

Applying LEAN Techniques to the Engineering Process

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ABSTRACT

Many companies have successfully adopted Lean manufacturing as an operational philosophy, creating a universal understanding of value and waste which in turn provides significant advantages in the market. However, few have reached the true goal of driving this mindset throughout the organization. For many reasons, this has proven particularly difficult in environments such as engineering and development due to the iterative nature of design and test, the lack of repetition, and the over-all length of time consumed by the process.

However, product development is in fact a process that can be controlled. This paper describes methods used by a group of Curtiss Wright companies to improve the overall execution of the product development cycle by first creating inter-departmental flow, tracking that flow with visual metrics, and improving performance with a variety of Lean techniques.

INTRODUCTION

As a sub-tier supplier in global Aerospace and Defense markets, *Curtiss Wright Controls Engineered Systems (CWCES)*, provides highly engineered components and sub-systems for a variety of specialized motion-control applications. Technology and organizational intellectual property combined with world-class operational excellence and customer support have enabled CWCES to maintain a competitive position as a key supplier in targeted markets.

As with many companies, this relentless focus on Operational Excellence based on Lean manufacturing principles, has not migrated throughout the organization, particularly product development processes. The brutal fact is that historically, new programs have suffered considerable over-runs in schedule resulting in over-runs in cost as additional resources are thrown in to correct the situation. These losses have been absorbed through customer funding, protected markets, and/or aggressive manufacturing.

Over the last decade, changes in the market have threatened this balance:

- Industry-wide pricing pressures have driven cost-cutting, challenging NRE budgets.
- Performance-based specifications push increased design responsibility and risk to sub-tier suppliers.
- Shortages in technical manpower [1].

Thus even as performance-based specifications drive increased levels of responsibility, capability, and ultimately investment, the market requires immediate cost reductions. When combined with the upturn in aerospace and defense markets seen in 2003-2005 and the difficulties recruiting sufficient numbers of skilled engineers, capacity in Product/System Development became a real challenge.

Thus it became apparent that the poor performance traditionally accepted in Product Development process threatened to be a critical inhibitor to success and must be addressed. Since few companies have ever mastered the complex art of managing product development costs and process, this seems to be a formidable challenge. However, it is really not dissimilar from the operational challenges that lead to the adoption of Lean Manufacturing principles, creating an ever-present drive to eliminate waste and an increase efficiency. In short, it became obvious that for the first time in its collective history, CWCES must re-assess Product Development through the prism of Lean Manufacturing.

In response, CWCES formally expanded the Continuous Improvement program to include an element called "Engineering Excellence" (EE). The original goal of EE was to ensure "Technology and Engineering" received the same management attention as Lean Manufacturing and Supply Chain Management in an effort to improve the performance of product development programs. That being said, EE is in reality the application of LEAN/6 σ tools in the Product Development environment with tactical and strategic elements.

Tactically, EE targets improving the Product Development process and introduced various visual controls and metrics for schedule and cost control. Strategically, EE focuses on optimizing the overall

investment and infrastructure and maintaining a formal innovation program (Figure 1).

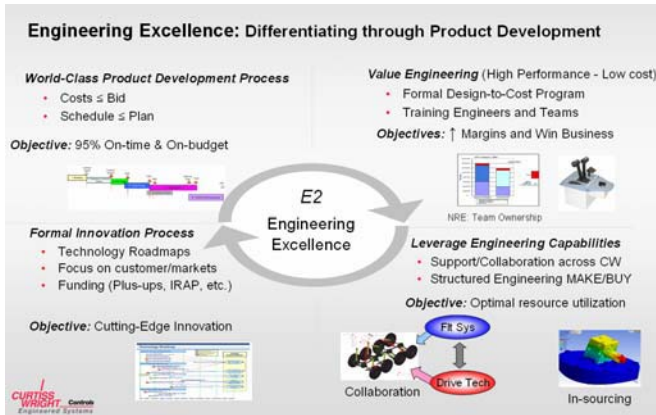


Figure 1: Engineering Excellence Process

It is important to realize that CWCES is a collection of businesses under \$100M in annual sales, competing against significantly larger companies through agility and “lean” (i.e. minimal) support structures. To preserve this strategic advantage, it was imperative that EE maintain a delicate balance between creating enough controls and structure to maximize efficiency in Product Development while still protecting the speed and flexibility that allow such organizations to thrive.

This paper describes the tactical implementation of EE in detail, focusing on the New Product Introduction process, Cost Mitigation methods, and the application of Lean tools in the Engineering Test Facility. This is followed by a brief summary of the strategic aspects of EE including the strategic optimization efforts and ends with a presentation of initial results and conclusions.

IMPLEMENTATION

CURRENT STATE - CWCES consists of four Engineering groups in three countries, each focused on a particular market and product line. While products and markets differ, the challenges regarding product development capacity were very similar.

An initial assessment conducted in the fall of 2005 demonstrated that Engineering and its related services accounted for approximately 20-25% of the total manpower and budgets across CWCES - an impressive statistic that understated total commitment to product development as it failed to capture non-Engineering support services. Despite this investment, the organization found itself essentially out of capacity in product development as it struggled to absorb as many as 17 new programs in a single business unit.

