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Lean Six Sigma: Tobyhanna 5M540 Kitting Process

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Abstract: The 5M540 Cost Center is responsible for kitting at the Tobyhanna Army Depot. Over the course of this project, the group used lean six sigma methodology to reduce schedule variance. Each phase in the DMAIC Process (Define, Measure, Analyze, Improve, Control) is made up of tools tailored to address the project's goals. With a team approach we identified root causes for missed schedules and delayed production orders. Our recommendation and final solution to address schedule variance was a process accountability mechanism to ensure communication, coordination, and accurate estimates that would be integrated into scheduling data. Along with this improvement we leveraged a variety of quick wins to improve process efficiency such as a reorganized floor layout, cleaned shop floor, and data entry techniques.

Keywords: Lean Six Sigma, DMAIC, Tobyhanna Army Depot, 5M540 Kitting Process, Systems Improvement

1. Literature Review

Lean six sigma methodology leverages the DMAIC process to address problems and iteratively improve systems (George, Rowlands, Price, & Maxey, 2005). In the project-team approach, teams led by Black Belts are deployed full-time to projects while their supporting team members work on the project part-time, taking anywhere from one to four months depending on the scope of the project (Selvi & Majumdar, 2014). Each phase in the DMAIC process contains tollgate requirements that ensure total completion while progressing through the phases. The tollgate requirements for each phase are such; Define: project charter, duplication review, SIPOC (Suppliers, Inputs, Process, Output, Customer), VOC/VOB (Voice of Customer/Business), and communication plan; Measure: operational benefits, process map, operational definitions, data collection plan, measurement system analysis, baseline statistics and baseline process performance; Analyze: value add analysis, prioritized root cause analysis, failure mode and effects analysis; Improve: "To-Be" process map, pilot plan, implementation plan, and prioritized list of solution; Control: transition plan, process control tools, and project summary (George, Rowlands, Price, & Maxey, 2005). Throughout each phase, quick wins are opportunities for process improvement that either quickly mitigate risk and/or make the process more efficient (Rodrigues et al., 2020). Finally, the parking lot refers to ideas that are set aside because they lie beyond the resources and/or scope of the project (Godfrey & Manikas, 2019). While the improvement process is iterative, remaining within resources, scope, and remaining focused on the goal statement, is a constant challenge. In anticipation of our project, we focused our research on the best telecommuting practices as most of our meetings, workshops, and exercises would be held over phone calls. Our research concluded that teleworking offered benefits due to its flexibility and integration with software. We leveraged Microsoft Teams, JamBoard, and project management techniques to ensure we kept pace with the project and were able to complete the tollgate requirements outlined above.

2. Methodology

The first step when approaching our project was to hone the scope and define the process involved with the 5M540 cost center. 5M540 focuses on the kitting process. Thus, we restricted our scope and process to the shop floor and scheduling strictly within the control of 5M540 employees. Early discussion yielded that a recurring problem was difficulty communicating to higher management that some production orders (POs) were delayed to an upstream failure to meet deadlines or acquire parts. Addressing this lapse in communication became a focus later in the project. In conjunction with our Tobyhanna team counterparts, we identified the following problem statement; "During the 3rd and 4th quarters of FY23 the kitting team has experienced scheduling variance from –1630 to 196 hours as production orders (POs) are on hold for parts". Further, we defined the goal statement; "Reduce hourly scheduling deviations to +/- 3% of planned by the end of 11 March 24". The SIPOC map helped focus our goal and problem further (see Figure 1). Specifically, we found that there was a large bottleneck within the inputs category of the SIPOC map. The Tobyhanna Army Depot uses just-in-time (JIT) manufacturing. JIT manufacturing is susceptible to delays due to upstream delays cascading. Ultimately, the most extreme schedule delays would occur at the 5M540 process, downstream, most near to the customer. One of the most important parts of the SIPOC map is the VOB and VOC. The overarching customer concern was delivery of completed kits in adherence to the planned schedule. Our first business concern identified was the frequency of hold notes, schedule estimates, and inaccurate traveler and Bill of Materials (BOM) information. Our second business concern was the visual representation of cost center PO status. These concerns fall within our scope and help frame our project as we moved forward.

