/21	0	1	0	0
Totals:	**3**	**7**	**1**	**2**

Table 10. Week 5 Average SP Per Engineering Level

Average SP Per Employee by Level:	
Level 1	3
Level 2	5
Level 3	5
Level 4	6

Table 11. Week 6 SP Data

	Special Problem Daily			
	Week 6 Statistics			
	Opened	Closed	Repeated SP Reported < 1	Non-Repeated SP Reported < 1
11/15/21	2	2	0	2
11/16/21	3	2	1	2
11/17/21	2	2	0	2
11/18/21	1	3	0	1
Totals:	**8**	**9**	**1**	**7**

Table 12. Week 6 Average SP Per Engineering Level

Average SP Per Employee by Level:	
Level 1	4
Level 2	4
Level 3	6
Level 4	6

3.3 Feedback Survey Data

In order to evaluate the reception of the presented changes amongst the test and system engineers, a survey was sent out during the last week of data collection. The feedback survey that was used is exhibited in Appendix A and was composed of questions targeted towards analyzing the efficiency and effectiveness of the change implementation and communication for improving the SP resolution process. Four out of the six questions that were asked were assessed quantitatively while the other two were qualitative responses that were taken into account individually. For the quantitatively assessed questions, a scoring system was used where the most positively impactful response was ranked the highest while the no effect/negative effect response was ranked the lowest as shown below in Table 13:

Table 13. Scoring Range

Score Level	Points Awarded
Highest	10
Intermediate	5
Lowest	0

Answer choice (a) represented the highest-level score for the most positive, impactful change while answer choice (b) represented the intermediate-level score for noticeable improvements and (c) for the lowest-level score marked by negative changes or no improvements. The points from each question were summed for each survey to equate a total score. Based on this system, the highest total score is 40 points whereas the lowest possible score is zero with the intermediate score of 20.

As shown in Appendix B, the average total score for the 18 feedback surveys received was 32, which ranks in the intermediate to high score range thus signifying that the changes implemented for the SP process were well-received and had a positive effect. This also demonstrates that further improvements can be done to improve upon the implemented changes. Comments from the survey recipients—part of the qualitative portion of the feedback survey—suggested the following:

- Increase the frequency and efficiency of the meetings to daily instead of every other day
- Try using a white board instead of index cards

- Ensure that the binders are updated and transitioned well especially upon team member replacement
- Create a checklist for the test engineers if there is not one already

Additionally, the 50% of the survey recipients said that the SP binder was the most helpful change followed by the index card system and then the checklist. Based on this feedback, the changes implemented were used and made a positive difference in the SP resolution process. The suggestions given may be looked further into to support the continuous improvement of this system.

3.4 Summary of Implemented Principles and Their Effects

The incorporated principles established better communication amongst the system and test engineers, which sparked increased collaboration and quick implementation of the presented changes to the SP reporting and resolution process. The methods and results of each principle are listed below in Table 14.

Table 14. Principle Implementation Summary Table

Lean Principle	Implementation Method	Result
Principle 4	Assign SPs according to strengths of team members	Decreased SP resolution lead time
Principle 6	Emailed updates and created standard process checklist	Established standard process and improved communication
Principle 7	Set up SP binder and index cards	Decreased repeated SPs reported
Principle 10	Stakeholder meetings	Increased collaboration and perception value of work
Principle 11	Communicated appreciation and improvement efforts with all stakeholders	Increased respect between teams and quality of work
Principle 12	Observed TE SP process and identified root causes	Decreased SP resolution lead time and repeated SPs
Principle 13	Presented data to stakeholders and brainstormed together	Improved communication and quick implementation
Principle 14	Surveys & twice-a-week meetings to update and reflect	Led to visual controls, standardization, and future improvements

4 Conclusion

As we end the project, it is important to archive documents and keep project artifacts for learning experience. LM is a great organization and has proven time of success through its commitment to delivering superior services over the years of experience. However, making changes and improving the process is important to continually remain successful and relevant.

