Implementation of Lean Processes at a High-Mix Low-Volume Aerospace Manufacturing Facility in France

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Submitted to the Sloan School of Management
and to the Department of Electrical Engineering and Computer Science
in partial fulfillment of the requirements for the degrees of

Masters in Business Administration
and
Master of Science in Electrical Engineering and Computer Science
in conjunction with the
Leaders for Manufacturing Program
at the
Massachusetts Institute of Technology
June, 2004

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ABSTRACT

The theories of the Toyota Production System have been operational touchstones now for over twenty years in North America and Western Europe. In spite of this many companies, particularly those in high-mix low-volume manufacturing, continue to struggle with their implementation. The goal of this thesis is to openly examine the fit of the Lean tradition with the realities of complex high-mix low-volume processes and pave the way for improvements.

This thesis explores the implementation of Lean processes at Jodd-Thonson's aerospace manufacturing facility, Daugy-Naudier, in France. The work is divided into two parts:

1. Implementation of Lean manufacturing principles in the Actuator assembly and machining department and benchmarking of challenges with other LFM Lean projects at other high-mix, low-volume manufacturers,
2. Implementation of a process to evaluate the cost and return on engineering changes as well as improvement to the change management process.

Through the analysis of case studies, this thesis questions the relevance of some widely accepted Lean tools in the context of complex high-mix low-volume environments. I develop a set of hypotheses about risk factors and solutions particular to high-mix-low-volume Lean implementations. The combination of strategic and tactical projects examined in this thesis shows that implementing Lean in high-mix low-volume is necessarily an enterprise-wide process. Its success depends on developing a Lean culture that can successfully leverage distributed, tacit knowledge about complex products and processes.

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Acknowledgements

I would not have succeeded in this project without the support of François Pommier, Francis Pezet, Michelle Bernson and Josh Binder.

I am also immensely grateful to the people in LFM and at Jodd-Thonson who have gave me the opportunity to learn so much about the world and about myself.

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Introduction

Economic Background

From June 2003 to December 2003 I undertook a research and consulting project at an aerospace parts manufacturing plant in the south of France, Daugy-Naudier. Daugy-Naudier is a 100 year old plant that was purchased in 1998 by Jodd-Thonson, which is itself a subsidiary of Multiplex Technologies.

Jodd-Thonson has made several strategic acquisitions and partnerships in Europe over the past 10 years in an effort to globalize their customer base and access skilled labor. In the wake of these acquisitions, the airline and airframe industry has been thrown into crisis by the events of September 11th, 2001 and supplier profit margins are under continual and unprecedented pressure. This has forced the high-mix, low-volume aerospace industry to reexamine how it produces and has accelerated the implementation of Lean production methods (and supporting 5S tools) developed in the 1970's by Japanese companies. The 5S tools: Sort, Straighten, Shine, Systemize and Sustain[1] have been widely applied in many types of production environments. The body of Lean theory, exemplified by the Toyota Production System[2] and canonized by Womack and Jones in "Lean Thinking"[3], was developed primarily in high-volume environments. It has proven challenging to transfer these Lean principles to such high-mix, low-volume industries as aerospace and this challenge has spawned the creation of the Lean Aerospace Initiative at MIT[4], as well as several Leaders for Manufacturing internships to tackle some of the challenges.

The situation in June 2003 at Daugy-Naudier was not exempt from these challenges. Jodd-Thonson had been making moves toward Lean and 5S in all of its American plants for several years and has more recently been encouraging its overseas plants to implement similar business processes and metrics.

Nature of the Work

Unlike many academic theses, this work is based on practical efforts to improve the profitability of a real business. As such, it has the disadvantage of being constrained by the real day-to-day needs and politics of a business: in many ways, I was limited in my ability to define the scope of the work, conduct experiments or implement complex or highly innovative solutions. This was particularly true given that my work was conducted in a department that was officially declared "in crisis" during my time there. On the other hand, such work provides a unique opportunity to understand in a practical way the areas where change was more or less possible given the nature of the work the company did and the political landscape in which the company and department operated. It also allows for an analysis of the ramifications of Lean transformation and the limits or failings of it. Where possible, I have sought to unearth some paths or patterns that may be generalized to other companies in similar industries.

I was also able to unearth some other less politically contentious and less risky areas where change could occur. I developed a method and tool to evaluate the cost of engineering change

[1] i-SixSigma webpage. http://www.isixsigma.com/dictionary/5S-486.htm Feb 26, 2004

[2] Kazuhiro Mishina, *Toyota Motor Manufacturing, U.S.A., Inc.*, Boston, MA: Harvard Business School Publishing, 1992.

[3] James P. Womack and Daniel T. Jones, *Lean Thinking*, New York: Simon & Schuster, 1996.

[4] Lean Aerospace Initiative webpage. http://Lean.mit.edu/ Feb 26, 2004.

orders which will save up to 500,000 Euros per year in obsolete parts alone, not to mention the benefit to the company of making better enterprise-level decisions about what engineering changes to make. In this thesis, I discuss both the evolution of an appropriate tool within the company's existing process and organizational structure, as well as the tool itself.

The result of all this is a thesis with fairly independent chapters that treat individual topics. As a whole, they present a comprehensive view of the challenges (and some solutions) facing a high-mix low-volume plant undergoing Lean transformation. It strikes me as important that some chapters deal with problems at the more strategic enterprise level, while others look at problems at the more detailed department or line level. The complexities and "particular cases" inherent in high-mix low-volume manufacturing have bedeviled many attempts to implement Lean tools blindly or by force. While the solutions and failures presented here may be particular to the situation, or at least to aerospace, the underlying need to understand Lean principles (not just tools), to ask questions and to make decisions at the level where the tacit knowledge lies is essential to the successful transformation of any complex process.

Organization of this Thesis

Chapter 1 looks at the scope of the project within the Actuator department as it was originally presented at the start of the project. It is useful to describe the original goals and planned activities in order to understand what was possible and what did not happen. This chapter also describes the original plan for my role as a participant within this project, how these activities evolved over time, and the thinking that led to this scope change. Chapter 2 describes the history of the plant and the organizational structure of the company, and may help explain the why and the how of many of the strategic level decisions that were made over the course of the project. It may also help the reader to understand how this particular case is relevant to other organizations. Chapter 3 delves into the first part of the project that was undertaken: Implementation of Lean Processes in the Actuator assembly area, followed by the limited implementation of Lean in the upstream Actuator Machining area (Chapter 4). The two chapters invert the actual production flow and reflect instead the order in which the problems were tackled—a crucial element in the limited success of this project. Chapter 5 takes a broader view of the problems of implementing Lean at Daugy-Naudier by examining qualitative data about other implementations in both high-mix and high-volume environments. These data points, gathered through extensive interviews with LFM colleagues, were not intended to permit statistically significant conclusions, but rather to develop hypotheses about best practices based on accounts of individuals with first-hand experience at implementing Lean in a project setting. Chapter 6 moves back up to the enterprise level and looks at the development of an Engineering Change management process including cost-benefit analysis and implementation tools. The chapter describes how the new process was iterated, validated and integrated within the existing business processes. Chapter 7 looks at the cultural impact of the project which was a significant deliverable from the point of view of Jodd-Thonson, but not at all within the scope of the original Daugy-Naudier project definition. It also describes relative to Chapter 2 why the success of Lean tools is both process-dependent and organization-dependent: developing Lean processes in a complex, high-mix low-volume product environment is strongly dependent on distributed tacit knowledge. This means that success is contingent on working in teams that bring the knowledge holders together for open communication. Evolving toward this operational model is one of the greatest changes facing Daugy-Naudier, with its hierarchical organization and tremendously skilled workforce. Chapter 8 concludes by looking at the common thread within the earlier chapters: the dynamics of change in complex environments. Organizations need to understand and address these dynamics in the change planning process if they are to continue making good decisions as the projects progress and new challenges emerge.

1. Problem Definition and Scope of the Project

1.1. Actuation Cells 3X Initiative

The original project definition is described in a document entitled "Design Review, Actuation Cells, Supporting 3X Initiative"[5]. The document describes a "core/ non-core" strategy that involves the outsourcing of parts that could be made by other lower-cost suppliers. The rationale behind this is to consolidate the department around the more technically complex and profitable products, thereby reducing product variability, improving profit margins and freeing up capacity. Free capacity can lead to greater profitability either by allowing the company to take on more contracts on high-margin items, or by allowing the company to respond to demand fluctuations just in time without holding inventory or buffers. It was estimated that nearly 40% of the machining would be outsourced, while all of the assembly would be kept in house.

The reduction in machined parts was also driven by a rationalization around product families according to the model described by Kevin Duggan in his book "Mixed Model Value Streams"[6]. The central thesis of this book is that products can be organized into families that undergo essentially the same sequence of processes. By organizing each family onto a line of dedicated machines organized in the sequence of operations, production can be planned more easily, "process loops" are avoided and no machines are shared. This allows for easy identification of bottlenecks, easy control of work in process (WIP) and easy prediction of when to launch parts given a required delivery date or a kanban system. Each family of parts can "flow" along the line unimpeded by the arrival of other parts. (On the other hand in many manufacturing systems with shared resources, a machine could be idle for 3 days and then in the space of 1 day 3 lots could arrive that require machining. The third lot would then have to wait to be processed, despite the fact that the machine was idle for a significant amount of the preceding days.)

The great challenge of all this is freeing up or duplicating capacity. When capacity comes only in large increments, enabling flow may result in extra capacity and the machines (and even occasionally the operators) may sit idle, particularly in periods of lower demand. In the 1970's and 80's, in North America and Europe, one of the great indicators of plant performance was machine utilization. This is particularly important in high CAPEX industries such as chemicals and oil refining, but it was widely used in almost all plants including those with heavy machinery. Machine utilization has been strongly ingrained into most work cultures, but it flies in the face of the idea of flow because in an environment with variable process times flow necessarily means that some machines will wait. If they were to work all the time, they would build up inventory, which is exactly the cost that flow attempts to drive down or out.

To recap then—the project plan was to create two lines in the machining area: one that makes the large nuts for the actuators, and the other that makes the screws. These nuts and screws can be anywhere from 3 inches long or wide, to about 2 meters long in the case of the new Airbus A380 screw. They are made out of different materials, but they undergo a roughly similar sequence of processes with some pieces skipping some of the steps. The

[5] Jerome Bastard, Nicolas Duret et al., *Design Review Actuation Cells—Supporting 3X Initiative,* May 2003.

[6] Kevin Duggan, Jefferey Liker, *Creating Mixed Model Value Streams: Practical Techniques for Building to Demand*, Productivity Press, 2003.

parts were to come out of machining into a buffer and then be picked up from that buffer by assembly. Assembly originally had non dedicated benches and shared tools and received its parts in kits from a stores rotating warehouse. The 3X project involved organizing the area around lines dedicated to a certain assembly or group of very similar assemblies with all of the parts and tools required present at point of use.

Also planned was a reduction in lot sizes across the board, though the details of this, the impact on total setup times and capacity utilization was not detailed in the original document. There was a plan to reduce setup times through SMED, but the resources available to do this were not defined. Likewise, one of the stated objectives was to improve quality, but there was not a clear plan about how to do this in the document.

The goals of the project were:

- Reduce manufacturing cycle time by 60%
- Reduce Inventory by 55%
- Increase inventory turns from 2 to 4
- Improve productivity by 10%
- Reduce non-valued added work by 15%

These project goals were defined by doing value stream maps of a handful of the higher volume products, eyeballing possible savings and generalizing the results to all product lines in the department. The method is a common, but unscientific one that can fail when there is variability or interaction between product lines and the assumptions made in the initial analysis do not hold true for the entire production system.

Interestingly, some risk factors were identified on one page of the original project plan. Unfortunately, there was no plan to manage them, and all of them materialized. They were:

- Delayed deliveries of purchased equipment
- Non core parts outsourcing schedule
- Insufficient engineering resources available to carry through material evaluations, process changes, etc
- Cell operations presume significant levels of employee empowerment.

1.2. Internship Project Original Scope

Within the overall 3X project, there were goals established for my role within it at the time that I arrived.

1.2.1. Assembly area

The first part of the project that I undertook (originally scheduled from June to September) was the implementation of Lean principles in the Actuator assembly area. When I arrived, the workbenches had been moved to their new location but virtually all of the parts were still in stores, there were no racks for point of use parts or tools and parts still arrived in kits to make batches of assemblies. It is also worth noting that at the start of the project only 40% of parts were arriving on time from the upstream machining process. Given that the assemblies had between 30 and 100 parts, this meant that many assemblies were completed within the last two days of the delivery month and nearly all of the others were delivered late. The result of this was that the assembly area was fairly quiet during the early part of the month and engaged in a large amount of non-value added activity: assembling actuators without the missing parts to make sure the rest of the parts fit well and then taking them back apart to add the missing bits at the last minute.

My work in assembly was to manage the implementation plan for point of use parts, but also to build on some Value Stream Maps (VSMs) that had been done in the planning stages of the project. These VSMs had indicated that there was significant non-value added activity in assembly. In order to hone in on some of these sources of waste, it was foreseen that I would undertake a Routing by Walking Around (RBWA) analysis. RBWA consists in watching and detailing process steps and times in written form to identify the sources of waste and develop ways to reduce the most costly ones.

There was also a plan to implement pull production with Kanbans that were controlled by a new software system called SFT. My third task in the assembly area was to work on the business processes and practices that would mesh with SFT and to act as a liaison between the shop floor and the IT and Logistics people implementing the software. The nature of this task was not well understood at the start of the project as the software itself was quite new (only its second implementation ever) and it had not yet been implemented in any other departments at Daugy-Naudier. The actuator department was eventually the second department to implement the software, but the products and processes within the actuator group were very different from those of the first department that implemented it, so there were many unforeseen problems during the actuator implementation.

1.2.2. Machining Area

The machining area was the second major part of the project. During the June to August period, there was a planning phase and a machine relocation phase that culminated in the installation of a new air-conditioning system at the end of August, just before the machines were turned back on. The new air-conditioning system was necessary for the machines to operate at a constant temperature given the tight tolerances on the machined metal parts.

My participation was scheduled for the September to December timeframe, once the machines were in their new configurations of one cell (or line) for nuts and one cell (or line) for screws. Within this new configuration I was responsible for the developing a set of process rules and operating guidelines that would address material release, WIP levels, integration with the SFT software, physical and visual management WIP and decisions about lot sizes. In particular, there was a plan to reduce the lot size after heat treatment which was the major remaining shared resource. Heat treat was a separate department and an overall bottleneck within the plant. It occurred about halfway through the machining process, twice on some types of parts.

1.2.3. Indicators

"You make what you measure" is a truism of manufacturing. Earlier in this chapter, I discussed the culture of capacity utilization where people get worried if the machine isn't running. Changing the work processes and work rules to a Lean manufacturing culture requires the revisiting of performance indicators and this was part of the Actuator 3X project plan. Part of my original scope was to go over the indicators, think about how they were calculated and make sure that the things we were measuring were driving the performance that we wanted. The primary guideline for this was the implementation of the "Thonson Six-Pack of Metrics"[7] which was instituted company-wide to motivate Lean performance.

[7] Jodd-Thonson, *Jodd-Thonson 6-Pack of Metrics*, France edition, 2001.

1.3. Evolution of the Scope

While later chapters will address the detail of how the project unfolded with a view to describing some of the generalizable problems and solutions, it seems important to describe the evolution of the project scope so that the reader can understand some of the overall enterprise dynamics that affected decisions about where to inject resources.

1.3.1. Assembly area

The assembly part of the project unfolded the closest to the original project plan with regard to steps, but took much longer than expected: material such as shelves, bins, labels, tools and workbenches was consistently delivered late and even the original expectations of delivery dates were startlingly long by North American standards. The problem was exacerbated by an internal purchasing process that was undergoing transformation, resulting in such anomalies as a 4 week approval process for a 6 Euro purchase of stickers.

1.3.2. Machining Area

Perhaps the most significant of the risks that materialized was that non-core parts were not outsourced. Outsourcing these parts was instrumental to streamlining operations around product families, to creating pull and eventually flow within machining, and most critically—to determining within a complex production environment the necessary resources and schedule to meet a downstream delivery date. Only a few parts were successfully outsourced due to lack of qualified suppliers. The problem was exacerbated by resource constraints within the supply chain organization that further limited that organization's ability to transfer knowledge and approve suppliers. Where there were attempts to outsource or rationalize the supplier base, the new parts frequently did not pass the First Article Inspection (FAI) resulting in numerous shortages. Furthermore, at Daugy-Naudier, orders did not decrease in 2003 as anticipated, leading to qualified labor shortages which limited the department's ability to inspect and respond to out of spec parts.

This had two results. The first was the impossibility of implementing visual indicators or effective scheduling because of the mix of parts. The second was an increase in delays due to lack of capacity, expediting of orders, process variability and increased rework to the point where the department declared a "State of Crisis" in October.

The situation was clearly worsening throughout the summer, with up to 23 days of WIP sitting in front of some machines. Figure 1 shows the number of hours of WIP in front of 3 machines every week during the spring of 2003:

WEEKS	1	2	3	4	5	6	7	8	9	10	11	12
Machine 1	273	294	215	230	216	250	270	318	423	442	410	384
Machine 2		497		405	408	360	502	497	394		420	514
Machine 3	164	139	144	147	103	137	199	366		146	183	302

Figure 1. Hours of WIP in front of 3 machines at the start of each week. Spring 2003. (Gaps in chart are where data were not available).

Because of the number of parts and the number and complexity of the process steps, it was virtually impossible to plan production or optimize lot sizes (to balance capacity and speed) either manually or analytically. Without outsourcing non-core parts, the universe of parts and processes were too variable to simplify into meaningful groups. This led me to push for resources to model the process as a dynamic simulation. The thinking was that a dynamic simulation of process steps and WIP, while complicated to build, would provide better estimates of completion times than the guesswork that was currently being used. The current manual scheduling only allowed for visibility 2-3 days out at most. SAP and SFT, the old and new scheduling systems, were completely overwhelmed by current supplier transitions, quality problems and expediting and so were no longer dependable for planning production.

The dynamic simulation had the advantage that it could provide useful information and visibility into the future state, but it still left decisions in the hands of people in the department. This was critical to a successful system, given the impending crisis: there was enough fear that it was difficult to implement any drastic or dramatic solution such as Conwip, completely visual production management, or delaying release of material onto the shop floor.

Ultimately, the resources agreed to were not allocated to the simulation and so that part of the project was not completed. The push toward dynamic simulation did however have the effect of alerting the organization at a high level to the lack of an effective production planning system.

1.3.3. Indicators

The development of indicators and metrics was essentially removed from the scope of my project because developing new metrics is ultimately a political and strategic process that required decisions at a more senior level in the organization.

One of the ways in which indicators resurfaced however, was in trying to change the organizational culture. Indicators can have two roles: the first is to discern problems and manage by making data driven decisions. This is the objective of the 6-Pack Jodd-Thonson metrics[8]. It is also the objective that was best understood at Daugy-Naudier. The second role that metrics can play is to motivate desired behavior. It is linked to the first but it may require a rethinking of how metrics are applied at different levels of the organization. People will only be motivated to work to a metric that is within their control. If they can not affect the achievement of the goal, they become intensely frustrated or stop caring.

Here is an example of the difference between the "problem identification goal" and the "motivation goal": if you want to understand how your preventive maintenance program is working, or where you should invest in new machines—a line manager or department manager might want to measure the number of out of spec parts produced by each machine. On the other hand, if you are cross-training workers and you want to motivate them to ask each other for help and make sure they are building in quality within their cells, they might want to measure out of spec parts produced by cell in each shift.

[8] Jodd-Thonson. *Jodd-Thonson Six-Pack of Metrics,* France edition, 2001.

1.3.4 Engineering Changes Project

As it became clear that it would be difficult to have an impact on the crisis situation evolving in machining, I searched for a project that would provide a significant impact that could be tackled in the last two months of my tenure.

The implementation of point of use parts brought to light the stocks of obsolete parts. Investigating the causes of these inventories led me to realize that there was no enterprise-level mechanism to evaluate the cost or profitability of engineering changes at Daugy-Naudier. The problem had the advantage of being significant, costly and not yet highly politicized so I decided to take it on it. A detailed analysis is provided in Chapter 6.