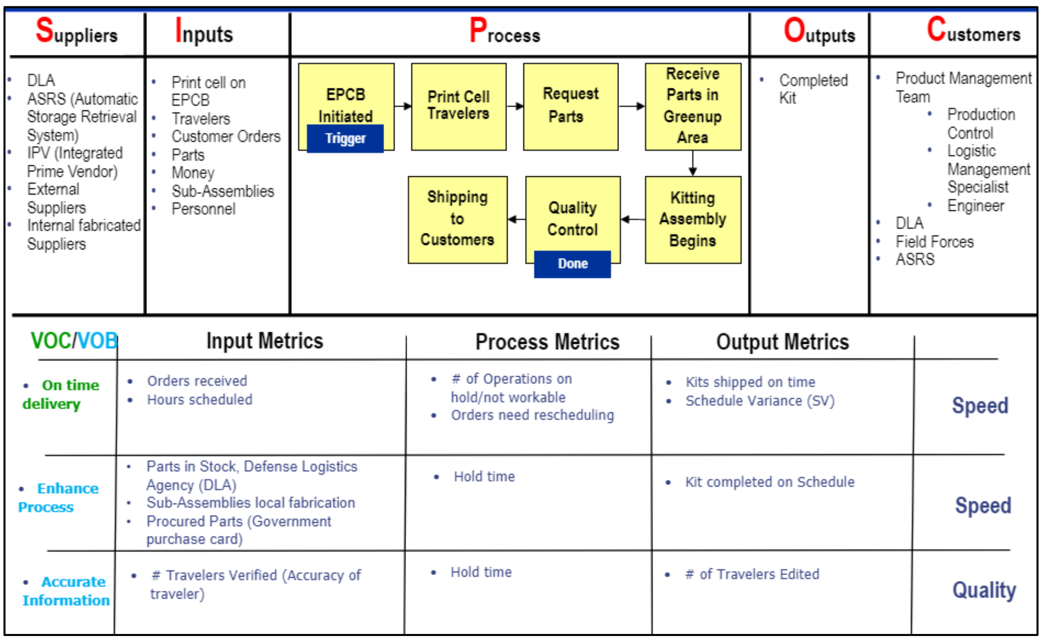


Figure 1: SIPOC diagram used to conceptualize the complexity of the process components.

Moving into the measure phase, we first found difficulty mapping the process. Variability in types of kits contributed heavily to this. While a framework is encouraged, no standardized framework is required (Jacobson and Johnson, 2006). Leveraging flexibility, we created a new process map with our 5M540 counterparts to formalize the flow. The formalized process contained 23 individual steps within the flow. The process was complicated and required visualization to fully understand the 5M540 kitting process. We created a process map with production management to gain a shared understanding. Next, we sought to establish operational definitions. The operational definitions standardize terms and acronyms within the process (Jacobson and Johnson, 2006). An abundance of acronyms was broken down during this step. Once we established this foundation, we could move into data collection. Having a good data collection plan ensures continuity, replicated and catching data-related problems in future phases, setting an azimuth for project success. The three key performance indicators (KPIs) identified were the difference in target RCT (repair cycle time or entire project time) and actual duration, change in target start date and actual start date, and schedule variance. For our KPIs, we gathered our data in days. Inconsistent with our goal statement we adjusted the goals to match the units. We additionally identified bias in our calculations due to the inability to account for weekends and holidays that would skew our data further left (see baseline statistics in Table 1). Both qualitative and quantitative data require scrutinization to avoid the human tendency towards overconfidence in research (Lash et al., 2014). Data collection bias was mitigated by using standardized procedures. Preparing the data for the analyze phase exposed a variety of issues and procedures with current practices. It was necessary for data managers to incorporate data validation to standardize data. After cleaning the data, we were able to generate baseline statistics.

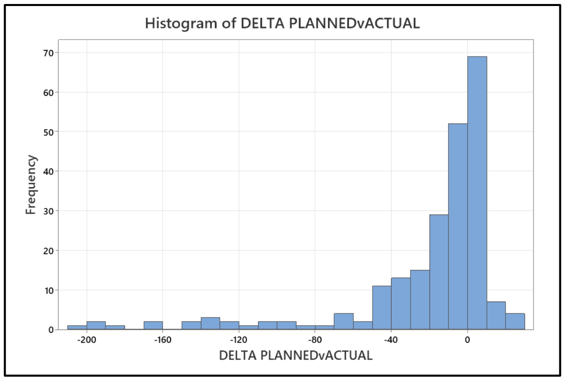


Figure 2: Histogram depicting the difference between PO schedule time and PO actual time.