The project focused on a particular department at LM, a case on eliminating waste and miscommunication in the flow process between the SEs and TEs responsible for the identification and the resolution of Special Problems occurring in fighter-jet simulation labs. At the start of the project, a consensus was drawn that we would implement lean principles because lean focuses more on ways to increase flow in the production process, which was our intention. A total of 8 principles were implemented:

- Principles 4 – Level out the workload (Heijunka)
- Principle 6 - Standardized tasks are the foundation for continuous improvement and employee empowerment
- Principle 7 - Use Visual control so no problems are hidden
- Principle 10- Develop exceptional people and teams who follow your company philosophy
- Principle 11- Respect your extended network of partners and suppliers by challenging them and helping them improve
- Principle 12 - Go and see for yourself to thoroughly understand the situation (Genchi Genbutsu)
- Principle 13 - Make decisions slowly by consensus, thoroughly considering all options; implement rapidly (Nemawashi)
- Principle 14 - becoming a learning organization through relentless reflection (hansei) and continuous improvements (Kaizen).

Based on each principle we applied some tools including colored index cards for visual controls, index binders, sending daily emails to improve communication, created a standardized document for SPs, held weekly standups and kaizen events with TEs and SEs for feedback, met with team leads to resolve issue of leveling out the workload, also encouraged team leads to visit problem areas of SPs to better understand the underlying issues, and reason for repeated SPs. And in the last week of the project, we conducted a survey on the entire process.

The results from data after implementation showed a reduction in lead-time in terms of closing SPs when compared with the data analysis at the start of the project. The average **SP_closed ≤ 4** in the first 3 weeks before lean implementation. After implementing lean, the average jumped to **SP_closed ≥ 9**. Repeated SPs also reduced which shows an indication of improvement in communication between SEs and TEs. At the start of the project, average **SP_repeated ≥ 5** and after lean implementation, **SP_repeated ≤ 1**. The team also experienced better handling of special problems as the work breakdown structure of the SEs improved in terms of levelling out the workload. Difficult and more complex problems were assigned to the more experienced SEs. At the 6th week we had an even balanced SP per employee level as indicated in the report.

Feedback from the survey questions also indicated a satisfactory experience from the process and employees from both SE and TE had a buy-in in the process as 80%, indicating a positive effect on the overall performance.

There is still room for improvement as further implementation process might be the combination of lean and six sigma on the flow process at LM, which gives a more scientific approach to the project. We might run test hypothesis and analysis on the lean principles applied, effectiveness of the tools (binders, email notification) against the response data and survey feedback to see if there was a significant change in communication between SEs and TEs at Lockheed Martin. Results obtained will help in continuous improvement and standardizing the process.

5 References

Liker, Jeffrey. *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. 1st ed., McGraw-Hill Education, 2004.

6 Appendix

6.1 Appendix A – Feedback Survey

LOCKHEED MARTIN SP IMPROVEMENT PROJECT

Feedback Survey

For each question, please circle or highlight the option that best matches your response:

1. Have you found the SP reporting system to be more convenient and effective?
   (a) Yes, I've noticed a dramatic change!
   (b) Slightly, I've seen some improvements but nothing drastic.
   (c) Not at all, the changes have not improved the SP reporting process.

2. What has been the most helpful change for you?
   (a) Index card labeling system for reported SPs
   (b) Posted SP binder
   (c) Other: ____________________________

3. Have you noticed a change in the number of newly reported SPs?
   (a) Yes, the number of SPs reported have dropped dramatically because of awareness of existing SPs.
   (b) Slightly, the number of newly reported SPs has decreased but not by much.
   (c) Not at all, the number of newly SPs reported has not changed or has increased.

4. Have you felt that the SP resolution process has gotten faster?
   (a) Yes, SPs are getting resolved much more quickly than before and process is more efficient.
   (b) Slightly, the process is becoming faster, but I am still getting used to the changes.
   (c) Not at all, I haven't noticed a difference.

5. Was communication effective in introducing and implementing the changes to the SP reporting system?
   (a) Yes, I have felt on the same page with our teams and have noticed improved collaboration.
   (b) Slightly, the communication was done well, but it took time to get used to the changes.
   (c) Not at all, I have been lost as to what has been communicated and implemented.