In summary, the project scope evolved significantly over the course of the internship in response to other elements in the project implementation, new information and materialization of early-identified risk factors. In particular, the cultural and political landscape within the company affected which problems an outsider could tackle in a six month period and caused me to significantly re-think the ways in which I could add the most value. The next chapter describes some of the economic, political and cultural dynamics at play at Daugy-Naudier. These are important to understanding some of the challenges and decisions described in the later chapters.

2. Cultural and Economic Context of the Project

This chapter takes a step back from the specific deliverables of the project to look at some of the economic and cultural drivers that shape decisions at Daugy-Naudier. On the economic side, the plant benefits from a rooted, stable and educated workforce. While it has traditionally positioned itself as a leader in technical excellence, shifting dynamics in the airframe industry, shrinking margins and competition from Eastern Europe are forcing Daugy-Naudier to improve production efficiency. On the cultural side, Daugy-Naudier has to contend with strong functional silos that limit accountability and problem-solving across departments. Production has little ability to affect its operational framework which perpetuates the firefighting mode of operations. On the other hand, the plant benefits from a strong, mainly positive relationship with the unions—this is particularly true of relationships between middle management and the union. On the whole, the organization has been shaken by the rapid pace of recent changes. The perceived disempowerment of some employees and departments has created morale challenges that must be addressed if improvement is to continue.

The chapter provides some specific examples but seeks primarily to provide a context for the description of specific issues later in the thesis. As a whole, the chapter will help the reader to understand some of the particular challenges of implementing Lean operating principles within this type of environment.

2.1. Economic Context

2.1.1. The Plant and the Region

Daugy-Naudier is located in the south of France in the Midi-Pyrenees region. The plant was founded 100 years ago and initially made wings and propellers for early wooden airplanes. Over the course of its history, it has made automobiles, bicycles, motorcycles, helicopter and airplane parts. It currently has 6 departments, 5 of which specialize in machined and assembled subsystems for aircraft and 1 heat treatment department that is a shared resource for the other 5.

The plant has a long history of making high-quality, high-margin products and prides itself on its research and engineering departments, with research leading the band. There is a strong emphasis on delivering high-quality parts, setting and meeting tight specifications, that exceed the regulatory constraints of the airframe industry. This concern for delivering quality and achieving technical excellence is present at every level of the company including operators. Technical and performance challenges are taken on, sometimes even at the expense of manufacturability, an attitude which may contribute to high levels of scrap and rework. Most people seem to accept these performance/ manufacturability tradeoffs. The costs associated with these tradeoffs most often show up within the P&L of the 5 production departments, but what Research says, goes.

The plant employs about 1000 people, a level that has been steady for the past 20 years. It is located just outside a small town of 10,000 people, with the nearest large city about 2 hours away. The area has many small towns 10 to 15 kilometers apart that provide the workforce for the plant, which is the major economic driver in the area, along with tourism and small scale agriculture. The people who work at the plant are very attached to the region: most families have lived there for generations and most employees are descendants of people who have worked at the plant. Few people venture out of the south of France for vacations, and most are convinced that they would not live any place else. There is a strong attachment to the land that has enabled the lengthy coexistence of industrialization and agriculture: until the late 1970's, most people worked half a day at the plant and half the day on their subsistence farms.

This attachment to the region results in strong community and family ties that affect working relationships within the plant. There is an initial mistrust of almost all newcomers and foreigners; in fact it is not uncommon to hear people vocally disapprove of foreigners. The attachment to the region means that many people have stayed even as real salaries have decreased over the past two decades and the cost of living has gone up significantly with the advent of the Euro.

2.1.2. Macroeconomic Landscape

The airline and airframe industries have suffered a massive downturn since September 11th, 2001, with margins decreasing in both industries, thousands of airplanes being mothballed in the Arizona desert, and the emergence of new low cost carriers and producers of small planes such as Embraer[9]. This has created an interesting situation for aerospace parts manufacturers such as Daugy-Naudier, who benefit from a diverse customer base. When the major airlines began to mothball planes, many parts manufacturers allowed their workforces to reduce by attrition and planned to scale down operations over the next few years. However, the new low-cost airlines have helped maintain orders for new planes, especially in the mid-size and regional jet categories[10]. Oddly, while demand has stayed stable and supply has tightened, margins have become tighter than ever—largely due to the no-frills approach of the emergent airlines.

This has created labor shortages for plants like Daugy-Naudier, a particular challenge in high-skill industries where tacit knowledge transfer between operators and between engineers is slow. The impact on the workforce at Daugy-Naudier is described below in the section on labor, but there are other large-scale trade impacts. Many aerospace manufacturers have begun to look to Eastern Europe to outsource some of the high-skill work that used to be done in-house[11]. While this lengthens the supply chain it is a medium term antidote to rising production costs in the Euro Zone (and particularly in France, where many people believe that the 35 hour workweek has significantly reduced industrial competitiveness). In addition, purchasing from a lower cost region is a particularly advantageous solution if the purchaser's currency (the Euro) stays strong. Companies like Jodd-Thonson have already outsourced some production to Eastern European countries and it seems likely that they will continue to do so. One of the major challenges of this outsourcing is that even though the labor is tremendously skilled, machines in Eastern Europe are older and less technically sophisticated. There are some limitations in machining to very tight tolerances, but a great deal of expertise in machining complex shapes.

While outsourcing to Eastern Europe remains a choice, these production markets may well become competitors in the next few years, particularly as the Euro Zone extends, and tariffs and offsets are no longer a barrier. This coming competition is also a driver in companies like Daugy-Naudier investing in Lean production methods. The capabilities of the Eastern Europeans are already affecting decisions about core products, competencies and strategic investments.

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[9] J. Lynn Lunsford, *Trends (a special report): Aviation; Bigger Planes, Smaller Planes, Parked Planes,* in *The Wall Street Journal*, Feb 9, 2004.

[10] *Face Value: The Boeing Beater* in *The Economist*, Jan 17, 2004, p.58

[11] William Armbruster, *Heading East* in *The Journal of Commerce,* May 26, 2003. p.1

2.2. Cultural Context

2.2.1. Hierarchical Organization Structure

French organizational culture tends to be more hierarchical than in North America, and Daugy-Naudier is a particularly strong example of this. At one point in the summer it was possible to identify 6 levels of management between a line worker and the plant president (in a plant of 1000 people and 6 production departments). Artifacts of the formal and hierarchical culture include the prevalent use of "vous" the formal version of "you", instead of the less formal "tu" in most organizational relationships. Most people would only use "tu" with a very small number of their colleagues (3-8) and use "vous" with virtually everyone else, and almost always with their superiors. There is also widespread use of last names as in "Mr. Jones" rather than "Peter". Managers frequently do not sit next to the people that they manage and need to talk to all day in order to have the distance of a separate office.

This hierarchy can provoke problems in the decision making process. Decisions are frequently made at a high level and require enforcement at a high level. Coupled with this, people who have information about the decision are frequently not consulted in the decision or planning process. For example, the machining line managers were never consulted about the reorganization plan for the implementation of Lean manufacturing in the machining area. This has two consequences: reduced ownership of decisions which leads to limited sustainability of implementation and lack of continuous improvement, and perhaps more seriously, it can lead to bad decisions. Decisions made at a high level are difficult for line managers and engineers to implement on a day to day level, particularly when implementation requires interdepartmental cooperation. People with little ownership of the decision often do not do the work that is asked of them on the first or second request, resulting in delays and a great deal of senior management time spent on mundane administrative checking-up and firefighting.

While the organization has by all accounts been hierarchical and formal in its relations since time immemorial, most people report that management appears to "listen less" in the last few years. This may be due to the upheaval of being purchased by an overseas company and targets coming down from a non-local owner, or it may be a result of the constant change in the last few years which creates information overload for management and leads to a more controlling and less consultative management style.

Whatever the reason, this centralization of decision making has reduced staff and operator ownership of a difficult change process that very much requires their input in the design, sustenance and continuous improvement phases. A large part of my project time was spent opening these vertical channels of communication. I became one of a handful of people in the plant who could have an informal chat about goals and direction with both an operator and a VP. Another assembly department that implemented Lean a year ago has experienced a slide in its performance indicators in the months following the completion of the "project" phase. There is speculation that the department was not implicated in the change process in a way that would allow them to internalize decisions and foster continuous improvement.

2.2.2. Strong Functional Silos

Daugy-Naudier was a stand alone company for nearly 95 years before controlling ownership was purchased by Jodd-Thonson in 1998. As such, it has within it all of the functional elements of a company. None of the support functions (accounting, HR, IT) have been consolidated into the parent, perhaps out of a concern to remain close to the customer and keep the face of a European company, or perhaps because of the accounting and HR practice differences between Europe and North America.

Besides the above mentioned support functions, Daugy-Naudier has a full complement of design and production departments. There are 5 product departments which are supported by: heat treatment, engineering, research, purchasing and supply chain, sales, after-sales service, maintenance, outsourced maintenance, receiving and cleaning. The last three of these are outsourced, resulting in tensions about who is responsible for which activities and how quickly they need to be done. There do not seem to be effective dispute resolution or arbitration mechanisms for solving these disagreements.

There are strong divides within the internal service departments as well. For example, in an enterprise culture that values technical excellence and innovation, Research holds pride of place, with larger desks and more space per person to work. During a recent move, all of the relocated research employees got new desks, ergonomic chairs and storage units, while the production department offices, relocated right next to them, have desks that are literally falling down and mismatched chairs with the stuffing falling out in their meeting room.

In general, Production has little input into the decisions that ultimately affect it. This despite the fact that all of the costs of errors accrue at the level of the production department. There seems to be no retribution on any other department for errors of judgment or execution, and little opportunity for production to negotiate or discuss implementation plans for projects or production targets. Production department managers are then held accountable for achieving multiple outside objectives. For example, the actuator department manager was not involved in the detailed planning about how all of the machinery moves would take place, not was there any visible discussion of how the reconfiguration of the machines might affect the production schedules. Line managers were not at all involved in this process. In fact the bulk of the project plan was put together by engineering, who even during the implementation phase, had a relatively limited presence on the shop floor. The only member of the production department who actively participated in the project planning and execution is a relatively junior engineer with no direct responsibility for achieving day to day production targets and limited ability to argue against unrealistic objectives. When the department implemented the "crisis plan" in early October, the impetus—and all of the responsibility for the problem—was squarely on the shoulders of the department manager, despite the fact that much of the disruption had come from the limited implementation of the project and the materialized risk factors. As far as I was able to tell, there were no repercussions on the head project planner, the project manager, or the directors that had approved it. In fact, in November, the project manager moved on to the next project with no clear post-mortem on the first.

This anecdote is only one example of the relationships between the service departments and production. In another case, a new software system was implemented with no consultation of production department heads. The limitations and bugs in this software system also fed into the crisis situation that was eventually owned by the department manager. The department manager was never consulted in the preparation of the 2004 budget, and the production expectations that were used did not reflect either actual known sales orders, or expected backlog.

Another example is that when maintenance was asked to "go Lean" they dramatically reduced their inventories. However, whenever they were missing a part, they would come and take it from the production department—often not even registering the consumption of the part in SAP. This exacerbated shortages in the production department and caused several days of inventory counting over the course of two months, but it is unclear that there were ever consequences for maintenance—other than being repeatedly asked not to do it.

When I noticed at one point that we had large overstocks in a number of parts, I looked for someone in supply chain or purchasing that would be interested in the data points as a basis for a root cause analysis. It was unclear whether the overstocks were caused by a bug in our ordering system, a faulty parameter, or just over-delivery on the part of the suppliers. I had to call five people in accounting before I could find someone who would accept delivery of periodic emails about the problem. Even so, this person never responded to any of my emails, and as far as I am aware, no action was ever taken. This happened despite an imperative on the supply chain organization to reduce parts inventories.

The accounting system, with the production departments as the primary cost center, is not unusual in itself, but there was limited communication between departments and limited accountability for mistakes made by the service departments. This tends to exacerbate tensions and further decrease communication between departments. People stopped raising problems because they felt that their documentation of the problem would never be used. It was not infrequent to suggest communication with another department to resolve a joint problem and to get the response "oh, I've already tried that and they never listen." This lack of accountability outside production tends to leave problems at the "production firefighting" level rather than fundamentally resolving the problem in a cooperative and conclusive way with all of the stakeholders.

There are some positive trends despite these divisions. On new projects, the plant is implementing a project organization that cuts across functional silos and creates goals on a project basis. This new organization will be phased in over the course of the next few projects and should significantly improve relationships and informal channels of communication between departments. One of the most powerful things that senior management could do to support this new structure is to openly celebrate the achievements of teams and reward the teams for achieving joint goals.

2.2.3. Labor Environment

Unions are strong in France, but their structure is different from that in North America. Several unions represent workers at the plant, and individuals can chose which to belong to or chose to belong to none. Most union lobbying during this project was directed at government policies such as the reduction of the retirement age and number of years worked to be eligible for pensions. The union also had a strong push to reduce the plant's reliance on temporary workers and to increase the number of "Contrats a Duree Indeterminee" or CDIs—which translates into Contracts of Indeterminate length. In France, an employee hired under CDI is very difficult and expensive to lay-off, and these contracts are still the norm and the expectation for workers. Though about 10% of the workforce is temporary, it is widely expected that they will be transferred to CDIs once the economic outlook improves.

Perhaps a more surprising union demand is the reduction of overtime work. Overtime has gone up two to threefold in the last two years as the government regulated workweek has gone to 35 hours and as the plant undergoes a series of transformations. Management has used overtime to manage the backlog rather than hiring on new permanent workers. The major issues with overtime are that it is frequently on Saturday mornings and disrupts the work-life balance in a culture where people value their leisure time more than in North America.[12] Also, overtime is paid at the regular rate until 100 hours of it have accrued, and only then is it paid at a time-and-a-half rate. This reduces the economic incentive that exists for overtime in North America. Finally, only 75% of overtime is paid out in the month that it is accrued and the rest is paid out at the end of the year. This remuneration structure may explain some of the unpopularity of overtime hours, which in turn reduces management's ability to use overtime to accommodate variations in demand.

The unions are represented by a "Comite General des Travailleurs" or CGT in their relations with management. The members of the CGT are elected by the members of the unions at the plant. The CGT hands out yellow pamphlets at the exit to the cafeteria every second or third day detailing their negotiations and meetings with management as well as their more general demands with respect to the government. There were several strikes over the course of this project, nearly all of them against government policies. The strikes lasted for only a few hours a day and were voluntary—not all employees struck, and relations remained friendly between those who did and those who didn't. Managers agreeably kept track of how many hours each person was out, and individuals were comfortable negotiating who would go out based on what work needed to be done. Part of the reason behind these cordial relations may be that even people at a fairly high level belong to unions, as do people in non-traditional (for North America) departments such as engineering and IT.

There is also a fairly strong Socialist culture in France which is reflected in the idea of the government enterprise being responsible for taking care of workers[13]. One of the ways in which this manifests is in subsidized lunches for all employees and management push for improved safety standards which are sometimes rejected by workers. (This is entirely opposite to the dynamic in North America where unions have been instrumental in improving safety. For example, despite consistent efforts over the course of the project, it was impossible to instill mandatory wearing of safety glasses in the machining and assembly areas of the actuator department. Another example is that some line managers would not wear safety shoes as a sign of their status.) The Socialist view of the enterprise tends to focus on its role as a job provider rather than on the changing market forces that create the need for plant competitiveness. Perhaps also because of the longevity of the plant, there is a sense that it will be around forever and the economic motivation behind management decisions is poorly understood.

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[12] "Some Americans may actually want to work more than 48 hours [a week], but surely no European would be so daft," Anna Diamantopoulou, European Commissioner for Employment and Social Affairs, cited in *The Economist*, Jan 10, 2004.
[13] Richard C. Morais, *Even the Chefs are Leaving France* in *Forbes, Nov 30, 1998*

One final impact of the union environment is that an unusually high percentage of the plant's employees are on a regulated 35 hour workweek. This includes individuals from engineering, IT, logistics, purchasing and research. With all of these people punching in and out at regular intervals, despite the magnitude of the problems facing their departments, the few managers who are not hourly end up with a substantial amount of work. Thus, in a culture that values leisure, there are large numbers of people who work 35 hours, and then a gap, and then another small lot that frequently work 60 hours. At the end of a 12 hour day, not too many of these 60-hour managers have much room for strategic thinking when the firefighting workload goes up.

2.2.4. Morale Challenges

The combination of a challenging economic climate, limited identification with overall company objectives (in favor of self or department preservation), and resentment about the decreasing ability of the plant to provide for its workers, have all taken a toll on morale. There is concern about the plant's direction among the operators, and a lack of understanding of the principles of Lean manufacturing. A common question is "why are so many people waiting during the week and then working on Saturdays?" While this may be an indicator that resource planning could be improved, it is also correlated with the excess capacity required to operate in a low-inventory environment that has the ability to respond to variable demand.

Among management, there is a sense of being overwhelmed by the transition and uncertainty that the plant can survive this phase, despite a powerful history of change and adaptability to market demand. In the near-crisis or crisis firefighting modes in which many production departments operate, it is difficult to find time to think strategically or to celebrate tactical successes. However, overall economic success will require a high proportion of the pieces to fall into place. There is still every reason to mark the achievement of intermediary objectives, given the challenge of change and the hard work and good will of the people implementing it.

When the plant achieved 5S "Bronze Certification"—a Jodd-Thonson benchmark of success—celebration within the departments was sporadic. Some line managers picked up the tab for a drink; in others the frustration of line managers with other problems led them to leave the event unmarked. The people responsible for 5S within the departments did not see it as their responsibility to celebrate, even though they saw it as their responsibility to make the changes and continuously improve to achieve the next level. In the actuator department, the celebration was delayed by nearly two weeks and eventually the department manger graciously stepped in and picked up the tab. It seems strange that if this was an objective that the company wanted to reward, that they did not mandate the celebration and officially pick up the tab.

This situation is improving, however. When the actuator assembly department Lean project was completed, there was a celebration with many senior managers and all of the hourly assembly operators. This was a great and well appreciated opportunity to thank people for their efforts and had a strong positive impact on the people in the department who have seen little in the way of concrete results of their efforts because of delays in the upstream production process.

The other side of improving morale—besides celebrating tactical successes—is in seeing results. The frequent lack of negotiation of objectives (or of how to reach them) can lead to lack of ownership of the objectives. This, coupled with a culture that does not reward risk taking and does not penalize “staying in the box” reduces the incentive and ability of individuals to take risks and make change. If people can have more ownership of challenging goals, and have open discussions with management about how to achieve them, if they can be encouraged to take risks and be rewarded for their success (and not just penalized for their failure) then there may be more room for organic growth at all levels within the organization. This is likely to be a slow process to change because it challenges all sorts of deep beliefs about how to run an organization and the roles of individuals within it, but Daugy-Naudier has many talented people within its ranks, and in order to achieve results and be a world leader, it will need to learn to exploit all of their potential and insight.

3. Lean Assembly Implementation

This chapter describes some of the challenges faced in the implementation of Lean in the actuator assembly area. It does not describe all of the actions that were taken or all of the problems that were faced, but rather treats the areas where some unusual or new solutions were implemented to manage the particularities of the environment. The challenges described were chosen for their potential applicability to other situations, and toward this end, they are described in detail. This chapter and the next are divided into three parts that reflect the three components of the enterprise architecture that work together to deliver value: the organizational architecture, the physical architecture of producing and moving goods and the informational architecture of managing and planning.

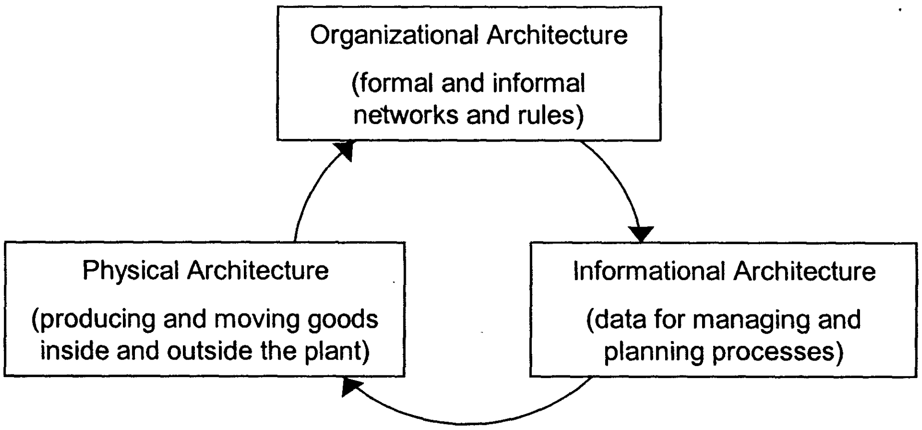

Figure 2: The Three Components of Enterprise Architecture that Deliver Value

The two chapters treat them in a different order, according to the dynamics of how these architectures affect each other.