A major concern when interpreting our baseline statistics was shifting schedules when delays occurred. Controllers, who schedule hours, are forced to alter schedules based on the cascading delays. Essentially, the final approved schedule would reflect the actual production. In truth, the original planned schedule differed greatly from actual production. To address this, we had to find what the original schedule was for a fair comparison to the actual duration of the PO.

The histogram above in Figure 2 depicts the difference between the original planned schedule and actual duration of each production order for the 2023 calendar year. The histogram revealed an inefficient process, with a mean delay of 21.59 days which varied greatly, indicated by a standard deviation of 41.29 days. Along with a control chart indicating process instability, we found many points that fell outside the lower control limit (-1.35 days). Our histogram validates this finding due to the left skew and extreme production orders delayed up to 200 days.

The last chart we generated during the measure phase was a variety of pareto charts. Pareto charts help identify potential root causes and examine the 80/20 rule; 80% of the defects arise from 20% of the problems (Pareto Charts & 80-20 Rule - Clinical Excellence Commission, n.d.). While the pareto charts were interesting, the team identified significant bias due to recent influx in specific production orders currently in-progress.

Transitioning into the analyze phase, we began with the Ishikawa or fishbone diagram seen below in Figure 3. We constructed the Ishikawa diagram as a group which enabled employees across the cost center to air their opinions on what could be contributing to schedule variance. The categories and associated ideas brainstormed are below.

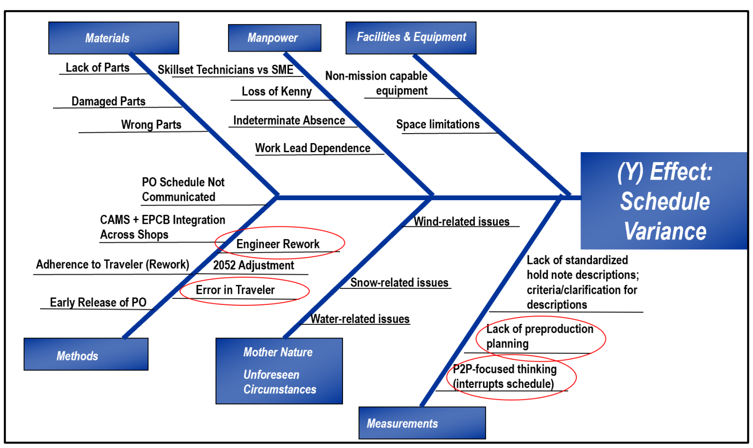
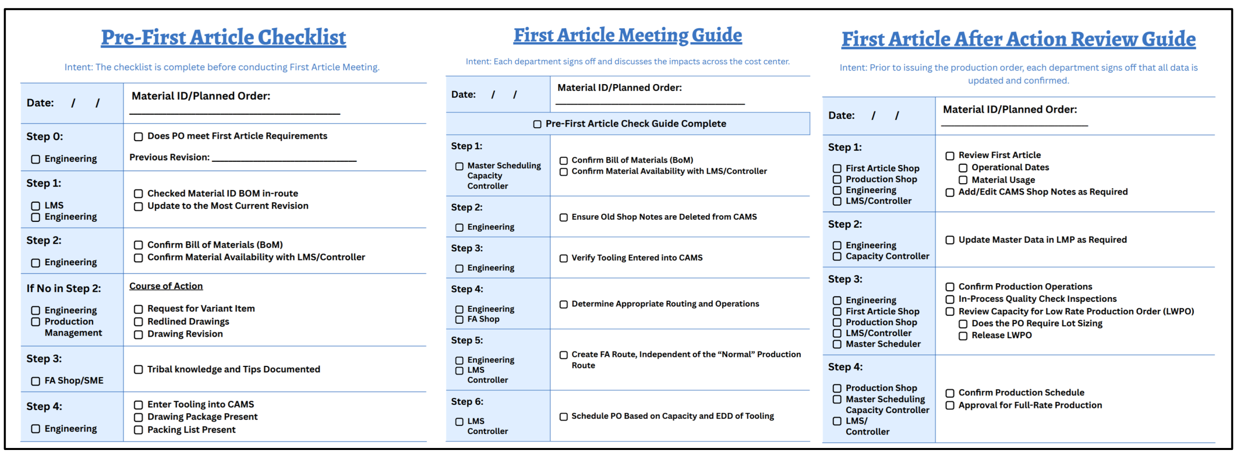


Figure 3: Ishikawa (Fishbone) diagram to identify causes and effect relationships on schedule variance.