6. Do you have any comments or suggestions to improve this process?

Please return this form to Stephanie Trevino or Jesus Rodriguez via in-person or email at rod45488@ttu.edu by Friday, November 19th, 2021 at 5:00pm CST.

6.2 Appendix B – Feedback Survey Results

Survey #	(1) Convenience & Effectiveness	(2) Most Helpful Change	(3) Change in # of Reported	(4) Resolution Process Faster?	(5) Communication	(6) Other Comments	Total Quantitative Score
1	10	SP Binder	10	10	10	N/A	40
2	5	Email reminder	5	5	5	N/A	20
3	10	Index cards	5	10	10	N/A	35
4	5	Meetings	5	10	10	Daily meetings instead of every other day	30
5	10	Index cards	10	10	10	Great job!	40
6	10	SP Binder	5	10	5	N/A	30
7	5	Checklist	5	5	10	N/A	25
8	10	SP Binder	10	5	10	Create checklist for test engineers	35
9	5	SP Binder	5	10	10	Go through meetings faster to get back to working on SPs faster to close out	30
10	5	SP Binder	5	10	10	N/A	30
11	10	Index cards	10	10	10	N/A	40
12	5	SP Binder	0	5	5	N/A	15
13	10	Checklist	10	10	10	Continuously add more info/good resources to checklist	40
14	5	SP Binder	5	10	10	Binder was really helpful; just need to make sure it gets updated especially if Stephanie and Jesus transfer teams	30
15	10	Index cards	10	10	5	N/A	35
16	10	SP Binder	10	5	5	N/A	30
17	10	SP Binder	10	10	10	Try using white board instead of index cards?	40
18	10	SP Binder	5	10	10	N/A	35
Avg. Rating:	8.1	-	6.9	8.6	8.6	-	32.2
Mode:	10	-	5	10	10	-	30

6.3 Appendix C – SP Checklst

Checklist for SP's Development

Phase I Implementation..

Phase I Internal Review..

Phase I External Review..

Phase II Implementation..

Phase II Internal Review...

Phase II External Review..

Phase III Implementation..

Phase III Internal Review..

Phase III External Review...

	Checklist for SP Development	
	Phase I Implementation	
Guideline for Work Effort	SP Work Instructions	Check
	Have you completed detailed SP planning?	Y or N
	Have you researched the Capability	Y or N
	Have you chosen to simplify design and reduce scope whenever possible?	Y or N
Coordinate with Functional Lead and Block Lead	Have you initiated a dialogue with your Functional Lead? Have you initiated a dialogue with your Block Lead?	☐ ☐ Check
Coordinate with Hardware Engineer	Have you initiated a dialogue with the Hardware Engineer to make sure this SP has not been reported twice?	Y or N
Coordinate with SP Contacts	Have you identified the following POCs? Identify POC Identify Subsystem and/or Capability POC Identify experts in the Capability Establish list of individuals who will be signing this SPs	Y or N ☐ ☐ ☐ Check

Templates to Populate (Create/Modify)	Do you have current copies of the following? System Requirements Analysis Template System Operations Template System Safety Template Performance Analysis Template Design Rationale Template (notes on tradeoffs and design decisions made)	Y or N ☐ ☐ ☐ ☐ Check
Product Produced	Have you defined initial displays and control approach? Early coordination from the "big picture" approach General concepts in this phase, not a lot of detail	Y or N ☐ Check
Use Cases	Establish the Capability by developing the Use Case Diagram in Rationale Rose Include: Variant, Pre-Conditions, Description, Exceptions, Post-Condition	Check
Coordinate	New capability: o Yes oNo If yes, coordinate with the Block Lead	Check
CM	Have you entered products into Configuration Management?	Y or N
Coordinate	Establish Functional Lead concurrence	Check
Book room	Get a conference room as soon as you can.	Check
Invite	Block Lead, Functional Lead, if needed, a team of design engineers as well.	Check