Given the strategic nature of product development and the obvious bottleneck in design, the assessment highlighted a number of critical issues to be addressed:

- No formal efforts were in place to measure or improve efficiency and utilization.
- Processes linking Engineering to the overall Value Stream were inadequate. (particularly Business Development and Operations)
- Visual metrics were non-existent in the product development discipline
- No formal integration plan existed to link the 4 Engineering groups.

FUTURE STATE - A multi-disciplined team was asked to identify opportunities to improve the performance, capability, and capacity of the various Engineering elements throughout the company. While this goal is painfully broad, the approach taken was based on an excerpt from Lean Thinking [2]:

“Just as activities that can’t be measured can’t be properly managed, ...activities necessary to create, order, and produce a specific product which can’t be precisely identified, analyzed, and linked together cannot be challenged, improved (or eliminated), and eventually perfected” (italics added)

In short, the key to improving any complex multi-functional system is to first understand the underlying value stream, improve the related activities where possible, then manage the execution with metrics.

For the team, this required an understanding of key processes and deliverables throughout the product development cycle as well as the creation and tracking of relevant metrics. With this approach in mind, the Engineering Excellence team provided a management vision that systematically addressed product development on four distinct fronts:

- i) **PROCESS** (for New Product Introduction) - focused on communications and metrics.
- ii) **COST** – aggressively track and eliminate waste in the same manner as operations.
- iii) **TOOLS** – apply proven Lean techniques in Engineering environments
- iv) **OPTIMIZATION** – strategically align the organization’s investment and IR&D to optimize the results gained through tactical process and cost control.

NEW PRODUCT INTRODUCTION (NPI)

As any Project Leader can attest, developing and delivering new products requires coordinated action from the entire organization. To accomplish this multi-disciplined feat “on-time and on-budget” in today’s

market demands a very robust process [3] for product development.

At the outset of this effort, existing processes driving NPI (mostly developed and documented in the early-mid '90's) were simply not capable of responding to current market demands. Primarily written more for compliance to ISO and D1-9000 and not guiding execution, documents focused on specific functional departments. This created dependence functional specialists within each department that understand and drive inter-departmental communications and cooperation. While feasible in very stable environments or extremely small organizations, this dependence on "tribal knowledge" is clearly untenable in larger groups due to countless inefficiencies that arise.

In fact, many employees supporting product development found themselves on teams with no clear "common language" which resulted in a nightmare for communication. To illustrate this point, one 6-man team realized that not a single person had been in their current job function for more than 18-months (with four having recently arrived from other companies)! In the absence of a clear NPI process, it was unreasonable to expect this team to have a uniform understanding of deliverables, roles and responsibilities, or metrics. Additionally, many supporting team members (Finance, Manufacturing, Procurement, etc.) participate on multiple teams and found themselves confused by the variation in critical tools such as schedules and budgets.

It is worth noting that while all four engineering departments faced this same issue, there were two distinct paths to this current state. Two businesses operate in defense-related markets and outsource manufacturing (retaining only Assembly and Test). While these contained well-established product development functions, they were based on the traditional (and cumbersome) MIL-STD mindset. The other two businesses operate in military and commercial aerospace and have traditionally focused on Operations and Manufacturing. Both were re-defining their business models resulting in significant growth for product development.

Initially, the well-established business units approached the problem with a focus on execution and schedule – convinced that since existing processes were sound and people trained, the problem MUST be in the execution. Conversely, the growing departments identified the absence of clear processes as the highest priority and therefore focused on the process elements. Interestingly enough, both approaches converged over time as it was realized that the key to successful product development is a combination of both schedule execution and process definition.

In fact, it became apparent that everyone must understand that Product Development is NOT the engineering function department. Fundamentally, it is

what companies providing engineering solutions do – and it involves every aspect of the business from Business Development through Repair and Overhaul and it is therefore imperative that everyone throughout the organization have the same mental map representing the design cycle. Moreover, as with any other process, repeatability is a key to successful product development as is shown in the Capability Maturity Model Integration (CMMI) (see Figure 2).

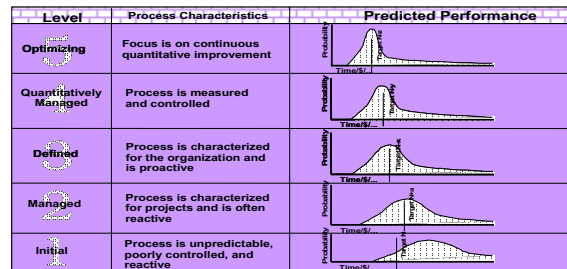


Figure 2: CMMI Levels Reflect Process Control

CWCES decided to refer to the overall design cycle (from market pursuit through the transition into production) as the New Product Introduction (NPI) process and set out to create a multi-functional system to support this mission. To achieve the overall visibility and improvements described in Lean Thinking, a number of tools were utilized including process mapping, standardized work, visual controls, and management metrics.