To prioritize which of these issues to focus on, we quantified them by using Failure-Mode-Effects-Analysis (FMEA). Across three factors: severity, occurrence, and detectability, we deduced a risk priority number (RPN). The higher the number, the greater the concern. The four highest RPNs are circled in the Ishikawa diagram in red: Error in Traveler (1000), Engineer

Rework (900), P2P (Promise-to-Perform) Focused Thinking (700), and Lack of Preproduction Planning (630). To interpret the impacts quantitatively we interviewed employees to refine our RPN assessment and gain insight from the kitting process employees. These engagements consisted of questions aimed at determining how often these root causes occur, how impactful these root causes are, and if they are familiar with these root causes. Trends in the results indicated that all employees work beyond their assigned jobs, there is a high impact of no pre/post first article meetings, and these root causes have an impact on the kitting process. The results also confirmed assumptions about the lack of communication amongst the shops involved with the kitting process. The analyze phase also uncovered a variety of quick wins that we address in Section 3: Quick Wins and the Parking Lot.

Targeting the root causes identified in the analyze phase, the improve phase began with potential solution generation. Via JamBoard, a virtual collaborative whiteboard software by Google, we invited stakeholders from all levels from the kitting process to offer suggestions. From each of the four identified root causes: Error in Traveler, Engineer Rework, P2P-Focused Thinking, and Lack of Preproduction Planning, we hosted a virtual brainstorming session to address how each impacted schedule variance. We bolstered both the quantity and quality of ideas by utilizing an anonymous platform and allowing the group to explain ideas before the author of the idea. Grouping the solutions into similar themes, we pitched pilot plans to start implementing the potential solutions. Many of the solutions brought about by each of the stakeholders pointed towards a plan that would ensure pre-production meeting accountability, updated data, and better communication techniques. Due to this congruency, our pilot plan was unique because the only costs incurred by implementing it would be the additional bureaucratic oversight and meeting accountability measure. From our prioritized list of solutions, we focused efforts on meeting accountability to specifically target our schedule variance goal. The other suggestions brought up during ideation are addressed in Section 3: Quick Wins and the Parking Lot.



Pre-First Article Checklist

Intent: The checklist is complete before conducting First Article Meeting.

Date: / /	Material ID/Planned Order: ____
Step 0: ☐ Engineering	☐ Does PO meet First Article Requirements Previous Revision: ____
Step 1: ☐ LMS ☐ Engineering	☐ Checked Material ID BOM in-route ☐ Update to the Most Current Revision
Step 2: ☐ Engineering	☐ Confirm Bill of Materials (BoM) ☐ Confirm Material Availability with LMS/Controller
If No in Step 2: ☐ Engineering ☐ Production Management	Course of Action ☐ Request for Variant Item ☐ Redlined Drawings ☐ Drawing Revision
Step 3: ☐ FA Shop/SME	☐ Tribal knowledge and Tips Documented
Step 4: ☐ Engineering	☐ Enter Tooling into CAMS ☐ Drawing Package Present ☐ Packing List Present

First Article Meeting Guide

Intent: Each department signs off and discusses the impacts across the cost center.

Date: / /	Material ID/Planned Order: ____
☐ Pre-First Article Check Guide Complete	
Step 1: ☐ Master Scheduling Capacity Controller	☐ Confirm Bill of Materials (BoM) ☐ Confirm Material Availability with LMS/Controller
Step 2: ☐ Engineering	☐ Ensure Old Shop Notes are Deleted from CAMS
Step 3: ☐ Engineering	☐ Verify Tooling Entered into CAMS
Step 4: ☐ Engineering ☐ FA Shop	☐ Determine Appropriate Routing and Operations
Step 5: ☐ Engineering ☐ LMS Controller	☐ Create FA Route, Independent of the “Normal” Production Route
Step 6: ☐ LMS Controller	☐ Schedule PO Based on Capacity and EDD of Tooling

First Article After Action Review Guide

Intent: Prior to issuing the production order, each department signs off that all data is updated and confirmed.

Date: / /	Material ID/Planned Order: ____
Step 1: ☐ First Article Shop ☐ Production Shop ☐ Engineering ☐ LMS/Controller	☐ Review First Article ☐ Operational Dates ☐ Material Usage ☐ Add/Edit CAMS Shop Notes as Required
Step 2: ☐ Engineering ☐ Capacity Controller	☐ Update Master Data in LMP as Required
Step 3: ☐ Engineering ☐ First Article Shop ☐ Production Shop ☐ LMS/Controller ☐ Master Scheduler	☐ Confirm Production Operations ☐ In-Process Quality Check Inspections ☐ Review Capacity for Low Rate Production Order (LWPO) ☐ Does the PO Require Lot Sizing ☐ Release LWPO
Step 4: ☐ Production Shop ☐ Master Scheduling Capacity Controller ☐ LMS/ Controller	☐ Confirm Production Schedule ☐ Approval for Full-Rate Production

Figure 4: Snip of the prioritized solution to ensure complete data inputted on first articles before complete roll out of a production order.