	Phase I Internal Review	
	Do you have your Functional Lead concurrence? Have you actioned your work package?	Y or N
Review	Hold an internal review of Phase I SP products	Check
Address Action Items	Have you completed all Action Items?	Y or N

	Phase I External Review	
Review	Design Reviews guidelines Phase I and Phase II guidelines	☐ ☐ Check
	Action to baseline pending: System Operation System Safety Performance Analysis	 ☐ ☐ ☐ Check
	Attach System Requirements Analysis doc to change doc	Check
	Distribute review package	Check
	Hold External Review	Check
	Work Action Items	Check
Obtain Signatures	Pilot Vehicle Interface Requirements Management System Verification Safety	☐ ☐ ☐ ☐
PVCS	Have you updated PVCS with completion date?	Y or N

	Phase II Implementation	
External I/F	Identify all Use Cases with External I/F and work those first	Check
Activity Diagram	Create or Modify and Activity Diagram for each Use Case	Check
Functional Decompositi on	Follow IERROR process if applicable Follow Using LERROR guideline if applicable	☐ ☐ Check
Scope	Choose to simplify design and reduce scope whenever possible	Check
	Allocate activities to system classes	Check
	Create transitions and/or object flows among activities and/or objects	Check

Design Rationale	Create or Modify the Design Rationale	Check

	Phase II Internal Review	
	Functional Lead concurrence	Check
	Hold meeting with at least 5 attendees including: Block Lead Functional Lead	 ☐ ☐ Check
	Have meeting	Check
	Have you worked Action Items?	Y or N

	Phase II External Review	
	Functional Lead Concurrence	Check
	External review package distributed	Check
	External review held	Check
	External review action items closed	Check

	Phase III Implementation	
	Functional Lead concurrence	Check
Scope	Choose to simplify design and reduce scope whenever possible	Check
	Create or Modify System Interfaces	Check
	Create or Modify Software Requirements Specification (SRS)	Check
	Create or Modify Activity Requirements Template	Check
	Format description Tables	Check
	Update Symbology Library	Check
	Design Rationale with Safety Insert	Check
	Have you obtained all signatures on signature sheet?	Y or N

	Phase III Internal Review	
	Functional Lead concurrence	Check
	Coordinate Meeting with: Lead Engineer Interface Lead Tech Writer Design Engineer 1 Design Engineer 2	 ☐ ☐ ☐ ☐ ☐ Check
Steps	Hold meeting	Check
	Are all Action Items worked?	Y or N

	Phase III External Review	
Review	Phase III guidelines	Check
	External review package distributed	Check
	External review held	Check
	External review action items closed	Check
	Gather all signatures	Check

6.4 A3 Report

Problem statement in Test sytem Labs at LM

After careful delibration and consensus from both teams we identified the following problems :

- *Increase in number of unclosed SPs.*
- *Repeatedly reporting SPs.*
- *Problem of miscommunciation between SEs and TEs.*
- *Unleved SPs among the SEs*

*To your right, **Fig 1,** gives a breif discription of the number of SPs opened, closed, and repeatedly reported on a weekly basis. Blue is week one, pink is week 2 and red is week 3.*

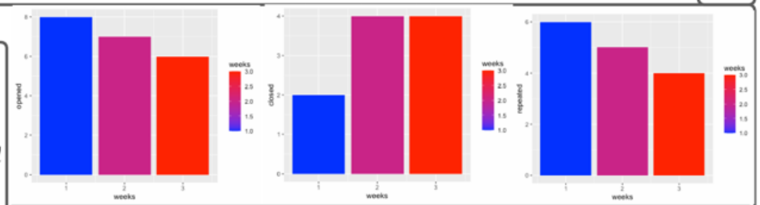

Fig 1. opened barplot *Fig 2 . closed barplot* *Fig 3. - repeated barplot*

"x" axis rep weeks and "y" axis rep number of opened, closed and repeated SPs reported.