NOTE: This summary focuses on the process mapping conducted by the CWCES Flight Systems located in North Carolina. A parallel effort was conducted by the CWCES Drive Technologies group in Neuhausen, Switzerland utilizing outside resources [see acknowledgements] resulting in very similar results.

PROCESS MAPPING - Numerous NPI processes have been documented and a thorough literature survey was conducted, starting with internal processes, customer processes (e.g. GE, Boeing, Lockheed), and those of peer companies (e.g. CWC Embedded Computing).

Once these best practices were identified, small teams from the traditional process owners (Program Management and Project Engineering) created an outline of key process milestones and a flow chart of current state actions (Figure 3 demonstrates linear nature of original processes).

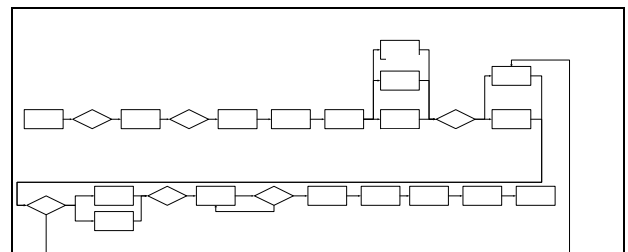


Figure 3: Linear Flow Chart of Current State

This exercise, demonstrated that few people understood the overall process and even this group expressed divergent opinions on functional responsibilities and ownership. As stated, this condition resulted from existing documentation being functional in nature (i.e. department specific) and did not follow the overall value stream. In fact, there were few instances of clearly defined inter-departmental transactions and/or mutually defined roles and responsibilities.

To address this condition, a cross-functional team conducted a process mapping exercise in two 2-day sessions to create a globally accepted NPI process. Working from a very high level down to specific execution, the goal was to define an overall process, key deliverables within each phase, and most importantly functional roles and responsibilities for each.

The 6-phase phase-gate process (Figure 4) was selected due to its commonality in aerospace. In this model, each phase is controlled by a semi-formal gate in the form of a design review (typically customer driven) and a final seventh gate added to capture technical learning realized during the qualification testing.

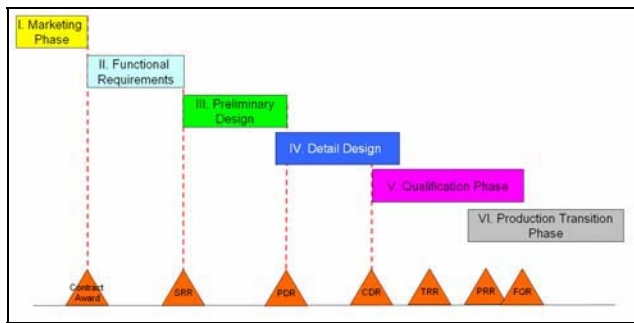


Figure 4: Phase Gate Process

The team then systematically stepped through the process using the literature survey and lessons-learned to define the goal of each phase, key elements, specific actions, and deliverables and assigning each to the functional owner.

To accomplish this, the team utilized a standard process mapping technique in which the targeted process is first described at the highest level with 3-5 note cards taped to the wall. Then systematically, each of these sub-processes are described using 3-5 note cards – followed by each of those cards being described in finer detail until the lowest card contains a very specific work element or deliverable. In most cases, the NPI Team went 2-4 levels down the process map – but from the outset separated each element into “swim-lanes” for the responsible functional department.

Figure 5 shows the final output from these mapping events where the six columns represent phases, the nine rows represent functional areas, and the colored note cards indicate different elements of the process.

As mentioned, a very similar exercise was conducted in parallel by the Swiss facility with astonishingly similar results. The key differences revolved around the divergent business models and of course the language barrier. While certainly interesting, the details of the resulting NPI processes are outside the scope of this paper which is focused on the tools used to improve Engineering efficiencies.



Figure 5: Criteria by Phase (col) and Function (rows)

PROCESS CONTROL - Once the NPI activities and deliverables were identified and linked together, a method of analyzing and controlling this process was required. Once established, these control mechanisms could be used to understand and improve the overall efficiency.

Four tools were developed and introduced, each providing a specific element of control: Pipeline Charts, Dashboards, Checklists, and various Standard Work packages.

Pipeline Charts – A fundamental principle in Lean Manufacturing is to always maintain a simple method for visually presenting WIP within a factory. When attempting to coordinate concurrent development programs through various disciplines, it is imperative that the entire organization easily understand the current status of “WIP” (or on-going programs) – including a measure of their relative size and location in the NPI process.

While this seems trivial, it is impossible to underestimate the importance of having a universal understanding of what programs exist and where they are in the pipeline. In the absence of such an understanding, it is difficult to maintain a “level playing field” regarding prioritization - so when resource conflicts arise, the outcome is based more on the persuasive power of the Program Manager than the real impact on the organization. As organizations become dependent on matrix-based cross-functional Integrated Product Development (IPD) teams, such prioritization is critical to success.