Figure 4 (above) is our solution for meeting accountability. This figure above is a snip of the detailed solution. Upon reflecting on our preliminary discoveries, assumptions, and interactions with stakeholders during the define and measure phase, we initially observed that production orders placed on hold could be attributed to two main factors: either they should not have commenced due to an oversight in parts accounting, or they involved engineer rework that ideally should have been identified during the initial production phase. Both impacted the traveler. One of the major grievances aired by management was that despite the hold note resolution being outside of the 5M540 shop responsibility, dashboards reflected that the respective material was within the 5M540 domain. Rather, these production orders should have never begun in the first place, especially when considering missing parts/material, engineering design changes, and quality assurance should have been addressed during first article production. First articles are products being kitted in 5M540 for the very first time. Our detailed solution seeks to address these egregious delays that skew our variance in our initial problem statement. No major risks were identified in implementing our solution aside from distaste by employees due to extra paperwork and assigning oversight responsibilities which we address in our control phase.

During the improve phase we consolidated ideas to arrive at our production meeting accountability mechanism. This solution seeks to proactively address the hold notes that could occur during the 5M540 Kitting Process. Rather than having production orders on hold for long durations of time, they would not begin in the first place. Caught during first article production and reflected in the master scheduling data, the schedule can more accurately depict actual duration upon the commencement of full rate production. Initial production runs may result in hold notes due to engineer updates, uncertainties about production timing, and other factors.

The control phase aims to integrate the improvements from the previous phases into the organization's structure and culture for continued process improvement. The first task of integration was to conduct an accountability analysis of the tasks outlined in the first article meeting guides and consolidate them into a responsibility assignment matrix (RACI matrix). A RACI matrix, which stands for Responsible, Accountable, Consulted, Informed, is a useful tool for clarifying roles and responsibilities within a project or process. Completing the RACI matrix ensures that the appropriate parties within the organization are held liable for their roles in accomplishing each task (Sarkar et al., 2014). Once we validated the RACI Matrix with the kitting process team, we moved forward with standardizing our meeting guides into a compatible format that the Tobyhanna Army Depot can integrate to their software. The next task was to validate and demonstrate the effectiveness of our proposed to the client. To accomplish this, we fully implemented our solution (Figure 4) and evaluated the effects using our KPIs from the measure phase. Our findings are discussed in Section 4: Results and Conclusion.

3. Quick-Wins and The Parking Lot

Quick-Wins during the define phase were identified during the initial site visit. Loose paperwork, cluttered spaces, and miscellaneous parts littered the 5M540 shop floor. A lean six sigma strategy referred to as 5S: Sort, Set in Order, Shine, Standardize, and Sustain completed this early effort (Terra, 2022). By encouraging leadership to take on a 5S approach we were able to free up space and clean the area. During the measure phase we identified that data we were excited to dissect and visualize lacked standardization and inputting procedures. A Standard Operating Procedure (SOP) for inputting data was a quick win to facilitate future data analysis. With the foundation in place from define and measure, we returned to quick wins in the improve phase as we fielded a variety of ideas from stakeholders. One significant quick win identified in ideation was implementing a scheduling strategy that more accurately mirrors activities on the 5M540 shop floor. Rather than the previously scheduled immediate start to kitting, a buffer was added as well as a parallel activity to compile parts and account for the actual time that passes during the material staging portion of the process. Another quick win from the improve phase included a shared email box amongst the engineering department to quickly respond in the event of the assigned engineer's absence. Previously, although any engineer could make a "level 1 change", the absence of the assigned engineer would result in a hold note. Our final quick win in the improve phase was a solidified definition of what constituted a first article so that the appropriate routing could take place. During our control phase on-site visit, the team recommended a mitigating measure to address rust forming on the roller used during kit assembly. The second quick win in the control phase was an evaluation of the process flow and layout of the shop floor as depicted in Figure 5. We underwent a correlation exercise to identify themes and how to best orient the shop. We found that some storage locations disrupted flow and work leaders were not ideally located. Among other themes we presented opportunities to enhance the flow, oversight, and management of the shop floor.