RPubs

Current Conditions at LM test labs

- *There is increased number of SPs opened per week and poor state of resolution time, which leads to repeatedly reported SPs.*
- *The weekly average SPs opened is 7 from wks 1 to 3 which can't be influenced but we can work on timely resolution.*
- *The number of unclosed SPs increased between wks 1 to 3 from 2 to 4. This might be due to the inexperience of the SEs.*
- *Because the SPs are taking long for resolution, the weekly average of repeatedly reported SPs is 5.*
- *We also noticed workload is not evenly distributed among the SEs handling the SPs*

Goals/Targets

- *Reduce the amount of repeated SP reported daily to 0.*
- *Increase the amount of SP closed on a daily basis.*
- *Improve the communication between SE and TE.*
- *Level out the workload amongst the team for most efficient result.*

Analysis

- *Increased number of unclosed SPs.*

Because we can't influence the number of SPs opened, we need to work on timely resolution. We might consider designating difficult SPs to the more experienced engineers. This will reduce Unclosed SPs. Also new SEs don't have a standardized process template to follow, another issue is SPs that are unique in nature and rarely reported.

- *Repeatedly reporting SPs and lack of communication*

TEs don't have a system of verifying if an SP is on WIP, before reporting it. This causes a communication gap between SEs and TEs.

- *Unleved SPs among the SEs*

The SEs experience uneven workload as there is no system or order in which task(SPs) are assisgned therefore leading to unbalanced workload.

Countermeasures

- *Document a standardized procedure on how to approach task*
- *Create a binder that includes process steps for generating SPs*
- *Weekly email sent to TE team that includes index cards/binder information updates status of SPs, reported or not reported.*
- *Use of visual controls so no SP is hidden*
- *Sensitize TEs to refer to binder for existing SPs and work-arounds*
- *Weekly standups with TEs and SEs to get feedback on new process*

Plans

- *Email implementation will be tested in wk1 as there are concerns of TEs accessibility to mails in labs and delibrate disregard.*
- *Contingencies for email implementation failure will be applied.*
- *Different colored index cards will be updated weekly (Monday & Wednesday) in the lab .*
- *Stephanie will be in charge of sensitizing the Teamleads, SEs and TEs of the binder updates.*
- *Meeting with LM Team supervisors to brainstorm on balancing workload per SE.*

Followup

Text

6.5 Visual Controls- Index Card (Example)

Radar

Special Problems Reported

-Unidentifiable object not detected
-Radar disconnect from EW
-Distance not accurate to object
-Wrong version loaded

Sensors

Special Problems Reported

-Sensors turning off mid test
-Camera sensor gives error message
-Height sensor displays wrong data

Core Processor

Special Problems Reported

-Processor hears up after 30 minutes
-Processor runs slower than expected
-Processor communication with Radar is lost

Software

Special Problems Reported

-Wrong message display on screen dealing with a certain version
-Software GPS shows negative altitude

6.6 Visual Controls- Binder (Example)

SP Reported			
System	**Title**	**Status**	**Work-Around**
Radar	Unidentified object not detected.	Open	Initiate ACM mide in order to identify the unidentified object.
Radar	Radar disconnects from EW.	Open	Power cycle Radar.
Radar	Distance not accurate to object.	Open	RESIM simulation in order to get accurate distance.
Radar	Wrong version loaded.	Open	Power cycle Radar.
Sensors	Sensor turning off mid-test.	Open	Power cycle Sensors.
Sensors	Camera sensor gives error message when start-up.	Open	Hold the error message for three seconds then resync the sensors.
Sensors	Height sensor displays wrong data.	Open	RESIM simulation in order to get accurate height data.
Core Processor	Processor heats up after thirty minutes.	Open	Power off simulation and let it sit untouched for ten minutes
Core Processor	Processor runs slower than expected.	Open	Power cycle Core Processor.
Core Processor	Processor communication with Radar lost.	Open	RESIM simulation in order to boot communication again.
Software	Wrong message display on screen dealing with a certain version.	Open	Disconnect all participants from SDS and re-load simulation.
Software	Software GPS shows negative altitude.	Open	Initiate SDS to re-sync alll participants.