3.1. Problems and Solutions Specific to High-Mix Low-Volume Lean Assembly

3.1.1. Point of use parts

One of the key elements of the Lean project as it was conceived for the assembly area was point of use parts. Previously, assemblies had been made in batches of three to twelve finished items, and the parts were kitted in advance for the assembly of subsystems or finished items. Completed subsystems were returned to stores and taken out again in kits for final assembly.

For reference, the assembly nomenclature in this section is as follows:
Parts + Parts → Subsystems
Subsystems + Subsystems + Parts → Assemblies

Because of subsystems were assembled by the same operators that did the overall assembly, and because there was still a great deal of variability (and lateness) in the arrival of parts from machining, it was necessary to have some variability in the order of the process steps. (Variability alone could have been managed with the buffers that were set up, but because of machining delays, some buffers were always empty.) This precluded a single piece flow line such as those used other assembly departments at Jodd-Thonson and Daugy-Naudier. While the objective remains to do assembly in single piece flow, current conditions in machining preclude having the operator follow the part along to several stations where parts are sequentially added to the assembly.

The resulting setup is that each line is made up of two to four assembly benches with a test bench in the middle. The parts for the subassemblies and assembly steps that take place before the test bench are located together near the "before" workbenches and the parts that are used after the test bench are located next to the "after" workbenches. Nonetheless, these assemblies can be large and often have over 75 parts resulting in space constraints to keep all parts in arms reach of the operator. Large parts are placed in plastic bins on shelves, with the heavier parts near the bottom to avoid back strain when storing or removing parts from the bins. Smaller parts are kept in drawers on wheelie-carts that can be moved closer to where the operator is working. Attempts were made to store parts that are used together on the same wheelie cart.

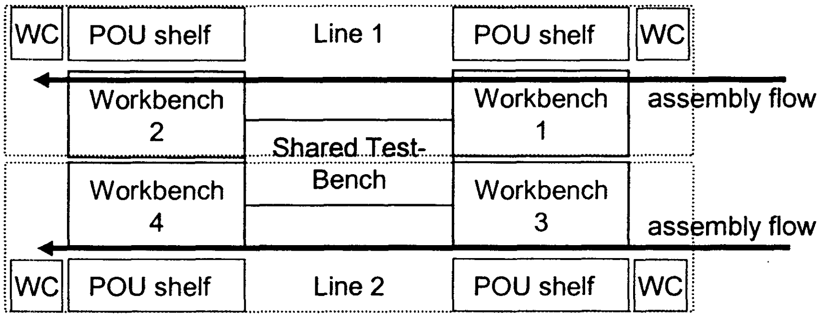

Fig.3. New Assembly Area Configuration. Workbenches 1 and 3 are "before" and 2 and 4 are "after" the shared test-bench. WC are the wheelie-carts, POU are the 4-shelf racks for larger parts and subsystems.

3.1.2. Visual markers

Nonetheless, this arrangement, constrained by part size, box size, drawer size and proximity means that parts that are used together are not always located right next to each other. One of the objectives of the layout was to allow for single piece flow, and the pulling out of parts is significantly slowed by the time that it takes to find the storage spot. Even for an experienced operator who makes 20 assemblies per month (on the highest volume line) finding all of the right parts straight away is no easy matter. For an operator who comes over from another line to assist at peak volume periods, the time wasted searching for parts is significant (15 to 20% of the assembly time).

A solution came to light while discussing the problem with some of the assembly workers: since all of the assemblies have similar types of subsystems, why not label the boxes and drawers with the subsystem that the part belongs to? We eventually settled on a system of colored dots that is used consistently across all of the ten lines. There are 5 colors of dots corresponding to each subsystem and the dots have the name of the subsystem written on them. By looking for the colored dots, an assembler can quickly locate parts and easily make sure that he has collected all of the parts necessary to the subsystem. This is much faster than checking the work instructions and the practice is transferable between all the benches, which is particularly useful in improving cross-functional capability.

3.1.3. Kanban inventory management

As mentioned, parts on the racks and in the wheelie carts are placed into boxes appropriate to the current kanban size. The shelves are deep enough to hold two boxes in depth and are open on both sides. Operators consume parts from the box on the bench side, and when a box is empty, they switch the boxes to bring the full one next to them. Boxes are filled on the "back" side of the rack by the stores person. This looks physically like an empty box/ full box kanban system, but it is not. While assemblers are constrained to stop producing when the boxes are empty, there is no constraint for machining (or suppliers) to stop producing when a box is full. The presence or absence of parts in the "front" box does not provide a signal to build. Sometimes, when delays are serious, the operator builds 'around' the missing part to make sure everything else fits and then disassembles later to add the missing part. Another reason that these boxes do not work well as a visual kanban system is that the size of the parts precludes setting the shelves at an angle so that operators can easily see into the boxes. The parts are too heavy for this kind of stocking on the shelves that were purchased. Consequently, it is difficult to tell at a glance what parts are out of stock.

Instead, kanbans are electronically managed by a software system called SFT that is described below. It is expected that over time, lot sizes will decrease. When this happens, the boxes will not be re-sized. Instead, lot sizes that are smaller than the boxes are bagged and sealed with a kanban card in the bag corresponding to the number of parts. When a bag is consumed, the card is dropped in a transparent 'mailbox'. Cards are collected once a day by the stores person, the bar code is scanned and the information about the consumed kanban lot enters the SFT system.

The use of bags is important given the size of the parts, the variability of part sizes and the expected reduction of kanban sizes. It is also important to completely seal the bags so that two kanbans can not be consumed at the same time. Open bags need to be clearly distinguishable from sealed ones—otherwise separate boxes do become necessary. One other rule that proves useful in managing the point of use parts is actually an exception to "stock at the back, consume at the front". If a shipment arrives from a supplier and is not an even multiple of the kanban size, the stores person makes as many even lots as she can. For the last (odd) lot, the number on the kanban card is manually changed to reflect the actual remaining parts, and the bag containing that lot is placed at the front of the front bin. This means that the software system does not have to be configured to deal with odd lot kanbans, and the error is quickly 'consumed', triggering another order just a little sooner (if the odd lot was smaller). Since receiving and supplier payment is done through SAP, the odd lot does not create a problem for supplier accounting and the problem is best solved manually. Changing the number on the Kanban card manually allows for accurate inventory counts by looking at the cards (without counting each part individually).

This solution is typical of many that were implemented. In any transition that involves software control of manual processes, there will be transition and integration challenges or even some debugging of the software that needs to take place. Often, it is better to find simple foolproof manual processes that yield good results, rather than trying to write a whole lot of exceptions into the code at once. The problems should be catalogued however, with a view to making better strategic decisions about how the software should work and devising elegant solutions to general problems rather than many small exceptions that can become bugs later.

3.1.4. Point of use tools

As in many enterprises, there was a fair bit of resistance among the hourly workers to point of use tooling. The primary reason for this is that when workers have dedicated tools, they can keep track of the tools, lock the toolbox when they are not around, and prevent tools from wandering off. In a point of use tool system, tools are necessarily shared. This means that tool drawers or boxes at point of use need to stay unlocked so that someone else can use them. This frequently leads to a higher incidence of missing tools because there is no accountability.

Daugy-Naudier was keen to go to point of use tools on the assembly lines. Facing resistance from the line workers, I benchmarked some of the practices of other aerospace, defense and electronics companies around point of use tools. The solutions implemented ranged from a team of people dedicated to checking and maintaining all the tool boxes and stocks of extra tools to replace the missing ones quickly, to a separate and sufficient budget for tool replacement and a streamlined ordering process to replace missing tools. Almost all of the people I spoke to informally while conducting this benchmarking concurred that tooling costs would be higher under a point of use system—at least initially until people had taken the tools that they wanted to take.

Unfortunately, accessing the tooling budget at Daugy-Naudier was complicated. There was a project budget for initial tooling purchases, but the ongoing tooling budgets were substantially reduced due to the number of temporary workers' salaries that were being paid out of the department 'consumables' budget (from which tools also come). As mentioned earlier, there were also substantial delays in the ordering process within the plant, and on the supplier end. At one point, an order of standard wrenches and screwdrivers took 6 weeks to get out of the factory and 4 more weeks to be delivered from the supplier. These delays exacerbate problems with the acceptance of point of use tooling and legitimate all of the worker concerns.

The most important conclusion from these problems is that in order to increase the acceptance of point of use tooling, it makes sense to have a good plan for how the missing tools will be replenished *before* point of use tooling is put in place. Among the people I talked to, all experienced 'tool shrinkage' after the transition. If the budget for duplicate tools (initially) and tool replacement (ongoing) can not be found, then it may be better to keep worker toolboxes. In the Daugy-Naudier case, this might have been a viable solution since workers use almost all of the same tools on each line. Purchasing all of the tools for each worker and then having the toolboxes on wheelie-carts would likely be cheaper and satisfy the objective of having all the right tools at hand. The nature and number of the tools does bear examining before implementing point of use tools just because the Lean books say so.

3.2. Problems and Solutions Specific to Implementing a Lean Culture

In a Lean organization, particularly one that makes complex products, people at all levels of the organization need to be part of decision processes and need to be empowered to continuously improve. In order to do this effectively, they need to have a deep understanding of both Lean principles and of the organization's goals.

3.2.1. Understanding and ownership of project goals

As mentioned in the section on Cultural Context, the Lean project was planned with little input from the production department, in particular the line managers and hourly workers. This means that project goals were not well understood at the start. There was an understanding that the project was designed to improve productivity and efficiency, but the changes—the tools of Lean—arrived unannounced. It was not infrequent for a mover's arrival to signal to someone that their work location would be moved that day. It also resulted in people seeing the tools of Lean, but not necessarily understanding the project goals or the methods and philosophies of Lean. This in turn made it difficult for people to evaluate the best way to implement given the technical complexities of their environment.

The budget for the project was decided without input from the people with technical production knowledge which limits the ability to target the points of greatest impact and understand some of the possible complexities of putting in place Lean tools. For example, one of the major complications to the parts management system was ball bearings. For a given product, the assembler chooses one among 5 possible sizes based on the size that will achieve the tightest tolerances with the machined track in which the bearings circulate. The variable size bearings are used to compensate for variability in the size of the track which is expensive to control tightly. The bearings are chosen after the track is machined and measured and as a result it is impossible to predict in advance the consumption of each of the 5 sizes. There are also complicated procedural constraints about how the beads are handled to avoid mixing sizes, or lots within an assembly. Finally, the beads are sometimes taken out and replaced with another size after the test bench, and are sometimes reused, sometimes not according to a set of conditions. All of this leads to a complex set of assembly rules, the results of which need to be accurately transmitted to SAP to ensure adequate, but not superfluous inventories.

This is just one example of the types of technical challenges that arose in reducing inventory, implementing kanbans and point of use. These were not foreseen in the planning stages of the project and ultimately required large group meetings to solve them. Initially, meetings were limited to 3-4 people in the interest of effectiveness, but the results were always overturned by the operational reality. It was only when the meetings were extended to 10 people, from hourly workers representing the two different types of bead use, to the assistant department manager, who understood the cost accounting, to one of the IT people who understood the limitations of the software accounting methods that a viable sustainable solution was found. The details of the solution are less important than the process by which it was reached. Big meetings can be longer and more unwieldy than small ones, but in reaching solutions about problems with diffuse tacit knowledge, they may be essential.

One of the other things illustrated by these implementation meetings (on ball bearings and other topics), is that the expertise required to solve the problem was often distributed through all levels and departments of the organization. As a result, a project plan with wider participation will likely be improved, and an implementation with even wider participation is equally important. This seems particularly true in high-mix low-volume environments that make complex products. There is so much information about the products that it is impossible to know it all, and generalizations from a small subset are usually not consistently applicable to the whole set of parts.

On the other hand, if there are going to be a whole lot of people present at some of the meetings, it becomes essential for all of them to understand the project goals and organization goals, as well as the philosophy that is being applied to achieve these goals. Open communication about goals and budgets is one of the best ways to make large meetings more effective. One of the major efforts that I undertook over the course of the assembly implementation was to talk at length with groups of one to three people about the company's goals and the project goals. These conversations were informal and took place whenever people were stopped for lack of parts, or when we were putting something in place and someone asked "why?" The hierarchy of the organization made it difficult to have open conversation in a meeting with 7 hourly workers and someone standing up at the front talking. It had too much the air of a classroom—in fact such meetings are called "formations"—a word which loosely translates into being taught or formed. On the other hand, informal conversations about macro-economics, non-value added activities, point of use, 5S, economic order quantity, and other such topics allowed people to ask questions.

Perhaps even more importantly, they allowed me to understand better how these concepts applied or needed to be altered to fit the specific working conditions. When people with technical knowledge ask questions about the tools, it becomes easier to see if the tools will really support the Lean principles or if there is a way to reach the goal that is better adapted to the environment. Many of these issues are treated more in-depth in Chapter 5. A culture of open communication through the hierarchy and across departments is essential to finding these types of solutions.

3.2.2. Continuous improvement

The other reason to communicate about project goals and budgets is that Lean does not end when the project ends. Continuous improvement and Kaizen are a big part of a Lean organization and depend on understanding of goals and establishing problem solving teams in pursuit of these goals. The notion of Kaizen is fundamentally one of grassroots problem solving, and this is a challenge to reconcile with a hierarchical organization. People undertaking Kaizen projects need to believe they will be heard. They also need to learn to communicate their conclusions effectively within the organization.

At the start of the project, there were two continuous improvement tools in place at Daugy-Naudier. The traditional tool, in place for a long time, was the keeping of dedicated notebooks to track problems. This had been done for quality and productivity in machining for several years and for quality and delivery problems in assembly. These notebooks were sometimes very useful in identifying trends and finding solutions at the department level. Some of the notebooks got lost however, and it was difficult to get public recognition of a problem if the notebook found its way into the wrong drawer. In short, the information in the notebooks is not always public or visible enough to effect change.

The other tool in place was a suggestion sheet called Cre-atier. The sheet was based on Jodd-Thonson's continuous improvement process sheet and had space to note the problem, possible solutions and to do a cost-benefit analysis. The sheets could have been submitted through the line managers or anonymously in mailboxes and were kept in a binder that was accessible to all. The major difficulty with the Cre-atier sheets is that there were not enough resources to process them. It was originally intended that Engineering would conduct the cost-benefit analysis, but this was not a priority for them, so many suggestions never got an answer. The person managing the sheets at the department level had little authority and too many other responsibilities to effectively push the sheets through the system. Finally, there was no clear decision making structure or criteria for the suggestions, which made it difficult to make a go ahead decision and allocate a budget to process improvement.

At the start of the project, there was disillusionment with the Cre-atier process. A frequent response when a better process emerged in a discussion was "oh, I already suggested that in Cre-atier and never got a response." It became clear that fostering a culture of continuous improvement would require first building trust, and second, developing advocacy tools for solutions.

One of the first things that I put in place was a whiteboard next to the assembly lines where people could communicate about problems and solutions. The whiteboard forced me, as a project implementer—and later people on the line who took on some of the improvements—to be publicly accountable for the progress of the improvements. I would go by every week or so and update the progress on addressing the changes. When they were achieved, I would leave the solution up for a week and then erase the line item. It would soon be replaced by a new one. Sometimes, I would go by the board and ask people to prioritize what was up there, or ask them how they thought we could tackle one of the problems. After a while, I started getting people to track the frequency of some of the problems so that we could put a cost on them. For example, the assemblers often had to wrap parts before they were shipped, even though this job was officially outsourced to the shipping and receiving subcontractor at the plant. The other organization was being paid to do the wrapping, and the time that the assemblers spent doing it showed up as slippage in the month-end indicators. On the other hand, leaving the parts sitting unwrapped was not an option: the wrapping needed to be done in a hurry because most parts were being shipped late. What we decided to do was track each instance of assemblers wrapping parts over the course of one month—including what part they had wrapped and the date that it had been done. We then measured the time that it took to wrap a part and calculated the per-month cost to the plant of the assemblers doing some of the wrapping. The numbers were then sent to purchasing who used them to re-negotiate the contract with the shipping and receiving organization. The entire tracking effort was led by one of the assemblers who originally raised the problem.

This sort of cultural change is slow. It takes tremendous initiative to follow up on things during the weeks or months that it can take to see results. It also takes time to coach someone else through the data gathering rather that doing it directly. But it also creates more sustainable results. In the same vein, many other problems depended on people communicating about the problem with other departments. As much as possible, I tried to set standards of responsiveness and then dis-intermediate these communications so that people on the line knew directly whom to call if they had an overstock of a certain type of part. Getting the responsiveness on the other end without escalating the problem remains a challenge (particularly given the strong functional silos) but it is the key to eliminating organizational waste. There is no point in having the same conversation three times, or involving five people in resolving an incident, where two people have all of the necessary information.

3.3. Problems and Solutions Specific to Managing IT in the Lean Transformation

As mentioned above, the implementation of Lean in the assembly area involved the implementation of kanban inventory management. This was coincident with several transitions in the supply chain organization including kanban ordering with some suppliers, the elimination of some suppliers and the introduction of some new sources. These transitions were accompanied by the implementation of SFT, an SAP plug-in designed by a small French consulting company, that was intended to enable kanban functionality to integrate with the many other business processes that were run off SAP.

The major challenges that arose around information management were threefold:

- first, many parameters such as lead times, inventory coverage and lot size were changed within the software resulting in some unintended shortages and delays,
- second, the SFT system had some bugs/ unknowns where it did not integrate with SAP as expected,
- third, there was poor predictability about customer delivery because of poor visibility into the upstream machining process.

The first two issues are treated here and the third is left to the chapter on the machining area where it is treated in greater depth.

3.3.1. Changing System Parameters to Get Lean

The supply chain organization, under an imperative to reduce inventory, changed many parameters in the ordering software and set new ones. Safety stock levels had historically been arbitrary in the SAP system. When some products were transferred to SFT, safety stocks were reduced to a time interval of consumption (based on the calculated demand during that time interval.) However, this safety stock level still did not take into account the high variability in delivery service levels from the suppliers. When I asked the Purchasing Manager about why we were not using the standard deviation as well to calculate an appropriate safety stock for the products that were still being managed in SAP, he told me that it was too complicated and we just had to reduce inventory levels, period. This can be especially risky in situations where many supplier parts are required for each assembly. Only one missing part prevents an assembly from being shipped—so a 1% risk of stock-outs on any given part for an assembly that uses 40 independent purchased parts results in only a 67% service level to the customer.

$$(0.99)^{40} = 0.668$$

I tried to explain that arbitrarily lowering SAP safety stocks might create some risk situations, but I was told that unless I wanted to re-write the SAP code, it wasn't going to change. I was in the midst of the assembly implementation at the time and decided that I was not in the right political position to push this change as it was completely outside the scope of my project and my work within the department.

The sort of 'back of the envelope' parameterization practiced by the Supply Chain/ Purchasing division ended up causing problems. In another case, a series of suppliers to the actuator department were being transitioned in an attempt to rationalize the supply base. The new suppliers were chosen and given dates when their first order would pass First Article Inspection (FAI). This is customary in the aerospace industry where parts must meet tight standards and often require complex machining. The old suppliers were given an "end date" for their last order, which was two order lot sizes worth after the new supplier's FAI. This was done irrespective of the confidence level in the new supplier (likelihood of passing FAI on the first try), and irrespective of demand for the part in the period following the FAI date (the two order lot sizes from the old supplier could last anywhere from two weeks, to 6 months). In the end, due to the complexity of the parts, many of the new suppliers did not pass the FAI. Many continued to have problems forcing Daugy-Naudier to go back to the old suppliers (who were not necessarily in the mood to be accommodating) or to make the parts themselves in a machine shop that was already severely behind schedule. Choosing a safety stock for the transition period with more consideration of variability and risk would have reduced the impact of the problem. In the end, a new policy was implemented: the old source was not discontinued until after the FAI had been passed, and after reasonable assurance that the new supplier had built up a stock of parts and the ability to deliver.