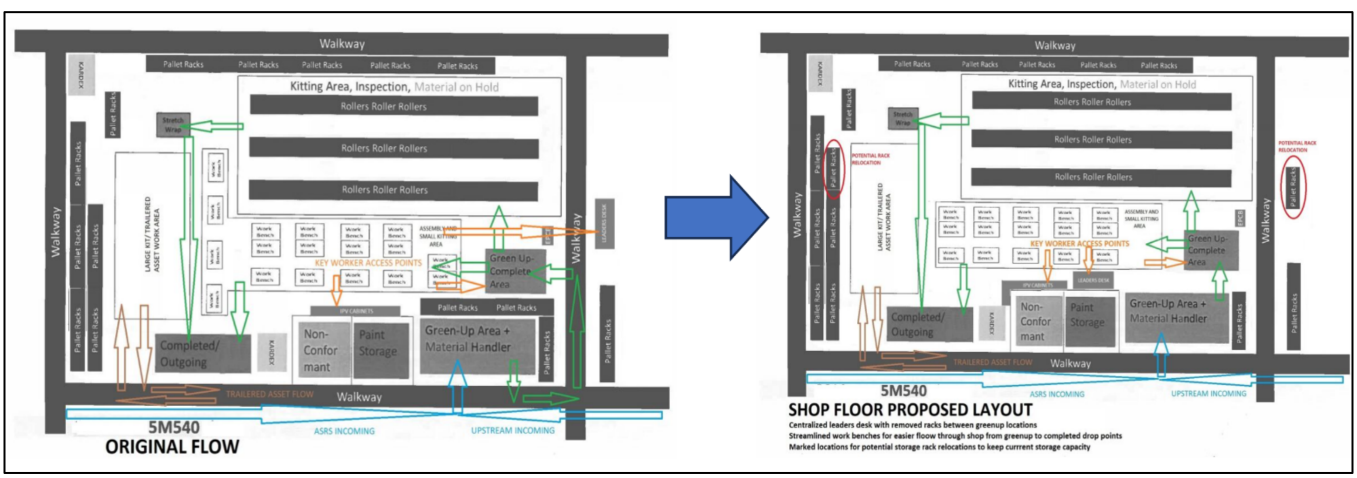


Figure 5: Shop floor layout quick-win improvement.

Identified as out-of-scope and/or misrepresenting of our project's goal, we discovered a variety of future projects that could enhance the 5M540 process and the Tobyhanna Army Depot. The first is incorporating a degree of material security especially when dealing with high value items. Second is an improved network connection regarding software access. Third, we found that employees generally took on apprenticeship roles before progressing through the ranks. Rather, we recommend an onboarding process and formal training when transitioning jobs to ensure there is no loss of trade skills or proper techniques. Fourth is when negotiating contracts to include a comprehensive BOM for variant item requests to avoid drawn out approvals for easily exchangeable parts. Our final recommendation would be to employ the meeting guide checklists from our project to other shops where first articles are regularly processed.

4. Results and Conclusion

In conclusion, the rigorous application of the DMAIC process, complemented by the project-team approach, has led us to reducing scheduling variance within the 5M540 Cost Center at Tobyhanna Army Depot. Beginning with a thorough definition of scope and goals, followed by meticulous data analysis and root cause identification, we have collaboratively pinpointed key issues and developed solutions. Through virtual collaboration tools and stakeholder engagement, we have devised actionable plans to improve accountability, enhance communication, and refine processes. By integrating these improvements into the organization, alongside the identification of quick wins and future considerations, we are addressing immediate challenges and promoting continuous improvement. The changes from this project can be seen in table 1.

Table 1: Control chart in days of Baseline data and after improve solution was implemented (in days).

KPI	BASELINE	19MAR	03APR
MEAN Δ IN SCHEDULED TIME AND ACTUAL TIME	-21.59	-1.04	-1.81
VARIANCE	1,704.86	25.35	31.17
STANDARD DEVIATION	41.29	5.04	5.58

Our data in Table 1 reflects positive trends in process performance. Starting with the mean, the average hold note time being reduced from ~22 days to ~2 days, and schedule variance has improved from ~1,705 days to between ~25 and ~31 days thus approaching our problem and goal statement. Both of these KPIs indicate that the implementation of the first article meetings have reduced delays and improved the flow of the process. We suspect increased comfortability with the new process will enhance on-time delivery and contribute towards reaching organizational goals.

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