It is worth investing time in understanding past data before changing information system parameters. In particular, understanding past variability, and using it as a predictor of future variability in setting safety stocks is particularly useful in managing risk. This is not a new conclusion, but it does bear mentioning given that organizations under pressure are often reluctant to spend time understanding their data with statistical tools. Without evidence of the problems described above, it can be difficult for them to justify the time investment in understanding things like standard deviation of past data.

3.3.2. Implementing and Integrating New Inventory and Ordering Software

Over the course of the Lean implementation, Daugy-Naudier was phasing in a new software system called SFT that allows management of low-volume kanban systems. While the core module of SAP has some basic kanban functionality, the functionality required by the highly variable and low-volume environment at Daugy-Naudier would have required the purchase of the SAP add-on module. Instead, the company decided to purchase SFT and plug it into SAP.

Actuators was the second department to be moved onto SFT. Like most system integrations, this one had some problems.

For example take a lot of 10 parts. When half the lot of parts is expedited, another order number is created in SAP to correspond to the 4 expedited parts, and the old order is reduced to include only the remaining 6 regular paced-parts. When the 4 expedited parts are finished, the special expediting order is closed, and when the 6 regular parts arrive the remaining 6 parts are officially received and the old order number is closed.

In SFT, the new expedited order is not automatically created. This is not a huge problem since the expedited parts are just moving along faster. When the 4 expedited parts are completed, they are not closed out in SFT because nothing on their new expedited order number is reflected in SFT. However, when the old order is received and closed out, only 6 parts are received in SAP and the information is passed to SFT. SAP only expects 6 parts, but SFT expects all 10. For SFT, the order is still open, because the reception of the 4 expedited parts is not reflected in SFT. Consequently, SFT expects 4 parts to arrive imminently, concludes that there are still 4 parts in WIP and does not launch another kanban.

As expediting increased over the course of the summer, this situation was repeated leading to production shortages because kanbans were not being launched. It was only in September that this came to light. The temporary fix is manual and a little risky: the stores people who receive an expedited order of parts find out from the planning and scheduling team what original order number they were taken from. They then call IT and ask for a manual change to the SFT order to show partial completion for the expedited parts. When the remaining parts arrive, the modified SFT order should be complete.

Similar problems arose with parts that were removed from production because they were out of spec: SFT only registered the reception of partial lots (the in-spec parts) and did not launch new orders. These problems came to light at the weekly SFT meetings that I started. Seeing some of the earlier bugs, I had tried to fix them by gathering information from the affected parties. As in the case of planning physical solutions, it became apparent that the solutions were never definitive until everyone who had a piece of the information was in a room together. We began having weekly half hour meetings with planners, product managers, stores people and IT to raise problems, brainstorm solutions, and follow up on the previous week's problems. These were very effective in documenting the important issues so that people understood the short term risks in their respective business processes and that IT understood the need for longer term solutions.

3.4. Impact of Lean Implementation

One of the good things about beginning a Lean implementation in an assembly area is that the problems are discrete. Most problems are solvable by increasing communication between departments, and in the end the parts are either there, or not. The biggest challenge of doing Lean in high-mix low-volume assembly is that there are so many particular cases, and therefore so much information to manage. One applies the 80-20 rule, only to find that it is impossible to generalize about the 20, and the 80 present another set of problems entirely.

Machining on the other hand is more like a web of problems, particularly in a capacity constrained environment. Rather than facts, there are forces at play, and every time one thing is tweaked, it has an impact somewhere else. Understanding and managing these dynamics was to be the second part of the project, but they bloomed to envelop the whole department. In the next section, I describe these challenges, not all of which have been solved.

4. Lean Machining Implementation

In this chapter, I describe some of the challenges of implementing Lean within the machining area. While some aspects of this transition were originally within the scope of my work, the retention of non-core parts and the capacity problems that ensued made the problem much less tractable. In the end, the entire department focused its efforts on containing the customer impact of the machining problems. As a result, it was difficult for one individual to have much strategic input or to make process changes. This chapter describes the problems that arose and with the benefit of hindsight, some of the choices that led to them, and some of the tools that could have mitigated them. In most cases, the problems were difficult to foresee and arose from complex interactions between what were otherwise sound decisions at all levels of the organization. The goal of this chapter is to document some of these interactions and some of the risks of implementing Lean tools in this type of environment.

4.1. Challenges of Implementing a Lean Organization

Most of the problems in the actuator machining area boil down to down to people and knowledge—more precisely lack of human resources and knowledge exchange between parts of the organization. The capacity of the heat treatment ovens was sometimes limiting, but for the most part, having the right people, with the right skills, working the right shift, with the right understanding of the production transformations taking place was the number one thing that was missing. The crisis resolution plan delivered in October refers to human capacity constraints on 17 of its 25 pages. Coupled with this was a lack of accountability for decisions taken by other departments. Since nearly all problems that surfaced in production were owned by production, many of them were only resolved only at the firefighting level (rather than the root cause level which might be in engineering design or purchasing). Firefighting efforts contributed substantially to the resource shortage in production. This section describes the high level capacity and quality problems within the department and explains why the root causes were in large part organizational.

4.1.1. Capacity Problems

At the start of the project, in June, there was 40% on time delivery of machined parts to the downstream process (assembly). At the end of the project, in December, there was only 20% on-time delivery. Major capacity problems were encountered in the machining area due to the following factors:

- External factor
  - Greater than expected demand
- Department organization
  - Attrition of the workforce in anticipation of Lean, resulting in an inability to run bottleneck machines in 3 shifts
  - Lower productivity of less experienced temp workers
  - Limitation of willingness to use/ work overtime
  - Expediting of partial lots
  - Delays in re-installation of equipment and air conditioning system
- Supply Chain factors
  - Retention of non-core parts that were not planned
  - Finishing of out of spec parts received from suppliers
  - "Gap-filling" on failed FAI products
  - Delays in outsourcing surplus work
- Research factors
  - Machining time overruns on new products
  - Quality problems that lead to rework

How could these risk factors have been mitigated?

Department Organization
There is a school of thought in economics that if you make the environment more competitive, enterprises will rise to the challenge[14]. Within organizations, this translates to: if you can get the headcount down, the organization will adapt to get the work done. This may be possible, as long as significant organizational knowledge is not lost in reducing the headcount.

One of the efficiencies of Lean is to reduce wasted operator time, and the efficiency only reaches the bottom line if more goods are produced or fewer operators are needed. Often, the most painless way to reduce staff is to let attrition take its toll without replacing departed workers. This was the route chosen by the actuator department in the year preceding the Lean implementation. This can be problematic in an environment that makes complex products and where there is a great deal of tacit knowledge distributed in the organization. While standard work instructions can fill the gap and allow less experienced operators to perform well, checking the standard work at every step is slower than proceeding from 20 years of experience. Also, in very high-tolerance machining of different materials, even the same material will machine differently on two batches, or with a slightly different degree of tool wear. These special cases are difficult to document comprehensively in the standard work, and they can have a significant impact on quality.

Even including some of the newer and temporary workers, there was insufficient staff to run all bottleneck machines on weekends. In the middle of June, two of the bottleneck machines had 339 and 375 hours of WIP respectively in from of them. Running three shifts on weekdays, this amounted to over 3 weeks of work, but if there had been trained labor available on weekends, it would be just about two weeks (and would likely not have built up in the first place). In the crisis plan, Saturday morning hours were added on some machines and maintained on others, but it has been nearly impossible to operate 24/7. Among the existing workforce, there is a strong cultural resistance to working overtime that is exacerbated by the absence of overtime pay for the first few dozen hours of overtime in a year. While management pushed for overtime, the compensation and cultural issues created labor tension that could not be ignored and prevented overtime from being used as flexibly as it might otherwise have.

Within the department, there was an acceptance of expediting partial lots as a means of catching up on customer delays. The production schedule was very short term, so the system impact of expediting was not well understood. As has been widely documented[15] expediting uses up capacity by doubling set-up times and slows down all of the other lots behind the expedited one. This had the predictable result of creating several unhappy customers for every happy one. Within the capacity constrained environment, it exacerbated delays at all bottleneck processes that included a set-up time.

Finally, delays were exacerbated by an aggressive project schedule. As discussed earlier in the chapter on culture, it is difficult to negotiate realistic project plans in an organization where objectives come down from above. The knowledge of people on the

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[14] Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*. 1776.
[15] Eli Goldratt, *The Goal*. Gower Publishing, London, 1993.

floor about implementation challenges and resource requirements is not included. There are two consequences to this: the understanding of risks in the project plan is lessened, as is the commitment of people on the floor to achieving it.

Supply Chain Factors
Several supply chain factors increased the amount of work that needed to flow through the machining area. Not only were the supply chain risks poorly understood and managed (as described in the Chapter 3 section on FAI's), but the potential impact and interplay of these risks was also poorly understood. On its own, any one of the above factors would likely have been manageable within the production capacity constraints of the department, but together, they overwhelmed resources.

It took the department entering into an official state of crisis for these problems to have ramifications for the Supply Chain group. The head of the group decided to leave Daugy-Naudier in November. Even after this point, the Supply Chain group did not respond quickly to fix the problems it had created. This is fairly typical of the functional silos within the organization. The problem had become a production problem, which was production's job to solve. In the crisis plan of October 22, there is one page summarizing the supply chain problems, but only two mentions of people in the supply chain organization being responsible to fix them, and both mentions are joint, leading to potentially unclear attribution of responsibility.

Research Factors
Predictions of machining times on new products were understated in most cases, leading to delays in the planned machining schedule. Research also made changes to existing products that reduced machinability and led to time overruns. For example, one type of stainless steel that was used more and more widely for its wear and performance properties had variable hardness that was right at the machining hardness threshold. This created processing time and quality variations that were difficult to control. These ranged from broken machine bits to cracked parts. While the in-use performance characteristics were improved, the machining problems fell to the production department. Research tried to help find solutions to some of the major problems, but it is not clear that there was significant consideration of manufacturability at the time of the engineering change decisions. It is also not clear that there was direct accountability for research engineers of not having managed manufacturability as one of the criteria in the design change.

4.1.2. Quality Problems
As mentioned above, over the course of the Lean transition, the machining area experienced an increase in defects. On one of the higher volume products, a machined nut, the average number of defects in the first six months of 2003 was 10. From June to December, the average per month went up to 19 defects, almost double the level in the first part of the year. This in turn worsened delivery delays and capacity problems since parts required either re-work (including set-up time if the defect was identified at a later processing stage), or repetition of all process steps if the part needed to be scrapped. In the case of some defects, the parts would go to research to determine if they could be salvaged. Delays in getting a response from research often meant that a new lot of parts needed to be launched in order to maintain the delivery schedule. Over the course of the project, valuable efforts were undertaken to improve the responsiveness of research on fixes to marginal parts. This prevents the parts from remaining in an eternal WIP stage,

which costs money, causes delays, and causes supply problems in some of the very low-volume kanbans.

The main causes of quality problems were:

- Knowledge Base Factors
  - Attrition of the workforce resulting in fewer high-skill operators
  - Cross-training efforts, which tends to create a transitional period of lower quality
  - Distributed and "sticky" tacit knowledge about processes
- Process Factors
  - A culture of "inspecting in" quality after parts are machined
  - Limited systematic analysis and resolution of quality problems (this improved significantly over the course of the project)
- Morale Factor
  - Lack of operator motivation and disenfranchisement with respect to changes taking place

How can these risks be mitigated?

Knowledge Base Factors
While it is often easier to manage staffing levels by attrition, this can be risky in complex high-mix, low-volume machining. Even more so than in assembly, it is difficult to document all of the variables and contingencies of complex machining operations. Quality depends substantially on the skill and experience of operators who are called on to make a variety of parts. At Daugy-Naudier, only some of the machines are programmable. Even on these machines, variability in the materials is inevitable—raw materials and rough parts from suppliers vary in hardness and symmetry. Likewise, heat and surface treatment operations do not always produce identical characteristics for reasons like accumulation of deposits on the inside surfaces of ovens or slightly variable cooling rate because of the outside temperature.

Investing in training is a long-term proposition that may predate a Lean transition by as much as two years. While this requires some forethought, it is worthwhile to cross-train workers before the departure of some of the more experienced ones. This is particularly true in cases where there is tacit knowledge about complex processes that will be lost or left to just one or two individuals after the experienced operators leave. If budgets allow it, keeping on experienced workers through the Lean transition and cross-training process increases knowledge transfer and flexibility. Knowledge will be shared more effectively after a move to working in teams and cells, and even the configuration of these teams and cells can be improved by including the experience of older workers in their design. Daugy-Naudier had some major challenges, particularly in the inspection area of machining, but also on some machines, because of a lack of older experienced workers. At the end of October, when the crisis plan was implemented, 4 out of 7 inspectors were temps. One of the most competent permanent staff inspectors spent most of his time managing the group, leaving only two people who could work quickly and independently on most issues.

Cross-training, while painful in short term productivity and quality, is essential to creating a shop that can be responsive to variable demand. Cross-training on some of the bottleneck machines over the summer allowed management to run three shifts through the fall, significantly reducing the pile of WIP in front of them. This is one of the areas where the actuator department demonstrated long term vision—it continued cross training efforts despite the short term difficulties. The transfer of this "sticky" process knowledge would definitely have been less painful if staff levels were not themselves the most significant bottleneck.

Process Factors

Part of the response to the quality problem involved hiring additional inspection resources, or borrowing them from other departments. While this may be part of the solution, an important principle of Lean is to build in quality—rather than inspecting in quality. This is also known as the principle of Jidoka in the Toyota Production System[16]. At the machine level, processes were put in place to ensure that operators measured critical dimensions on their first part—but this still does not avoid problems on the first part. One thing that I unsuccessfully advocated was that operators be encouraged to work more in teams. With the new re-organization into production cells, teams could be responsible for the quality of their production. This would encourage operators working on an unfamiliar machine to ask for help from their colleagues if they were uncertain, before they machined the first part. There is a tradition at Daugy-Naudier of asking the line manager for technical help, as these people are chosen as much for their technical skill as for their managerial ability, but on the evening and night shift, there are no line managers. During this period, it seems particularly important to encourage cooperation and team responsibility for the quality of production.

The other key process improvement factor is to systematically identify and analyze the root causes of quality problems. This had been done in the past but was not done systematically at the start of the project. One of the results of the crisis plan was that the assistant department manager became head of quality and had daily meetings with all of the line managers to understand and address the major causes of defects. Anecdotally, this seems to be helping, but there are varying reports and still relatively little data with which to make a statistically sound pronouncement[17]. The downside to these meetings alone is that it still keeps the solutions one step removed from the operators. Line managers tend to understand the causes of the problems well, so having them at the meeting provided most of the useful knowledge, but if operators are not part of identifying and resolving problems, how can they "own" the quality problems?

One initiative that I put in place in tandem with these meetings was the establishment of operator-owned metrics. There were some production metrics in place on the floor, but the time intervals or the level of detail by which they were calculated often made them meaningless. Furthermore, operators had neither been part of defining them, nor had they been properly explained, so no one looked at them. The existing metrics charts were perceived to come down from above, and people on the shop floor had no sense of being able to impact them.

When I found out that the cells would have team-leaders, it seemed like a good time to have teams begin to address their own quality. After consulting with line managers and the quality manager, I went around to each of the team leaders and asked them what they felt most needed changing. Delays and quality were the top problems listed by all of

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[16] Kazuhiro Mishina, Toyota Motor Manufacturing, U.S.A., Inc., Boston, MA: Harvard Business School Publishing, 1992.

[17] Nicolas Duret, Telephone conversation, March 5, 2004.

them. By pointing out that changing these things would require documentation of the problem, we were able to agree that metrics could be a useful tool to both understand the causes of their problems and advocate for solutions. Over the course of several weeks, we had informal discussions about what to measure and how to measure it, which they went back and discussed with their teams. I left the solution completely open ended, only giving them examples of the ways that it might be done and typing up their suggestions.

In the end, we came up with two sheets to be posted on each machine: one for quality problems and the other for machining times that overran the allotted time. In each case, the date, lot number and details of the problem could be noted for further analysis. It was agreed that the sheets would be reviewed and that eventually some of the causes might be grouped and measured to see which was the most frequent so that they could decide which to address. I was not able to see this effort through to completion because my role in the project ended, but to the extent possible, I set up frameworks for it to continue with the existing management. The excitement and ownership of these metrics relative to the old ones (that no one looked at) is a good example of the change in attitude that can be achieved by involving people in designing their own solutions.

Morale Factors

Machining responded less well to the Lean transition than assembly. Anecdotally, I am told that this is not uncommon. However, it is not surprising that the machine operators were not enchanted by the short term results of the project: four months out, the Lean transition in machining had worsened quality, increased delays, increased expediting and setups, increased pressure on the workers and increased overtime. Many operators were convinced that the project had been a bad idea and was about to cost the company some large contracts. On a more personal level, the Lean transition had forced people to move locations and machines, to work with machines that were still not properly calibrated, to have engineering, planning and research continually coming to ask for parts faster and then complaining that they were not right. The pressure had increased but there had been no corresponding increase in control over the ability to deliver. This type of change does not set the stage for a happy and productive workforce.

In the absence of being able to involve operators in planning a change that had already taken place, I tried to explain what had happened. Every time we sat down, I asked operators if they had been told about why we were doing this project or how Lean would help improve efficiency. None of them had. We sat in groups of two or three every time I could find a machine that was down or waiting—I owe the line managers a great deal for their help in setting aside time for this. By the line or in a meeting room, we talked about the macroeconomic landscape of the aerospace industry and of trade changes in the European Union. We talked about why Lean production was important to keeping jobs that could pay decent salaries and about why investment in the plant was a positive sign. We talked about why small lot sizes could improve flexibility and responsiveness and why finished goods inventory was expensive and risky. We talked about product families and flow and why outsourcing was challenging. Like in assembly, I kept the groups small so that there would not be a classroom feel to it and that the operators could ask questions and challenge my views, which they did. They had good points. I replied that Lean in high-mix low-volume still has more questions than answers and that their questions and solutions were valuable.

I should mention here that there are opposing views on the issue of communicating with operators. Speaking at the Sloan School, Kevin Berner, a Vice President in McKinsey's operations practice, put it this way: "You have to convince the operators to do Lean with the strength of your own conviction, they don't need reasons, they need to see that you believe in it."[18] This may work for a powerful party in a short-term intervention with immediate positive results. In a place like Daugy-Naudier, however, where the results were not rapidly forthcoming, people needed better answers to their questions to keep them engaged.

I had these conversations 20-30 times and still did not manage to talk to all of the operators. With those that I did talk to, there was more willingness to work together after the fact. There was also more willingness to believe that there could be a solution and to be part of defining it. I am convinced that involving operators in understanding and planning the Lean transition yields more than just a tangible improvement in the design of solutions. It also sets the stage for them to be part of finding ongoing solutions, and to own the results.

4.2. Challenges in Managing Parts in Complex High-Mix Low-Volume Machining

The original project plan called for two product families, nuts and screws, to be machined on two flow lines and for other parts (designated as 'non-core') to be outsourced. The outsourcing did not take place, and as a result 80 non-core parts continued to be processed in the two reorganized nut and screw cells. This maintained a 'spaghetti flow' of parts through the machining area despite the reorganization of machines. Work planning for the machines was initially done on a weekly basis, with daily revisions, but as the situation grew more chaotic and critical over the course of the project, planning was limited to only a three day horizon out of a 4-5 month machining cycle time. It was difficult to tell if parts would reach assembly on time, and generally they didn't.

4.2.1. Emergent need for a dynamic simulation of resources and constraints

As it became clear that non-core parts would not be outsourced, the need for a new machine planning and scheduling system became apparent. Non core parts pre-empt the possibility of having flow with FIFO lanes between the cells because part routings are varied and full of loops that jump from one line to the other. There was no way to guess where parts would be in two weeks, nor what the backlog would be at machine X at that point. For while machine X could be idle today, three batches of parts could arrive on the same day two weeks hence causing up to a week in processing delay for the third batch.

What was needed was a dynamic simulation of where parts were in the current period and where they would be in the next period, and the period after that. Dynamic simulation would be useful because it is a type of model wherein the results of what happens today are the input for what happens tomorrow. The organization had reasonably good data about the order book, the location of the parts in the process, and the time required for each process step. By doing a dynamic simulation over two to three months, it would be possible to see roughly when parts might arrive at assembly. Dynamic simulation also allows users to see the impact of expediting batches or the bottlenecks that can occur sporadically because of the variability in demand and scheduling.

[18] Kevin Berner, Presentation to the Sloan Operations Club. September 17, 2003.

The department had used some analytical simulations (in excel or SAP) of machine capacity, but one of its major limitations is that this type of analysis tends to use averages which are not very good approximations in high variability environments. While the average demand over a year on a given resource might only be 50% of its capacity, if it all that demand comes in January, then the last parts to go through that resource will have waited 6 months in front of it. This is an exaggerated example, but illustrates the point.

I was able to get agreement to build the simulation, but was never able to get the time and resources that had been agreed to. Because of the interactions between processes, it was necessary to model all parts and processes to get good data from the model. This was a huge task that I attempted on Simul8, but was not able to complete because of lack of resources. In particular, I became concerned about the maintainability of the system in this environment, even if I could complete it. By early September, it became clear that the need for dynamic simulation had been understood within the organization. This understanding was leading to a more systemic software scheduling approach. In light of this, I redirected my efforts to other challenges.

4.2.2. Efforts to improve flow by reducing lot sizes

Another parallel effort involved calculating cycle times and reducing lot sizes to improve the physical flow of parts. Cycle times were calculated by summing up the setup, processing, transfer and wait times for all process steps for each parts. One of the problems with how the calculation was done was that in this analysis, wait times were fixed, rather than being the result of queuing from multiple process and setup times, machine capacity and volume of parts (as they would have been in the dynamic simulation). Wait times should only be scheduled in when a buffer is desired to prevent a bottleneck machine from sitting idle due to processing variations in the upstream machines.

Lot sizes were separated into lot sizes before heat treatment and after heat treatment. Heat treat was a shared bottleneck resource with long processing times and fixed capacity, so it usually made sense to run it in large enough lots that it was full. The new processing rules are:

- For high-volume items, large lots are now run until the heat treat step. After heat treat, the ongoing lot size is reduced with a portion of the parts sitting in a buffer waiting until the next kanban demand signal.
- For very erratic or low-volume items, lots are reduced to be equal to demand and full lots are run through all steps as a full lot.

In the high-volume case, lot sizes were sometimes increased before heat treat to keep unit costs down despite the inventory buffer that this creates after heat treat. This is an unfortunate consequence of the accounting systems and management metrics. Smaller lots would improve flow (and reduce capital tied-up in inventory), where larger ones block up machines for up to 2 days. However, until resources could be directed at SMED to reduce setup times, the compensating lot size increases were made before heat treat, to amortize the increased number of setups after heat treat.

4.3. Challenges in Managing Information in the Lean Transformation

Many of the bugs in the SFT system are described in the previous chapter on assembly but also had a significant impact on machining. I refer readers to the above section for examples and suggestions about how to avoid or manage some of these problems.

One of the biggest information challenges in machining was tracking the location of parts. Operators, particularly on the evening and night shifts, did not always scan-in process sheets to confirm that they had completed their machining operation. It is still not clear why this was tolerated though perhaps the morale problems made it difficult for managers to take a hard line. Parts were frequently lost in transit between departments (lab, heat treat, and three-dimensional inspection) and were not always scanned in when they were received. Email came at least once a week to the entire staff of the plant from planners who had "lost" parts. One particularly funny note was left to an actuator planner by one of the inspectors. The original is in Appendix A and below is a translation:

> Pieces FA/FE134-000-32 have not been received!!!
> How is this possible???
> How did they manage to get to my workbench to be inspected???? Was it by walking on their tiny feet, invisible to the naked eye?? What a phenomenon!!! Will historians and archeologists ever figure it out?

Finally, the manual planning and scheduling of parts and operations on was tremendously labor intensive. Expediting and quality problems only increased the workload because parts were taken out of the normal flow of work and needed to be followed even more closely. An automated scheduling and sequencing system—even if the results can be manually altered—will tremendously improve efficiency and predictability. Alternately, outsourcing the non-core parts before the transition, and then going directly to FIFO lanes between cells would simplify the problem enough to make it tractable with simpler analytical tools.

4.4. Impact of Lean Implementation

The Lean implementation in the machining area has not yet had positive results on the bottom line of the actuator department. Inventory levels have risen, quality has declined and so has on time delivery[19]. This is not an indictment of Lean, but such problems do warrant a thorough post-mortem with an analysis of the risk factors that could have been managed or avoided and some ideas about how to do this. In summary, my analysis has shown the following to be major risk factors:

- Lack of knowledgeable human resources
- Lack of participation in planning and ownership of project goals among line managers and operators
- Outsourcing of non-core parts not completed, and in a more general sense, inadequate supply chain infrastructure to support the move to lower inventories
- Lack of interdepartmental accountability structures or problem solving structures
- Lack of mechanisms to identify and solve quality problems
- Limited understanding of machining as a dynamic system and lack of tools to manage and plan in this environment.

In short, when an organization goes Lean, it "lowers the water level" and submerged problems come to light. It is useful to start identifying the magnitude and interplay of these problems before the water level goes down.

Seeing the implementation of Lean at Daugy-Naudier, it is clear that there were no cookbook solutions to implementing Lean in high-mix low-volume variable demand environments. It is also clear from industry investment in research such as the Lean Aircraft Initiative and LFM projects, that in environments such as aerospace, the specific risk factors

[19] Daugy-Naudier, Actuator Department Crisis Plan. October, 2003.

and solutions to implementing Lean are still not well understood. In the next chapter, I examine the results of cross-industry interviews about some of the challenges observed at Daugy-Naudier. The comparisons between the different environments and the problems that arise may provide better clues for future projects about what risks most need to be managed.

5. Synthesis of Case Studies about High-mix Low-volume Lean Implementations

5.1. Rationale

This chapter was borne out of the realization that for many Lean implementation projects "the devil is in the details". While many books address the theory of Lean, many implementations remain technically and organizationally problematic. Why is a process improvement method that has been practiced for at least 20 years in North America and Europe still a topic that poses major challenges for researchers and companies? Why are the benefits of Lean sometimes so dramatic and other times so elusive? In this chapter, I describe the results of a series of qualitative interviews about the challenges of applying Lean, particularly in high variability (high-mix, low-volume) environments.

5.1.1. Interest

Within the Daugy-Naudier context, there had been a Lean transformation plan that was initially presented to Jodd-Thonson to get approval for the project. The plan made sense at a high level, was in conformity with Lean principles, and was approved by strategic and operations directors with years of experience in the area, but the project did not succeed. The department where it was implemented was thrown into a state of crisis, inventories increased and service levels decreased. The supply chain components of the implementation were not achieved and the head of supply chain at the plant resigned. Why, with many smart people working on the problem, and a good high-level roadmap, was it so difficult for Daugy-Naudier to make the transition to Lean? On an intuitive level, the answers appeared to be a combination of the technical and the organizational: in high-variability environments new processes can be more costly to implement, difficult to generalize and higher risk. In complex product environments, information about products and processes is often distributed throughout the organization, requiring greater communication to reach solutions that often span traditional departmental jurisdictions. These hypotheses based on my own data point merited further investigation.

In September 2003, most LFM Fellows returned to MIT to present progress reports on their research. At that time, it became clear that many projects were facing similar technical challenges, particularly in high-mix low-volume environments. Furthermore, many of the researchers were not finding applicable answers in the literature on Lean. This chapter of qualitative data, based on in-depth interviews, is a first step in filling the gaps in the literature and describing some of the common themes that emerged in their work. In the long run, it will be helpful to Lean practitioners in industry if they can better understand some of the technical and organizational challenges that continue to thwart attempts to apply Lean tools.

5.1.2. LFM cooperation/ Learning

The situation of the LFM fellows presents an interesting opportunity to do a comparative study of Lean implementation practices and challenges across companies. Fellows all have engineering backgrounds and prior industry experience and are each thrown into a new industrial context for 6 months. This creates a total immersion experience, with a critical perspective that is grounded in a common understanding of theoretical principles and toolkits.

Doing the interviews for this comparative study and sharing the results provides an opportunity for increased learning for both researchers and LFM partner companies. The greatest challenge in this case was finding internships that had essentially the same parameters to allow for hypothesis generation. In the future, partner companies might want to have this cross-industry comparison as an explicit goal in determining the subject of LFM projects. This might allow for even greater hypothesis testing and knowledge generation.

5.2. Process and Intent

5.2.1. Planning

A qualitative study was designed based on guidance from Professor Lotte Bailyn of the Sloan School of Management, as well as principles outlined by Miles and Huberman in their seminal sourcebook of qualitative methods[20]. The intent of the study was to generate hypotheses about:

- Limitations to the applicability of some of the traditional Lean tools
- Technical and organizational predictors of problems with Lean implementations
- Innovative solutions to some of these problems
- Differences between Lean implementation in high-volume and low-volume environments.

The Miles and Huberman techniques are not meant to be generate statistically significant 'proofs', but to rigorously mine qualitative data for new information. The techniques have their roots in ethnography and allow for some flexibility in the data that is gathered which allows for unexpected hypotheses to be explored. On the other hand, sample selection and natural language processing tools are rigorous and systematic in their implementation.

The sample group consists of 12 LFM Fellows who had the word Lean in their midstream presentation title, or who presented their midstream presentation in the Lean subject category. All people falling into these groups were interviewed. All interviews were conducted after at least 5 full-time months at the industrial site, so all interviewees had deep knowledge of the plant's processes and first hand experience with the Lean transformation taking place there. Interviews were conducted by telephone and took one-and-a-half to two hours to complete.

5.2.2. Instrument

The interview instrument is attached in Appendix B. It has 4 parts: an introduction that is read to the participant, some basic questions about the type of operation in which they worked, some open-ended questions about the challenges of Lean and some specific questions about technical challenges. Interviews were not recorded, but notes were taken on computer in a word processing format, and tidied immediately following the interviews to fix spelling and grammar mistakes, complete quotes, or comment on general themes.

5.2.3. General and specific questions

Based on challenges at Daugy-Naudier, comments in the September on-campus presentations, and on discussions with other Fellows, there were some ideas that warranted particular investigation:

- Outsourcing as a capacity management tool
- Point of use stocking of tools or parts in low-volume, high complexity products
- How standardized work reconciled with product complexity and the need for critical thinking

[20] Matthew Miles and Michael Huberman, *Qualitative Data Analysis*, USA: Sage Publications Inc, 1984.

- The use of analytical solutions vs. dynamic simulation in analyzing capacity and lot sizes.

In an attempt to avoid leading the answer, these questions were preceded by some general questions about the challenges of implementing Lean and the solutions that may have been developed in response to the challenges.

5.2.4. Data processing

Data was initially classified into a Cross-Site Matrix[21] with the interviews (sites) on separate rows, and the subject areas (questions and comments) in columns. This allowed for cross-site comparisons on specific points. Data was transcribed verbatim from interview quotes where possible, and occasionally paraphrased to capture larger trends in a format that allowed for comparison. The entire matrix of interview data (transcribed from the notes in paragraph format) is available in Appendix C.

In order to generate some hypotheses about how high-mix low-volume situations differ from high-volume environments, I created a high-mix low-volume index. It is imperfect and is meant to generally group the sites rather than to establish a definitive rank. A high value for the HMLV index denotes that the demand pattern had high-mix low-volume characteristics. A low value (<1) for HMLV index indicates a high-volume environment.

HMLV index = (1/average volume per SKU per year) * number of different SKU's produced * machining factor

The machining factor is 1 if there are no (or small) changeovers or setup times involved in switching from one product to another (typical situation in manual modular assembly) and 10 if there ARE changeovers or setup times involved when switching from one sku to another. The 10 factor was used when the setups were present in even one part of the analyzed process. This is a rough measure of the "challenge factor" of the high-mix low-volume situation. It is obviously somewhat flawed however, since the multiplier 100 could just as easily have been chosen—I picked 10 because it was an order of magnitude greater than 1. Furthermore, this machining factor will have less impact in a higher volume situation than in a lower volume one. Finally, using just one number (in this case 10) does not reflect the number of setups, or the actual length of them relative to the machining processes. In any case the relative lengths are as much a product of business decisions about lot size as fundamental properties of the process and product themselves.

With more data, it might be more meaningful to refine this equation. For example, the machining factor could be made a function of the number of operations, the cost of the parts and the total volume produced.

5.3. Findings

5.3.1. Study group and product environment characteristics

Seven of the interview sites fell into the high-mix low-volume classification HMLV index >1. Five were considered high-volume-low-mix (HMLV index <1). Ten environments had machining characteristics and two were solely assembly with no machines or setup times involved. The highest volume operation made hundreds of millions of finished items per year, and the lowest volume made less than one per year. All respondents

[21] Matthew Miles and Michael Huberman, *Qualitative Data Analysis*, USA: Sage Publications Inc, 1984.

confirmed that their companies were attempting to apply Lean, all but two were explicitly committed to 5S, and 7 had six-sigma programs.

The variability between different sites limits the statistical significance of some of the conclusions noted below since some conclusions may be drawn between only 3-4 sites that have some situational similarity. However, this set of interviews is designed to suggest new areas for investigation in the practice and theory of Lean, rather than to generate definitive proofs. As such the "conclusions" of this chapter may be treated as hypotheses worthy of further investigation with a more structured approach and/ or sample groups chosen with a particular independent variable in mind.

5.3.2. What does high-mix low-volume really mean?

The creation of a high-mix low-volume index brought to light some interesting problems. For example, the need for a machining factor seemed to indicate that there were some fundamental elements in product and process design that affected the high-mix low-volume nature of the situation.

One indicator of process complexity seemed to be the presence and number of interfaces used in customizing the product in to multiple finished skus. If the number of skus is generated primarily through modular design and assembly interfaces that have virtually zero changeover time (for example, the choice between a grey bumper and a black bumper on a car) then a high-mix of skus causes very few of the problems associated with high-mix low-volume. If on the other hand the number of skus is generated by fundamentally different machining operations or integral (as opposed to modular) design configurations, then a relatively smaller number of skus can bring about many of the problems of a high-mix low-volume process. An example of this situation is in the manufacture of microchips where a tightly controlled chemical process environment produces a lot of wafers that are then cut into 600 chips (approx 30 per wafer). Intuitively, it is difficult to argue that these chips could be assembled from modular subcomponents or even manufactured in lot sizes of one. Manufacturing microchips in lot sizes of 1 would require a fundamental product and process redesign that is beyond the scope of most Lean projects. As a result, even a plant that makes a relatively high number of microchips might actually have the characteristics of a high-mix low-volume production situation.

The conclusion of this struggle to identify a "machining factor" is that in some situations, achieving single piece flow and eliminating some of the challenges of high-mix low-volume would involve fundamental product redesign, which may or may not be technologically possible. As a practical matter, it tends to be outside the scope of Lean implementation projects even though the Lean theory suggests that it should be included. In real life Lean implementations then, the high-mix low-volume nature of the situation may be dictated not just by the demand pattern for the product. A production environment may be high-mix low-volume because it is constrained by a minimum lot size greater than 1, which is not just the product of a tactical business decision, but a result of the fundamental nature and design of the product.

5.3.3. Lean Challenges and Solutions

The question asked was "What were the key points of Lean or TPS or 5S thinking that were complicated for the people that you studied?"

Of all the sites that had HMLV scores < 1, only one reported a technical challenge associated with implementing a Lean system. All the other challenges that they reported had to do with cultural issues. On the other hand, all the sites that had HMLV scores > 1, reported at least one (and sometimes entirely) technical issues in response to the same question. The chart below provides an illustration. Items in **bold** refer to technical challenges.

HMLV > 1	HMLV < 1
a. hard to have the impetus to go lean since they are a monopoly. the shipyards have not bought into lean, politics between the VP's take precedence over solving lean problems.--problems with incentives. b. functional silos make it hard to solve logistical or supply problems at an interdepartmental enterprise level--the problems show up in production and assembly gets blamed. Among other departments there is a "not my fault/not my problem" attitude -esp. engineering not pro-actively solving probs **c. high internal demand variability for parts, and poor logistical control-- makes it very difficult to do JIT delivery-- they try but 90% of parts are early or late.** **d. poor use of kanbans: e.g. a part for which you need 400 at only one time in the entire shipbuilding process, they keep a kanban of 50 in stock.--most of the time, that is too much, and at the time you need it, it is not enough.**	a. resistance of floor supervisors-- bursts of progress but always need impetus-- not self sustaining. Also resistance from union b. problems with interaction between production, engineering and maintenance came to the surface and so engineering and maintenance very resistant of scrutiny and taking responsibility-- more worried about protecting territory than about solving problems. c. illiteracy creates challenges in forming continuous improvement teams and giving more responsibility to people on the shop floor.
a. hard part of CONWIP to grasp: why do I want to hold on to these orders when my machines are empty? How can CONWIP levels be changed to accommodate things out of your control and not shut down the shop? b. convincing people to do work instructions and visual management systems when things already work. **Work instructions do not stand alone, because of variability in products. Can't have 200 kinds of precise work instructions ($$ of producing, maintaining)**	a. metrics only changed 6 months ago to encourage smaller lots-- people want to run high volumes and get it out the door-- b. pick out kanban cards to do the big lots-- but then leave a whole lot of small lots of uncommon stuff for the next shift. also problem with expediting some orders for demanding markets **c. all visual management systems "don't trust ERP"-- god but fragile-- hard to deal with stockouts**
a. build to order is in direct contradiction with level loading. Means that they sometimes have to send people home. b. minimize fixed costs and keep workers as part of variable cost that can be managed to meet demand-- well developed training and a flexible non-union workforce. Extra capacity of build cells, but these have a very low cost of setup. c. people reject lean for its name even through they are already doing many of the principles. **d. there is a lot of excess material movement, which is different from lean. also, not point of use stock, areas not immediately adjacent, buffers and queues everywhere (though they are short). but this allows for flexibility and responsiveness to different build times (don't need to make constant takt).**	a. hard for people who used to be paid on piece rate to not overproduce. Hard to get them to work to takt time. They don't like having the machine stopped. They don't like having to meet a target rate each day, fee like an average should be good enough. They feel like tracking production is like being policed-- not clear (even to intern) that the numbers are actually being used to reduced process variability b. union--mgmt tensions "I won't do this because you didn't do that"-- workers have not bought into, and are not participating in, lean
a. build what you need first, not safety stock (which justifies large batches). b. what to do when we have "nothing to build"? Hard to convince them to shut the line down. Strong drive to use extra capacity. C. people not doing their part in the kanban system (not moving the cards or registering process completion). No discipline about new processes despite strong discipline about old processes. **d. hard to transition between computer tracking systems and visual tracking without duplicating work.-- which one is the authority**	a. hard for people to deal with increasing number of setups (the corresponding reduction in inventory doesn't mean much because the inventory had previously been sorted in a warehouse: so no VISIBLE change) b. often inventory targets are unrealistically low (and arbitrary levels that are not negotiated or based on expected improvements from certain changes) which leads to c. c. managers set up metrics in a way that "games" the system, to meet the unrealistic objectives-- which in turn demotivates people from producing real change. d. project champions are often from engineering and have little leverage in the group where they are trying to make the change.
a. shoehorning lean tools into the process does not work. You need to make the major changes to make things flow in the whole system **b. lifespan of product affects the amount of investment that you want to make in point of use, standard work, or balancing a flow line (over how many products are you actually going to reap efficiencies?)**	a. hard to understand pull, hard to understand that buffer can be smaller than daily throughput. b. firefighting and changing priorities reduce effectiveness of approach-- hard to focus. c. operator training in Lean needs to be more thorough and closer to the time of implementation, need more emphasis on benefit of lean to workers.
a. very hard to find standard parts or processes-- not a lot of commonality and very variable demand month to month. The standard routing is not standard to more than half the parts and many are re-entrant to the standard routing-- very hard to identify families for VSM **b. hard to do line balancing because of volume and process variability-- different sequences make it difficult to staff line stations without waste** **c. hard to really understand how changes will pan out in procatice, what will be the effect on WIP, cycle time, inventory etc-- esp given variable volumes.--used simulation rather than excel** **d. in low volume, when you make a change, you need to let it just settled down before you evaluate if it's working-- you can't just start tweaking and cont. improvment right away. -- if low volume with half day takt times, it takes a while to see if the change has the desired consequence or if you are just looking at statistical noise.**	
a. benefits of lowering inventory not universally understood (engineering pushing for low setups to reduce unit costs) b. no cost accounting for inventory **c. not possible to do single piece flows, but smaller batches with conwip and buffers work well** d. danger of confusing tools of lean with principles of lean: single piece flow is a tool to reduce WIP and inventory **e. understand which sources of variability really affect performance of the product and only try to control those**	

The presence of so many bold items (technical challenges) in high-mix low-volume environments seems to indicate that there are still many problems left to be solved that are not covered in a satisfactory way by the current Lean toolset, or by current known Lean practices. Some of these technical challenges are treated in section 5.3.5, but many of them were unanticipated and would themselves be interesting points for further investigation.

Out of 14 technical challenges mentioned, 8 of them were explicitly attributed to product variability and demand variability which corroborates the idea that these technical challenges are a direct result of the high-mix low-volume environment. In particular, 5 comments were made about the uncertainty of investing in solutions in a high variability environment. It takes a substantial amount of engineering time to generate work instructions, balance a line, put parts at point of use, develop new routings, and measure progress. If parts have low demand, limited life-spans, and each one requires a separate analysis, the profitability of investing in all of the elements of building a balanced flow line can be questionable. The savings in direct labor may not justify the indirect engineering investment in solving such a complex problem. This is in direct contradiction with the widely accepted truism that Lean is about creating balanced flow lines driven by customer pull.

Five of the technical difficulties related to having accurate information about WIP and inventory levels, whether this was because of Kanban system performance, ERP system performance or two-tiered measurement systems. This lack of reliability in inventory and WIP levels makes it difficult to understand the impact of disturbing (making changes in) the system, and reduces service levels. A key lesson from this would be to ensure that information systems about part and product availability are robust, fixed and well understood before lowering inventory levels. This sounds obvious but the existence of challenges is corroborated by the Daugy-Naudier situation where poor inventory and WIP tracking systems were a major source of problems. Intuitively, the emergence of such problems is not surprising: when inventory and WIP levels are high, being "off by a week" does not disturb service levels, but when buffers or inventories are lowered to less than a week worth of parts, errors come crashing to the surface. Not all problems can be predicted and some will emerge as inventories are lowered, but working to identify problems while buffers exist can significantly improve service levels during the transition to Lean. In particular, many companies try to change the inventory management system *while* making Lean process changes, rather than before which introduces a large amount of stock-out risk. Doing it before appears to be especially critical in high-mix low-volume situations.

The most common cultural challenge, mentioned in 5 instances, was the difficulty of accepting that the machines could be shut off or that the workers should stop producing or go home once target levels of production are met. Machine utilization was, and in many cases continues to be, an indicator used in evaluating the efficiency of production environments. However, it provides a strong incentive to build inventory which is in direct contradiction to Lean. Eliminating the focus on metrics that measure machine utilization or output per worker is an important mental change that needs to be made to transform a shop from mass production to a Lean, responsive, low inventory environment.

5.3.4. Technical challenges

Beyond the general question about challenges with implementing Lean, respondents answered three questions with respect to point of use tools and parts, standard work instructions and analytic (Excel) vs. dynamic simulation modeling suitability. The first two points were touched on in response to the general question on Lean, which already corroborates their importance. Both point of use and standard work require significantly higher investment in high-mix low-volume environments. The general question on Lean also generated comments about technical challenges relating to information management and predictability of outcomes. While part of the challenge is getting good input data, processing it in a way that captures significant sources of system variability is equally important.

5.3.4.1. Point of use

Nine of the sites surveyed had point of use tools and or parts. None of the ones dealing with a small number of parts or tools had significant problems beyond operator acceptance. One site put high-volume parts at point of use and brought in less frequently used parts from a warehouse. Three sites experienced technical challenges as a result of point of use. Two of them were high-mix low-volume (HMLV>1) and one was not (HMLV< 1). The latter site solved space problems by reducing purchased lot sizes. The two high-mix low-volume plants engaged different solutions: one went back to kitting, concluding that the ergonomics of point of use were too complicated and the investment was too high for products with finite life spans. The other reconfigured the floor moving significant amounts of machinery in order to make room for point of use tools and material. It would be interesting to pursue this study and look for other situations where large parts create point of use stocking challenges. There may be some indicators that predict kitting is a good solution if the kitting stage does not add significantly to the cycle time. One of the high-mix low-volume plants has explicitly decided on a kitting process model and has configured the entire plant and process to accommodate this decision. In this case, the kitting adds little to the cycle time—but the accommodation systems to move the kits around create a certain amount of process rigidity which may affect future products.

Below are the 3 responses where point of use parts or tools were a challenge,

HMLV > 1		**HMLV < 1**
yes. Challenging to find space on the floor for all this. Did it by reducing some of the WIP and sending away some old machines that were not used anymore. Also challenging to find a budget for point of use tools-- people say they want them but need money for duplicate tools.	yes, but parts used by different cells, so to avoid 10 points of inventory, operator does mini-kitting for shared parts. Still secondary stores location. Need to think about form factor etc for point of use-- not great for short term or evolving products because it is such a rigid system.	some point of use for colored binders and tapes-- also getting smaller shipments of things like PE and PVC-- worked with suppliers to only get 1-2 tons at a time instead of 20. limit WIP with drums that can not be exceeded. Hard to figure out the right level of WIP

and the one response where kitting was explicitly chosen as a long-term solution.

HMLV > 1
yes for tools, no for parts. Kits shipped to point of use.-- single stock point where picking is done. Kit to order. There is one server line that has point of use with a balanced flow and it is more productive when it is running but often needs to be shut down--not enough flexibility which leads to poor capacity utilization.

5.3.4.2. Standard Work

All respondents were asked the following question: "How was the concept of standard work reconciled with product complexity and changing environment? Were standard work instructions kept up to date? What were the challenges in doing this? Were they totally comprehensive or did they depend on critical thinking from the line workers?"

Three of the five sites that were HMLV < 1 (not high-mix low-volume) had standard work instructions that were kept up to date at the time the researchers left the site. Only one of the 7 high-mix low-volume sites has standard work instructions for all steps of the process. The one site that did have standard work was the one with very modular products and simple interfaces—which in turn simplified the creation and updating of the instructions.

The high-mix low-volume sites explained the lack of standard work in terms of the indirect costs of preparing them, and the time that it would take the operators to consult them. Many places had simplified work instructions that were not really meaningful without the presence of complex drawings. In order to assemble parts or change setups in a reasonable time, the configurations were drawn from memory.

The most commonly understood benefit of standard work, based on my interviews, was that it reduces the risk of errors and reduces the need for operators to think. In many complex task environments however, workers who have succeeded are those with a high degree of critical thinking ability and problem solving skills. These people may share the predominant perception and consider that standard work is taking the thinking out of their job—or, to the extent that it is still needed to solve problems—invalidating the creative problem solving that they are good at and that is required to succeed.

A less common, but perhaps truer-to-Lean-principles view of standard work is that processes need to be done consistently in order to kaizen them and achieve continuous improvement. The notion of continuous improvement draws strongly on the critical thinking of operators and seeks to generalize their insights. This can only be done if the process is done in a way which is consistent enough to statistically measure the impact of improvements.

Achieving this type of kaizen situation is motivating to operators but requires some training and enough consistency in the processing environment in order to track the significance of changes. In a high-mix low-volume environment, the operators who have traditionally done well through critical thinking and creative problem solving may be particularly suited to kaizen type problem solving, but their processes may not. It is inherently difficult to apply statistical methods such as Pareto charts to high-mix low-volume situations. While some common processes can be improved through standardization and analysis, it may not be worthwhile to formalize all processes and create standard work, particularly in products with short production life-spans. The overall investment may be less if operators apply their critical thinking to the products they know well—particularly if they are alone or part of a very small group that performs a given process. Some parts of the process may be improved organically with as much efficiency as by standardizing, documenting and analyzing the work in the company of industrial engineers.

The truism that 'standard work is an essential component of achieving a Lean environment' is one that bears further examination.

5.3.4.3. Analytical Solutions and Dynamic Simulations

The questions that were asked with respect to this theme were "Did your company use analytical solutions or simulation in developing best practices for lot sizing and capacity management? Which of these tools did they use? What were the successes or limitations of each in your environment? What technical parameters lend themselves better to one type of solution or another?"

None of the 5 sites that had a HMLV < 1 used dynamic simulation (tools such as Simul8 or Witness) to analyze capacity or plan lot sizes. Three of the five explicitly concluded that analytical models such as excel spreadsheets would do the job fine; two of them commented that simulation was more useful as a tool for explaining process routings. These routings were consistent enough that it was possible to "simulate manually" moving Lego blocks or dots around on a map.

Of the seven sites with HMLV > 1, all but one attempted to use simulation to manage capacity and plan lot sizes. The one that did not was the site with only very modular assembly. They explicitly commented: "there are no re-entrant flows, or variable process times, or shared resources or variable setups to deal with." Of the 6 remaining sites that did use dynamic simulation, one used it only to explain process flow to coworkers (as a teaching tool). All the rest used it for capacity planning and lot sizing. This is particularly remarkable in light of the fact that most of the sites did not own such software. The people doing the Lean implementations decided that it was the right tool and went to some lengths to get it. All of the 5 researchers attributed their use of dynamic simulation to its ability to model complexity and variability. In particular, the ability to model re-entrant flows, shared resources and test hypotheses with exact demand patterns and process times were highly valued. As one respondent put it: "analytical solutions…result in GIGO [garbage in garbage out]—they don't take into account the synergistic effects of variability". Four of the five also commented on the difficulty of creating the models and the limitations of the tools, testifying to a desire for more robust and rapidly adaptable software.

The responses from the HMLV > 1 are included below. The non-user and the use that was only for demonstration purposes are omitted here due to space constraints but can be found in Appendix C.

HMLV > 1		
use simulation to schedule production-- complex processes with sequential interdependencies. They do not use analytical optimization because things are too complex and everything changes-- hard to model in a consistent way-- whereas in a simulation you can reset it with a new parameter value and run it again if something changes-- cumbersome to re-run it, but seems to work when things are too complicated for an analytical solution.	simulation is useful because it allows you to model the variability in detail, but it is time consuming to do so. The problem with a lot of analytical tools (which were used) is that they rely on averages. Ok for figuring out a conwip level (which is about averages) but not so good for some other things where variability counts.	used a simulation tool called Witness, but it was difficult to model single piece flow, variability and re-entrant flow. A lot of work to get all the parameters right for the simulation to be valid. Sometimes you are better to just go and test stuff out on the floor. Also hard to test the validity of a simulation, whereas in an analytic solution, easier to see if there are wrong assumptions.
simulation is good for modeling shared resources-- to understand the impact of batch sizes and different groupings-- impact on capacity and throughput. Simulation is good because it allows you to take the actual data distributions and test out hypotheses, rather than using a pretend approximation distribution. (in high-mix low volume where the variability is high, the distribution might even change with years which makes it especially hard to model because there are few data points). no risk that you are making wrong assumptions-- BUT unwieldy to model with current tools. People give up on modeling certain bottle necks analytically because they are too complex.	he leans toward simulation if you have variability from routing or setups, within processes (setups and runtimes) or in demand. Simulation is good because it allows you to test hypotheses and focus on the things that are going to help your business the most. Analytical solutions like excel are inherently deterministic-- you have to make many assumption about capacity or availability of workforce-- all of these averages in the parameterization result in GIGO.-- doesn't take in to account timing and synergistic problems of variability.	

These findings seem particularly interesting in light of the fact that many companies continue to use primarily analytical solutions for lot sizing and capacity analysis. The problem with a tool like excel, is that it limits the user to modeling averages, or pre-determined distributions. Even a predetermined distribution, such as Normal or Poisson, may not correspond to an actual distribution of demand, or workflow or setup times. Furthermore, even if it were possible to model these things as a combination of distributions, it may not be reliable to do so because there is so little data about each product that it is hard to chose a "metaphor distribution" for each aspect of its flow. Simulation allows the user to input actual parameters (like the true demand pattern) and even update them (tweak an actual process time) so that the simulation tests out hypotheses that correspond most closely to the actual situation in the shop. Dynamic simulation tends to give more weight (than most manageable sized Excel models) to things like timing of flows, which is why it captures things like synergistic effects and re-entrant flows so well. As the software tools evolve and mature, dynamic simulation may become a very powerful and more widely used tool in testing scenarios and understanding the impact of changes to the production parameters of complex high-mix low-volume environments.

5.4. Emergent Hypotheses and Directions for Future Work

As mentioned in the beginning of this chapter, the hypotheses that emerge out of these qualitative interviews are not statistically borne out, and should be the basis for further investigation. In fact, some of the questions that were asked did not yield useful answers because of lack of commonality in the independent variables. For example, one of the questions in the survey had to do with outsourcing challenges when outsourcing was a response to capacity constraints. This came out of the situation at Daugy-Naudier, and I expected the problems to be of the "knowledge transferring" and "knowledge maintaining" type. In other words, I expected that it would be hard to transfer quickly all of the knowledge about how to make many complex parts (which would slow the efficiency of outsourcing as a response to high demand) and that the sub-contractors would lose the skills (or move on to other markets) when demand decreased. Only one site had direct experience with outsourcing as a response to increased demand and the portion of the work that was outsourced was fairly consistent across products which simplified the knowledge transfer problem. Further study of sites that have common independent variables would be useful in order to verify these hypotheses.

In summary, some of the themes that might provide grounds for further investigation are:

a. The role of product redesign and simplicity of interfaces as part of the Lean transformation project in high-mix low-volume environments.
b. The value of some Lean investments in high-mix low-volume environments—analysis of indirect labor costs vs. gains in direct labor over product lifecycle.
c. Improving/ stabilizing inventory and WIP information systems *before* a Lean transformation as a predictor of success of the transformation in high-mix low-volume environments.
d. Benefits of explicitly reducing the focus on machine utilization and worker productivity during the Lean transformation.
e. ROI for point of use parts in a high-mix low-volume environment: predictors of value of point of use flexibility tradeoffs, and indicators for kitting.
f. Value of standard work in a high-mix low-volume environment. Impact on direct labor costs and morale. Indirect labor costs of creating and maintaining standard work instructions. Impact of having standard work on process stability and continuous improvement (is standard work an enabler of process improvement?).

g. Applicability of dynamic simulation to high-mix low-volume lot sizing and capacity planning. Specific limitations of the software and improvement needs. Predictability of resource requirements and transformation success with analytical models vs. dynamic simulation in high-mix low-volume environments.

One of the most interesting general conclusions of this qualitative analysis, is that in most cases, the conventional Lean tools and practices worked well in the environments with a HMLV index <1. It was in the environments that had high-mix low-volume characteristics (HMLV >1) that the tools became limited in their usefulness. This is convincing evidence that the tools of Lean may not be universally applicable in order to reach the goals and theories of Lean. High-mix low-volume environments pose challenges that have not yet been adequately solved in common practice and that merit further investigation. Implementing Lean practices in high-mix low-volume environments is a fundamentally different problem from traditional Lean, and merits focus on the unresolved technical challenges specific to that environment.

6. Engineering Changes Project

This chapter discusses the design and implementation of an enterprise-wide process for evaluating the profitability of Engineering Changes. This project was somewhat separate from the scope of the Lean implementation in the actuator department, but it is a typical example of the type of wide-ranging interdepartmental issues that emerge from lean projects. Its emergence and resolution show how Lean can begin as a discrete project in a production department and lead to strategic transformation of enterprise-wide processes.

6.1. Emergence of the Project

As mentioned earlier, Lean processes can have the effect of 'lowering the water level to see where the rocks are'. The activities of Lean, such as point of use parts, can and do force a reckoning with surplus inventories of current and non-current parts. Over the period from June to August, as the Lean assembly project was moving forward it became clear that there were hundreds of surplus parts in cupboards and stores that were no longer used. There were two causes: some programs had been concluded without exhausting the supply of parts, or in other cases a design change had been made that replaced the old part with a new one.

I hypothesized that engineering changes might be a significant cause of obsolete part write-offs and that there might not be a formal process to evaluate and manage this cost. This was particularly interesting since the timing of engineering changes is frequently controllable (except in cases of performance problems or emergent safety risk). This should allow the company to transition the parts in a way that minimizes obsolescence. The number of obsolete parts caused me to wonder about the company's process for managing engineering changes—and for deciding about them in the first place.

Daugy-Naudier documented many of its internal business processes in 2001 while preparing for AS 9000/ISO 900 certification. Looking through these processes, there is only one that addresses engineering changes, and it does so from only a technical perspective. There was also a process that looked at profitability, but specifically with respect to new projects. Discussions with the owners of these processes revealed that in fact, there was some cost analysis performed internal to Engineering, and some performed internal to Research, but that these analyses had a purpose internal to the departments and were not part of the decision making process to go-ahead or not with the change. "We rarely do a cost analysis for engineering change orders to look at whether the cost in obsolete parts or the cost of the new process outweighs the benefits... this cost analysis is considered by the change committee if it is provided, but it is not formally part of the impact analysis [of the change order]."[22] All of the decision gates at the enterprise level consisted of technical hurdles that the change needed to meet.

As discussed in the earlier Chapter on Cultural and Economic Context, these processes were part of a culture that valued technical excellence and had historically had high profit margins. In most competitive enterprises today, and in aerospace in particular, there is increasing pressure to justify design changes not just on technical merit, but on an overall profitability basis.

6.2. Cost Analysis

While such an absence of cost management or profitability gates for engineering changes is uncommon, it is nonetheless important to quantify the value that any additional

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[22] Daugy-Naudier Configuration Manager in a conversation September 25, 2003.

administrative process can bring. Arguably, the benefit of measuring profitability of changes is that the enterprise makes better decisions that impact a range of operating factors, from its ability to attract new customers, to the need to allocate CAPEX to extra machining capacity. The "better decisions" category incorporates so many factors, that an impact analysis is difficult to conduct on this basis. Instead, I went back to the apparent cost that had initially made me aware of the issue: obsolete inventory.

While obsolete inventory is only part of the "better decisions" equation, there were several advantages to analyzing this cost: it is clearly a problem, it is clearly solvable with an engineering change process that considers profitability, and it is historically measurable.

- Daugy-Naudier had at least one major obsolete inventory write-off in the last few years, and this was a good place to start.
- There is also an SAP "historic" category that is used to regularly set aside and depreciate parts that are no longer in use.

Parts can end up in both of the one-time write-off and the historic category as a result of customer cancellations, or engineering changes. The two categories are mutually exclusive. Appendix D describes the analysis in detail; the following paragraphs give a summary of some of the considerations in the analysis.

I first analyzed the one-time obsolete inventory write-off. It covered about 8 years (since the transition to a new inventory management system) and was classified by department. Causes had been filled in for most major write-offs. The two largest departments, 2 and 5 I went through in detail. I excluded all write-offs that corresponded to products that were no longer made or that corresponded to over-purchasing that would not be consumed. I considered the remainder to be due to engineering changes. (The initial list did not include any parts that were written-off due to quality problems).

In Department 2, Engineering changes accounted for 86% of the write-offs. In Department 5, engineering changes accounted for 48% of the write offs. Departments 1, 3 and 4 combined only had 1/7th of the write offs (in Euros) of the other two departments put together, so I did not analyze them in detail. To be conservative, I applied the lowest percentage, and assumed that only 48% of the write offs in these three departments them were due to engineering changes.

This resulted in 68% of the total write-offs attributable to engineering changes for a total of 1.2 million Euros. Dividing this by the eight years (during which there had been no depreciations) gives a yearly rate of 150K Euros.

For the "historic" category, I did a query to collect the value of parts that had been moved to "historic" status over the past 3 years. Parts corresponding to products that were discontinued were removed from the data set. The remaining total was then considered to be attributable to engineering changes. The total over 3 years was 1,1M Euros or 365K Euros per year.

The total cost per year of obsolete parts due to engineering changes is then in excess of 500K Euros per year, which is significant at a plant with approximately 130M Euros in revenues and fairly slim profit margins. When asked, the Configuration Manager (a senior member of the Research Department) confirmed that "at least 90% of engineering changes could have been phased in after stocks of the old part had been consumed."[23] This implies

[23] Daugy-Naudier Configuration Manager in a conversation on November 27, 2003.

that most of the 500K would be realizable as cost savings with an engineering change cost management process.

What was needed specifically is a process to decide WHETHER to make changes, WHEN to implement them and HOW to manage the implementation process. The first step in doing this was to benchmark other industry processes and learn about best practices. The second step was to integrate this knowledge base with the organizational structure and existing business processes at Daugy-Naudier. The following two sections describe these efforts.

6.3. Literature and Primary Sources Review

Most major textbooks on operations management and manufacturing engineering give short shrift to the design change process (also called engineering change process), focusing instead on stabilized operations[24, 25] and occasionally touching on product development.[26] In fact, to the extent that these books focus on change, it is most often within the walls of the shop floor, occasionally stretching to include the supply chain organization. Dealing effectively with engineering changes is challenging precisely because it includes inputs from so many parts of the organization. This complexity makes it important to have a well-designed, formal process that takes into account all of the required information[27]. Harris and Gonzalez provide a good overview of the number of different groups that need to be involved when changes are being considered. They also stress the need for information about approved changes to be systematically disseminated through the organization to the parties who need to use it[28]. Marsing discusses the risks and ramifications of engineering changes, and how they often far surpass the planned scope, cost, or impact of the change: "In an integrated production process, seemingly harmless improvements can throw a downstream processing step totally out of control."[29]

Informal benchmarking was conducted with several companies including an automobile company, a large low-volume equipment manufacturer, an airframe manufacturer, a microchip manufacturer, a software company, an imaging company and a gas turbine manufacturer. Most of the data gathering was done by email though some written forms and process documents from these and other companies were used. Information was also gathered anecdotally: the benchmarking was informal in that the level of detail varied and not all respondents touched on all facets of the process.

Some of the recurrent themes from this research were:

- The repercussions of a design change can exceed by many times the direct cost of the change order.
- Changes should be planned and if possible grouped to improve implementation and customer price leverage.
- Need to distinguish between critical and non-critical changes in how they are handled.

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[24] Eli Goldratt, *The Goal,* North River Press, Great Barrington MA, 1984.
[25] Steven Nahmias, *Production and Operations Analysis,* Irwin, Boston, 1989.
[26] Everett Adam and Ronal Ebert, *Production and Operations Management,* Prentice Hall 1986.
[27] Tien-Chen Chang, *Expert Process Planning for Manufacturing.* Addison Wesley, 1990.
[28] Roy Harris and Richard Gonazales, *The Operations Manager,* West Publishing, St-Paul, MN, 1981.
[29] David Marsing, *Taking Risks in Manufacturing,* in *Manufacturing Systems.* National Academy Press, 1992.

- Consider cost impact of the change on product support, supply chain and re-qualifying/ retesting.
- It is necessary that the departments providing information to this process believe in it and have an incentive to participate.
- Processes need an appropriate organizational structure to enforce them and make decisions.
- Complex or long forms and processes reduce usability.

Also, among the companies that provided this data, it was also customary to analyze 3 major components of the cost: technical and planning cost (one-time), material and processing cost (recurring), and inventory/WIP cost (one-time).

The next step in understanding current practice was to understand the processes of the parent company—Jodd-Thonson. This is particularly useful for two reasons—first, having similar business processes can generate operating efficiencies and allow for common information management architectures in the future. Second, the accessibility to internal documentation is possible at a more detailed level than with external companies. In this portion of the research, I am particularly grateful to Jodd-Thonson's Lean Manufacturing Coordinator, who had previously worked on some engineering changes projects and was instrumental in helping me find the right documents. The Jodd-Thonson method consisted principally of 3 documented processes:

- Segregation of Engineering Change Costs
- Proposal for Engineering Change System
- Product Configuration Control Plan

As well as corresponding Engineering Change and Cost Summary Forms. The processes reference each other and together allow for configuration control as well as technical and economic decisions about engineering changes. The most useful of these documents was the Cost Summary Form for which an equivalent did not exist at Daugy-Naudier. It became the basis for WHAT would be measured in the analysis. The form is attached in Appendix E.

6.4. Review of Internal Processes at Daugy-Naudier

Successful process change depends as much on understanding the dynamics and structures of the target organization, as on the cleverness of the ideal solution. If the new process does not make sense to the people using it, if it does not mesh with the existing organization and allow for reasonably efficient decisions and administration, it will not be used. So the next step was to understand how Daugy-Naudier structures its processes around change, product conception and industrialization, and profitability analysis.

6.4.1. Organization and Existing Processes

The Engineering Change Process is owned by the Configuration Manager in the Research Department, as is the Product Configuration Management Process. Both address the technical side of the problem, ensuring that the configuration or changes to it meet internal and external (FAA, JAA, client) performance thresholds. The Engineering Change Process also ensures that the required documentation is produced to both evaluate and track the Engineering Change Request over its life. There is an Engineering Change Request form that is defined as the tool to manage the information. This form may or may not require input from the Engineering Department depending on the nature of the change.

In practical terms, the Engineering Change process may result in the production of "Devis" or cost evaluation forms at the level of the Engineering Department or the Research Department. These forms cover different costs internal to the departments to allow some financial evaluation, but they are not formally or consistently part of the Engineering Chance process or the decision support process.

Decisions "outside the scope of normal development" require an "Impact Analysis" which does have a financial component (not defined) and must be approved by a "Change Commission". This was a new process addition, and had not yet been formalized. The Change Commission did not yet exist.

Many of the other processes that are similar in nature to the Engineering Change Process are owned either by the Research Department or by Engineering. These include: Conceiving a New Product, Manufacturing a New Product, Analyzing the Value of a New Proposal. The latter deals with profitability, but is a high level process that does not provide clear direction about how to manage Engineering Changes.

6.4.2. Evolution of the Organization

At the time that this work was undertaken, the Daugy-Naudier organizational structure was evolving. The strong functional silos described in the chapter on Cultural Context still exist, but there is a push from senior management toward a more matrix structure. A project organization that cuts across functional silos is being put in place on new projects. Resources are being devoted to training and creating effective decision making structures within the project organization. Many details remain to be resolved but the change seems permanent.

In a parallel movement, senior VP's are being installed with cross-functional jurisdiction. In particular, there is a Logistics VP who directly oversees some of the IT staff, but has strong influence on long-term supply chain and production structures. Similarly, a new Technical VP has been put in place with the goal of improving coordination between Engineering and Research on technical issues. The heads of Engineering and Research report directly to him.

In theoretical terms, these organizational changes support the implementation of cross-functional processes that address engineering changes. In practical terms, the Logistics VP was instrumental in providing strategic and political support to the project, and the Technical VP has become an integral part of the process solution.

6.4.3. Process Gaps

The organizational timing is good, the gap around financial management of engineering changes is confirmed both formally and informally and the cost of doing nothing is clear. There is a need for a process that both evaluates the financial impact of engineering changes and provides direction about how to manage the costs after the decision has been made. This is in fact two separate needs that are sequential and are addressed as two separate processes.

Given the limited time allocated to the project, the management of costs addresses only parts transitions and inventories, since this is what initiated the project, and is also the basis for cost savings calculations. However, the next process revision should include further tools to manage some of the other cost items items that are evaluated in the first step.

6.5. Developing a Sound and Viable Solution

This section describes the processes that were used to develop and implement the new processes at Daugy-Naudier.

6.5.1. Identifying Key Stakeholders

The benchmarking data was organized in order to understand what resources other companies use to evaluate engineering changes. This was done by creating a responsibility matrix (Appendix F) that looks at the input that various departments provide to the cost analysis process, and the role that various departments play in implementing the change. The departments are the columns, and the horizontal rows correspond to the information or internal processes that need to be provided.

This responsibility matrix can then be used as a basis to identify people in the company who need to be part of shaping the new business process. Many of these turned out to be the owners of related processes. By integrating these people into the process definition team, they can bring their knowledge to bear so that the process fits with existing ways of doing things. By choosing people who are respected in their departments, other people in the department are more likely to believe that their department is well represented and consequently to adopt the process.

The other element in stakeholder adoption is extrinsic motivation. New processes take time and change old ways of doing things. It is important that the organizational hierarchy approve and encourage the new process. This means involving senior managers, in this case the VP Logistics and the Technical VP. The VP Logistics was involved by presenting the cost of doing nothing as something that would impact his performance metrics. He became part of evaluating the process at an early stage and provided strategic direction to the project. He also helped identify the Technical VP as an appropriate decision referee given the nature of the technical-profitability decisions that the new process required. The Technical VP was involved after the first draft of the process was completed and was motivated to support it by the external benchmarking, the involvement of his subordinates in detailed definition, and the ability to have a personal impact in the decision process.

6.5.2. Involving Stakeholders in Process Design

This section describes how the interdepartmental team was put together and how it tackled the job of designing a new process.

The first step was to get everyone into a room together on 4-5 occasions. This is difficult with a 7 member team. The team consisted of: two people from Engineering, one person from Sales who was also involved in the organizational transformation to matrix project teams, one person from Research who handled related processes, one person from Finance/Accounting and one person from Production IT, who was familiar with SAP and production planning. Each person was approached individually with a good reason why they would benefit from being part of the team. Meetings were planned well in advance. The meetings were first thing in the morning and all meetings had fresh croissants. Finally, it was important to get people feeling like they were part of the team, and needed. At the first meeting, each person explained what they were working on in their respective department that made their presence on this team relevant.

Initially, the plan was to sketch out a flow chart of the steps that needed to take place to analyze the cost of a proposed engineering change. This proved too abstract, however, and the group decided to start with the details of what costs to analyze/ measure and then work back to how. From this list, the Daugy-Naudier equivalent of Jodd-Thonson's Change Cost Summary was developed. The "Analyse Financiere d'une Demande de Changement" or AFDC is now the tool for the cost analysis process (Appendix G). The AFDC became the basis for working back to the data gathering and decision making process, and the cost management process after the decision. These two processes were developed at a high level and agreed on by the team. From this initial agreement, details could be worked out without forcing constant revisions to the concept.

Once the processes were finalized, it was important to find members of the team who would become process owners. Process owners are responsible for keeping processes up to date, evaluating proposed changes, and re-evaluating process functionality once a year. A competent owner with a good informal network in the company will ensure continued and relevant application of the process, but these people are hard to convince because they tend to be very busy already. Developing the right people to take on this role is well worth the invested time and resources.

The last organizational step in process definition was to train people who would be using it. Half of the training for each group involved explaining why the process would improve their ability to succeed in their job. In a company with significant separation between functional groups, it was important to conduct training separately with different departments so that people's real concerns about interdepartmental cooperation could be raised and addressed.

6.5.3. Profitability Analysis Process

The profitability analysis process is called "Analyser la Rentabilite d'un Changement de Definiton" and is described in Appendix H. In summary, it begins with the assumption that all engineering changes will be subject to technical and profitability feasibility gates. Some exceptions are allowed. Products that are at a development stage with a project manager and pre-approved budget have a more streamlined approval process than mature products. Approvals in both cases depend on one individual, to keep things moving, but in both cases a pre-existing and relevant committee is informed of decisions on a regular basis to provide a measure of accountability. The process is simple and items that were left out of the evaluation are listed as possible additions in the continuous improvement section of the document.

6.5.4. Change Implementation Process

The change implementation process is called "Gerer les Stocks a la suite d'un Changement de Definition" and is described in Appendix I. It defines the processes to manage work in process (WIP) and inventories in-house, and at supplier locations, in the wake of an engineering change that affects inventories. It deals specifically with three cases:

- the first, where a change is brought about by a safety or performance risk and needs to be implemented right away,
- the second, where a change is desirable and new parts are not interchangeable with old ones (several parts need to change on the same date),
- the third where a change is desirable and parts are interchangeable (old parts can be entirely consumed before changing to the new).

Within each branch, the process addresses scrap and rework provisions as well as maintenance stocks.

Detailed processes for in-house and outsourced scrapping and re-work are defined in the process appendix for further reference. The detail is important for accounting traceability, which has been erratic until now. Defining these processes systematically has allowed for a better understanding of the SAP configuration required to support them in a more automated way. The next revision to this process may also address the management of parts when a program ends and there is no more (or very limited) demand.

6.6. Analysis Support Tools

The AFDC mentioned above is the tool that is used to gather information about costs associated with engineering changes. It is managed by an assigned Product Development Manager in the Research department—the person who already gathers the technical information about the engineering change. This person now also collects cost information from the different departments who are variously incentivized to cooperate. Lack of information may prevent a change from moving forward, or conversely, unreported costs can be attributed back to the delinquent department, rather than being charged to the project.

The AFDC form itself closely resembles the Jodd-Thonson Change Cost Summary (CCS), but also includes some line items on change benefits in profitability or operating efficiency. Like the CCS, it includes recurring and non-recurring physical and administrative costs.

6.7. Impact of Engineering Changes Process

The development of an Engineering change process enables better enterprise-wide decisions about what business to pursue. In products with production lifetimes of over ten years, and performance (maintenance) lifetimes of up to 40 years, engineering change decisions can have a long-term impact on the profitability of the company that goes far beyond the inventory impacts that were quantified here.

Despite the benefits, process change is difficult in any organization. This holds particularly true in organizations where the new process is outside of the traditional bounds of cooperation. In light of this, preference was given to simplicity and ease of use, occasionally at the expense of accounting rigor. Regular process revisions and competent process managers should ensure that these omissions are eventually included as the organization improves its ability to deal with them.

Finally, this process is useful to Daugy-Naudier, both as a model for evaluating economic hurdles in an enterprise that has traditionally focused on technical hurdles, and as a model for the use of interdepartmental teams that bring together information and trust in the development of cooperative practices.

7. Conclusion

In the first chapter of this thesis, I discussed the official project plan for the Actuator Lean Implementation. It contained a set of goals and a series of technical analyses and steps to get there. Like most projects however, there was also an unofficial plan. In a July telephone conversation, Jodd-Thonson's Director of Operations Strategy put it this way: "We did a similar project in another department, and while the results were good at first, it's now beginning to slide…it didn't stick, because people haven't fundamentally bought into it."[30] In short, the unofficial plan was to provoke a cultural transformation to Lean at all levels of the organization. This would pave the way for continuous improvement beyond the official project phase.

In both of the chapters on Implementation in Assembly and Machining, I devoted sections to the organizational impact of the implementation. Discussing project goals and coaching operators and managers on Lean principles took up a substantial amount of my time on this project. I can not overstate the importance of these informal conversations in achieving a widespread understanding and appreciation for Lean processes. Changing the decision process on complex issues to one that involves multiple levels of the hierarchy and multiple functions across the organization was another important aspect of the transformation to an enterprise-wide Lean culture.

This anecdote sums up the two types of change that are required to achieve Lean. The first is the technical solution set and the second is a Lean problem solving culture.

Organizationally, Lean has ramifications at all levels in the company. It is often initiated at the tactical level where it involves production decisions, run rules and supply chain improvements. But an enterprise is a dynamic system, and long term solutions in complex product environments inevitably have ramifications at the strategic level. As seen in the previous chapters, these can include the modularity of designs, the structure of enterprise processes, performance metrics and even the organizational structure itself.

On the technical side, this thesis has generated some new hypotheses about the applicability of the standard lean toolkit. While the general principles of Lean provide useful direction, clearly some of the traditional Lean tools are not well suited to the complexities of high-mix low-volume production environments. High-mix low-volume environments have a specific set of risk factors that consistently cause problems and need to be better understood and managed. These technical challenges should be met with two responses:

- In complex production environments, it is easier to teach everyone lean principles so that difficult decisions can be made at the optimal level where the technical knowledge exits.
- Principles of Lean do not lend themselves to a universal toolkit. Rather, they need to be adapted the specific context. Further research is needed to understand risks and predictors of risk in high-mix low-volume production.

Finally—and this is the single most important lesson from this thesis—succeeding at Lean in complex product and process environments such as high-mix low-volume depends essentially on gathering distributed, tacit knowledge from around the organization and getting it into the decision process. This means developing mechanisms such as organizational matrices and teams to move tacit knowledge through the organization. Only at nodes within this network can

[30] Jodd-Thonson Director of Operations, telephone conversation, July 28, 2003.

distributed, tacit knowledge be gathered to build the new right tools that will create breakthroughs in high-mix low-volume Lean change.

Réception des pièces FA FE134-000-52 non faite !!!

Comment est-ce possible ???

Comment ont-elles fait pour arriver à ma table pour se faire contrôler ????
Avec leurs petits pieds invisibles à l'œil ??
Quel grand mystère !!
Les historiens archéologues trouveront-ils un jour ?

Angel

Appendix B—Interview Instrument

Date:
Interviewee:

During midstream review, it occurred to me that nearly all of the presentations on the theme of Lean manufacturing revolved around high mix low volume situations, clearly a different context from the high volume environment in which the TPS emerged. Watching those presentations, there seemed to be some emergent themes about the "fit" of lean principles in these high-mix low volume environments. I thought that this was an interesting opportunity to do some cross-industry comparisons; so the reason that I'm interviewing you is to understand some of the challenges of Lean within your company.

In the first part of this interview, I'm going to ask you some questions about the business that your company is in, then I'm going to shift gears and ask you some fairly open ended questions about how your company is implementing Lean, and finally I'm going to ask you about some of the themes that came up at midstream to see whether they are relevant to your situation.

1. Where did you do your internship?
2. How many different products were produced at your plant/ in your department?
3. How many of each kind of product did you sell per year?
4. How were the assembly and/or machining processes organized?
5. How many products were assembled or manufactured on each line?
6. Is this company attempting to apply lean principles? 5S? 6 sigma?

Now I'm going to ask you about how your company is implementing lean. To the extent that you can give examples or anecdotal stories that support your impressions, that would be very helpful.

7. What were the key points of lean or TPS or 5S thinking that were complicated for the people that you studied?
8. In what way did these challenges arise?
9. How was it a problem?
10. How has your company dealt with these challenges?
11. Is this how you would have dealt with it?
12. How have your ideas been received? Have any of them been implemented?

13. Are there any other areas of lean or 5S or TPS that were problematic? (if so iterate through questions 8-12 again)

14. Have you read Kevin Duggan's book "Creating Mixed Model Value Streams"?
15. Have you experienced any situations that have a limited fit to his framework?

Now I'm going to ask you a few questions around some of the themes that I saw emerge out of the presentations at midstream or out of conversations with other LFM's subsequent to that. I'd be interested to know if you saw these challenges in your company, how they manifested themselves and how the company reacted.

16. Did your company use outsourcing as a capacity management tool? How did that work? What were the challenges to this? How well did it work out?

17. Did your company use point of use stocking (of tools or parts) for low volume, high-complexity products?
    What were the challenges to point of use stocking?
18. How was the concept of standard work reconciled with product complexity and changing environment? Were standard work instructions kept up to date? What were the challenges in doing this? Were they totally comprehensive or did they depend on critical thinking from the line workers?
19. Did your company use analytical solutions or simulation in developing best practices for lot sizing and capacity management? Which of these tools did they use? What were the successes or limitations of each in your environment? What technical parameters lend themselves better to one type of solution or another?
20. Is there anything that you wanted to add that I forgot to ask you about?

Appendix C—Matrix of Interview Data

product	volume per year	volume per model	demand known ahead of time	high mix low vol	high mix low vol score	families
ships	1/5	1/5 per year	yes-- long term schedule	yes because they are making many pipe assemblies for different parts of the ship, which are not the same.	3,000	no, though there are pipes and fittings which are assembled together but made separately
large electrical equipment	300 per year	1-20 per year	?	yes	200	not enough of any one type to make product families, though they did attempt to.
desktops, servers, storage laptop	7,200k items	0-200k (approx) of each model per year	no, all built to order	yes in a sense because 10 categories with 4 choices each = many possible combinations, but essentially high mix high volume	14	yes-- separate lines for severs, desktops etc, but on each line any configuration can be made. Kitting stage first, which is unusual---but allows for maximum configurations with one inventory point, and kit is processed to order and assembled within an hour.

product	volume per year	volume per model	demand known ahead of time	high mix low vol	high mix low vol score	families
electrical cabinets	25k-30k items per year	0-200 per year	no, mostly build to stock, except low run skus that are built to order.	yes-- top 180 skus, made about 150 of each per year	12	yes-- general sizes and combinations of "guts" with standard interfaces like a Dell PC
circuit card assembly	20k items per year	10-2,400 per year	2 week lead times, demand is steady but made chunky by monthly orders. 4 week buffer at customer end implemented for pull system.	yes because most products 6-12 per month, and some products demand is very lumpy over the year	7	200 products
aerospace machined components	19k per year	2-900 per year	yes, but can change and very volatile	yes	5	material is a distinguishing factor. Also some follow the standard process and some don't -- tried to divide according to this.

product	volume per year	volume per model	demand known ahead of time	high mix low vol	high mix low vol score	families
circuit assemblies	100-300 packages per year	2- 50k per year	yes	yes because there isn't a way to make one at a time for the wafers	4	5-10 families with 1-4 products each
low voltage cable	47k kilometers per year	1k km to 20k km per year	not much lead time	no but all 6 types run on one line	0.2	6 families of cable (that's what the volume per model numbers refer to in this case)
film	10's of millions of rolls per year	1k-30,000k per model per year	high volume items built to stock, low volume items built to order-- based on visual kanban	low mix, but high mix of packaging-- high volume	0.07	yes-- similar types of film-- spooling is pretty constant. More changeovers in packaging. A family and B family-- A = high vol items-- make in lots > 4 pallets to stay under capacity. B items make just what is ordered.

product	volume per year	volume per model	demand known ahead of time	high mix low vol	high mix low vol score	families
motor vehicles	84k vehicles	10-10k per model	no, assembled to order from a set of components	no-- high volume. Only 27 combinations, and max of 4 possible parts at any assembly station	0.01	no, one line
gears, spindles, relay rods, axles	40,000k parts per year	500- 8M of each part per year	schedule made 1 week in advance but orders come in through a pull system.	high volume, med mix	0.0004	5 product families range from 10-30% of production each. Total of 8 product families and 100 different products.
radar packages	150 per week	7800 per year (all one model)	no, trying to produce to each day's demand and not build inventory	high volume	0.0001	no

product	assembly process	machining process	lines around product families?	company attempting to apply lean?	company attempting to apply 5s?	company attempting to apply 6-sigma?
ships	pipes and fittings put together to make details, details + externally sourced valves make up assemblies. Assemblies go to the platen and then pieces put together in dry dock. The assembly shop has 20 different projects going on at the same time.	pipes and fittings manufactured in two different shops.	no, not clear how inside of assembly shop is organized	yes	yes	yes
large electrical equipment	winding (with a lot of process variability) followed by assembly of windings with other purchased components.	the winding sometimes involve clamping and heat treat-- but many windings are purchased ready-made	no, not able to find enough volume for second line	yes	yes	no
desktops, servers, storage laptop	manual or automatic part picking, and then parts are put in a tray and routed to free assemblers who assemble based on instructions off a computer screen. RFID tags scanned to check that correct parts are being assembled-- on a per order basis and then off to testing, software installation. Then to boxing, additional pick operation and finally shipping.	none. All parts purchased from suppliers.	only at a high level. Within servers, any assembler can do any box.	yes	yes	yes

product	assembly process	machining process	lines around product families?	company attempting to apply lean?	company attempting to apply 5s?	company attempting to apply 6-sigma?
electrical cabinets	after painting the cabinets are fork lifted 200 yds to a storage buffer from which they are pulled for assembly. Batch size of 5 in assembly-- go from 80 skus of cabinet to 300 skus of finished cabinets depending on what "innards" are installed. About 5 different configurations for most sizes of cabinets. assembly is done to an MRP plan with minimum reorder points in the finished goods and "cabinet stock" locations. Low run skus are built to order.	stamping and bending stage: highly automated. Welding stage:5 pieces are put together out of a buffer and welded. Because of mounting mechanisms, welding runs three products at once. Loaded onto pallets and moved to powder coat where they are painted.	no	yes	no	no
circuit card assembly	2 assembly cells, most products start automated mount, then semi automated, then by hand. Automated side has one line with a buffer hand off to manual assembly. 2 manual assembly cells, 1 cell= 1 product family, 1 cell= the rest. Each product family assembled around a bench with point of use parts and some worker specialization. Product families = 4-50 products	none, except the machined assembly area which is shared between product families	yes, cells and within that, benches dedicated to product families	yes	yes	yes
aerospace machined components	n/a	first step is turning with long setups and short runtimes, second step is blade milling with short setups and long runtimes.-- then a few other steps but much shorter relative to the first two-- honing, turning and grinding-- which are highly variable per part and limit the ability to put parts in families. then a set of common steps (balancing, spin, penetrant, anodization, final inspection)	trying, but not implemented yet	yes	yes	yes

product	assembly process	machining process	lines around product families?	company attempting to apply lean?	company attempting to apply 5s?	company attempting to apply 6-sigma?
circuit assemblies	automatic assembly, 3 machines, each product requires at leas two machines to complete processes. Not all the products go through all the steps, some go through in a different order-- re-entrant flows.	none, all components procured from outside.	attempting to put in 2 lines, 3 families each	yes	yes	yes
low voltage cable		copper rod drawn to different diameters, then extrude with insulation material on outside, then combine to units of multiple bundled pairs, then sheath on outside. 6 main processes, most types go through most steps	no. all types of cable use the same machine and go through most process steps (though there are major types-- no dedicated lines)	yes	yes	not really
film	lithographed metal sheet is made into the can. Film imported from France and put on the spool and in the can. Then back plastic can with the grey lid, and finally into packaging.	none-- except making cans which are the same	no, except 1 new one that is very mechanized all the way through-- seems to be used for high volume items-- side benefit that it has gotten the depts. talking	yes	yes	yes

product	assembly process	machining process	lines around product families?	company attempting to apply lean?	company attempting to apply 5s?	company attempting to apply 6-sigma?
motor vehicles	35 assembly stations, 130 parts per finished assembly-- the variability is in the color of parts, or a different engine is mounted, etc-- but consistent interfaces so that the guy mounting engines can put on the big or small one based on the order.	marketplace after machining for the parts made in house-- crank cases, rocker boxes, heads... warehouse after machining that acts as a buffer before assembly. They want to do JIT, but they use the buffer.	no	yes	yes	no
gears, spindles, relay rods, axles		each dept (part family) has 5 presses-- all ops done automatically within one press. Parts come out of the press every 6 seconds, and spend 20 minutes in it. Setups officially 30 min but actually 60 min-- tend to feel constrained to two setups per day.	yes-- departments around product families and a few presses within each department, products can move around (I think, between those presses)	yes	no (but unofficially, yes)	no
radar packages	20 operations with buffers in between and balanced flow goal. Buffer size = 6-36	none	n/a	yes	yes	yes

product	outsourcing as a capac management tool	point of use stocking of parts or tools	standard work reconciled with product complexity
ships	problems with outsourcing delays, but not sure if outsourced work was because of lack of capacity. -- likely technical problems with suppliers causing delays	no-- only JIT delivery of assemblies to dry dock	no standardized work except nuclear processes because all the work is one-time. Work instructions come with the engineering drawings.
large electrical equipment	Yes. They outsource about 50% of windings. Receive all the materials for their suppliers into plant and distributed them with the job information. Suppliers may not be able to purchase raw materials for a good price. Challenge: how to integrate these small shops with internal pull? No idea what these suppliers do when the demand goes down since their tools and skills are pretty specific	yes. Challenging to find space on the floor for all this. Did it by reducing some of the WIP and sending away some old machines that were not used anymore. Also challenging to find a budget for point of use tools-- people say they want them but need money for duplicate tools.	Each piece of equipment so custom that it is hard to make the work instructions general enough that they apply to many, but are useful for each. Also many references to drawings-- need to know where to look. Supervisors provide a lot of technical guidance.
desktops, servers, storage laptop	yes in terms of labor, but not physical production. The challenges are training and lower quality from "outsourced" work, and lower productivity on an individual basis. Also mitigated by simple modular assemblies that require little training to put together well.	yes for tools, no for parts. Kits shipped to point of use.-- single stock point where picking is done. Kit to order. There is one server line that has point of use with balanced flow and it is more productive when it is running but often needs to be shut down--not enough flexibility which leads to poor capacity utilization.	if you are in the top half of productivity you just need to get the right parts and you can build any way you want. If you are in the lower half of productivity you get trained on the most efficient order to build. Red flag on monitor for indications about odd things in build. scanning for error proofing and notice about missed parts.

product	outsourcing as a capac management tool	point of use stocking of parts or tools	standard work reconciled with product complexity
electrical cabinets	no, they were overcapacity	yes, point of use bins for assembly guts, with replenishment bins 20 m away. (several stock points) but only a few parts or subassemblies to mount in each box.	BOM acts as standard work, because it is clear how to install the parts if you know what they are-- and everyone has been around for 10 years, so there is little variability.
circuit card assembly	no	yes, but parts used by different cells, so to avoid 10 points of inventory, operator does mini-kitting for shared parts. Still secondary stores location. Need to think about form factor etc for point of use-- not great for short term or evolving products because it is such a rigid system.	standard work for assembly is on PC's and the engineers keep it updated. The inspection requires more training. Experienced operators are better at assembly, but in the end everyone uses the work instructions because everyone is making so many different boards.
aerospace machined components	no	not relevant to machining in this situation	trying to take the critical thinking out at the worker level but the standard work is not yet at that level of detail. Definitely a challenge to keep it up to date and in any case you nearly always find exceptions to the standard work in a complex product environment or multi-model cell. Tremendously labor intensive to keep everything up to date.

product	outsourcing as a capac management tool	point of use stocking of parts or tools	standard work reconciled with product complexity
circuit assemblies	no, it was used by the company but not in his area	no	does not exits for small assembly tasks that take up most of the time, only used for machine setups
low voltage cable	no	some point of use for colored binders and tapes-- also getting smaller shipments of things like PE and PVC-- worked with suppliers to only get 1-2 tons at a time instead of 20. limit WIP with drums that can not be exceeded. Hard to figure out the right level of WIP	tried to standardize process from shift to shift rather than little books of instructions.-- tried to combine these into one set of instructions that everyone could use. -- this allows measurement on same basis and statistical tools have some meaning. Critical thinking is key in learning to solve problems and thinking about cause and effect. "Standard work is a way to set a foundation so that you can rely on data and do critical thinking to improve your process."
film	no	yes, use point of use stocking for cartons of high volume items. For low volume items, they just bring the packaging to the side of the line 8-12 hours before it is needed (this causes even more problems when expediting or people switching cards in the manual kanban system.	no real standard work or work rules. If you were to ask somebody what jobs they do and what order they do them in they would say: "I just look around and see what needs to be done"

product	outsourcing as a capac management tool	point of use stocking of parts or tools	standard work reconciled with product complexity
motor vehicles	no	no-- used point of use tools and part, but only a couple of tools and parts at each assembly station on the line	no-- not reconciled with changes in a consistent and accurate way. Changes are made about 4 times per year per assembly guy but work instructions only brought up to date once a year.
gears, spindles, relay rods, axles	not yet but about to. Challenge of getting specific suppliers approved and up to speed. Very bureaucratic approvals process-- need to prove that there are no other possibilities and still get three quotes-- not a short term possibility as a response to demand.	yes-- but there are only 3-4 tools per machine	"the quality department has lots of time". So yes, they are kept up to date-- but the operators basically are fairly low skill and only need to put the material in the machine. --machine does all of the complex steps automatically-- worker expertise does not enter into it much.
radar packages	no	yes for both-- pour tools is in the plan but has not been implemented yet. Pour parts is ok because only 2-5 parts assembled per station	standard work is on a computer and they are building to the instructions on a screen. For legal reasons (contractual?) it has to be kept up to date and it is.

product	simulation and analytical tools	biggest problems with lean
ships	use simulation to schedule production--complex processes with sequential interdependencies. They do not use analytical optimization because things are too complex and everything changes-- hard to model in a consistent way-- whereas in a simulation you can reset it with a new parameter value and run it again if something changes--cumbersome to re-run it, but seems to work when things are too complicated for an analytical solution.	a. hard to have the impetus to go lean since they are a monopoly. the shipyards have not bought into lean, politics between the VP's take precedence over solving lean problems.--problems with incentives. b. functional silos make it hard to solve logistical or supply problems at an interdepartmental enterprise level--the problems show up in production and assembly gets blamed. Among other departments there is a "not my fault/not my problem" attitude--esp. engineering not pro-actively solving problems c. high internal demand variability for parts, and poor logistical control-- makes it very difficult to do JIT delivery--they try but 90% of parts are early or late. d. poor use of kanbans: e.g. a part for which you need 400 at only one time in the entire shipbuilding process, they keep a kanban of 50 in stock.--most of the time, that is too much, and at the time you need it, it is not enough.
large electrical equipment	simulation is useful because it allows you to model the variability in detail, but it is time consuming to do so. The problem with a lot of analytical tools (which were used) is that they rely on averages. Ok for figuring out a conwip level (which is about averages) but not so good for some other things where variability counts.	a. hard part of CONWIP to grasp: why do I want to hold on to these orders when my machines are empty? How can CONWIP levels be changed to accommodate things out of your control and not shut down the shop? b. convincing people to do work instructions and visual management systems when things already work. Work instructions do not stand alone, because of variability in products. Can't have 200 kinds of precise work instructions ($$ of producing, maintaining)
desktops, servers, storage laptop	lot size of 1, always. So not tool for planning lot sizes. There are some tools for capacity (HR) management--excel based headcount model. Only assembly though, so there are no re-entrant flows or variable process times, or shared resources, or variable setups to deal with.	a. build to order is in direct contradiction with level loading. Means that they sometimes have to send people home. b. minimize fixed costs and keep workers as part of variable cost that can be managed to meet demand-- well developed training and a flexible non-union workforce. Extra capacity of build cells, but these have a very low cost of setup. c. people reject lean for its name even through they are already doing many of the principles. d. there is a lot of excess material movement, which is different from lean. also, not point of use stock, areas not immediately adjacent, buffers and queues everywhere (though they are short). but this allows for flexibility and responsiveness to different build times (don't need to make constant takt).

product	simulation and analytical tools	biggest problems with lean
electrical cabinets	simulation is good for modeling shared resources-- to understand the impact of batch sizes and different groupings-- impact on capacity and throughput. Simulation is good because it allows you to take the actual data distributions and test out hypotheses, rather than using a pretend approximation distribution. (in high-mix low volume where the variability is high, the distribution might even change with years which makes it especially hard to model because there are few data points). no risk that you are making wrong assumptions-- BUT unwieldy to model with current tools. People give up on modeling certain bottlenecks analytically because they are too complex.	a. build what you need first, not safety stock (which justifies large batches). b. what to do when we have "nothing to build"? Hard to convince them to shut the line down. Strong drive to use extra capacity. C. people not doing their part in the kanban system (not moving the cards or registering process completion). No discipline about new processes despite strong discipline about old processes. d. hard to transition between computer tracking systems and visual tracking without duplicating work.-- which one is the authority
circuit card assembly	used a simulation tool called witness, but it was difficult to model single piece flow, variability and re-entrant flow. A lot of work to get all the parameters right for the simulation to be valid. Sometimes you are better to just go and test stuff out on the floor. Also hard to test the validity of a simulation, whereas in an analytic solution, easier to see if there are wrong assumptions.	a. shoehorning lean tools into the process does not work. You need to make the major changes to make things flow in the whole system b. lifespan of product affects the amount of investment that you want to make in point of use, standard work, or balancing a flow line (over how many products are you actually going to reap efficiencies?)
aerospace machined components	a. they are not tackling the variability from an analysis standpoint-- but they are trying to eleiminate some of the root causes of the variability for example-- variability in demand-- b. good analysis is extremely time consuming and it is easy to get sucked into fighting fires which they have done c. he leans toward simulation if you have variability from routing or setups, within processes (setups and runtimes) or in demand. Simulation is good because it allows you to test hypotheses and focus on the things that are going to help your business the most. Analytical solutions like excel are inherently deterministic-- you have to make many assumptiona about capacity or availability of workforce-- all of these averages in the parameterization result in GIGO.-- doesn't take in to account timing and synergistic problems of variability. d. capacity base lot sizing is a good way to work out lot sizes and account for people's time. EOQ has problems because it attaches no value to flow.	a. very hard to find standard parts or processes-- not a lot of commonality and very variable demand month to month. The standard routing is not standard to more than half the parts and many are re-entrant to the standard routing-- very hard to identify families for VSM b. hard to do line balancing because of volume and process variability-- different sequences make it difficult to staff line stations without waste c. hard to really understand how changes will pan out in procatice, what will be the effect on WIP, cycle time, inventory etc-- esp given variable volumes.--used simulation rather than excel d. in low volume, when you make a change, you need to let it just settled down before you evaluate if it's working-- you can't just start tweaking and cont. improvment right away. -- if low volume with half day takt times, it takes a while to see if the change has the desired consequence or if you are just looking at statistical noise.

product	simulation and analytical tools	biggest problems with lean
circuit assemblies	simulation used mainly as a tool to explain things like conwip system to people. Spreadsheets are fine for capacity modeling and eon	a. benefits of lowering inventory not universally understood (engineering pushing for low setups to reduce unit costs) b. no cost accounting for inventory c. not possible to do single piece flows, but smaller batches with conwip and buffers work well d. danger of confusing tools of lean with principles of lean: single piece flow is a tool to reduce WIP and inventory e. understand which sources of variability really affect performance of the product and only try to control those (not sure about this one)
low voltage cable	he would have used a spreadsheet but " is not a big spreadsheet guy" so he modeled some things (movement of drums) manually. He thinks that once the processes were a little more reliable and stable he could have modeled lot sizes and capacity using crystal ball (dynamic simulation). -- but need to have 80-90% uptime to make it worthwhile and make it possible to model the supply (machines and labor availability) constraints to the problem.	a. resistance of floor supervisors-- bursts of progress but always need impetus-- not self sustaining. Also resistance from union b. problems with interaction between production, engineering and maintenance came to the surface and so engine and maintenance very resistant of scrutiny and taking responsibility-- more worried about protecting territory than about solving problems. c. illiteracy creates challenges in forming continuous improvement teams and giving more responsibility to people on the shop floor.
film	use a "Lego simulation" moving Lego bits around the factory in discrete periods. This is mainly used to understand flow, but too manual to be used for capacity planning. He used some excel analytical tools to work on lot sizing and capacity and thinks that this is the way to go (at least in this environment)	a. metrics only changed 6 months ago to encourage smaller lots-- people want to run high volumes and get it out the door-- b. pick out kanban cards to do the big lots-- but then leave a whole lot of small lots of uncommon stuff for the next shift. also problem with expediting some orders for demanding markets c. all visual management systems "don't trust ERP"-- god but fragile-- hard to deal with stock outs

product	simulation and analytical tools	biggest problems with lean
motor vehicles	no	a. hard for people who used to be paid on piece rate to no overproduce. Hard to get them to work to takt time. They don't like having the machine stopped. They don't like having to meet a target rate each day, fee like an average should be good enough. They feel like tracking production is like being policed-- not clear (even to intern) that the numbers are actually being used to reduced process variability b. union--mgmt tensions "I won't do this because you didn't do that"-- workers have not bought into, and are not participating in, lean
gears, spindles, relay rods, axles	used simulation mainly for explaining to people about system dynamics. Fairly steady demand so analytical models worked well. Able to do averages and standard deviations and figure out what inventory levels would support what kind of service levels.	a. hard for people to deal with increasing number of setups (the corresponding reduction in inventory doesn't mean much because the inventory had previously been sorted in a warehouse: so no VISIBLE change) b. often inventory targets are unrealistically low (and arbitrary levels that are not negotiated or based on expected improvements from certain changes) which leads to c. c. managers set up metrics in a way that "games" the system, to meet the unrealistic objectives-- which in turn de-motivates people from producing real change. d. project champions are often from engineering and have little leverage in the group where they are trying to make the change.
radar packages	Raytheon uses simulation software for a lot of their high-mix low volume stuff, but chose not to use it here because of high volume line flow, high replicability-- major challenge was just to even out takt times.	a. hard to understand pull, hard to understand that buffer can be smaller than daily throughput. b. firefighting and changing priorities reduce effectiveness of approach-- hard to focus. c. operator training in Lean needs to be more thorough and closer to the time of implementation, need more emphasis on benefit of lean to workers.

Appendix D—Analysis of Cost of Obsolete Parts

Calcul du cout des stocks historiques, dépréciés et / ou ferraillés

Base de départ : stock déprécié en 2003– approx 2,8M corespond à la période 1995-2003 (8 ans)
+ stock passé en historique correspond à la pérode 2000-2003 (3 ans)

Ajustements:

1

stock déprécié en 2003-- approx 2,8M

- affaire Dornier
- affaires non-stabilisées

TOTAL ajusté: € 1,702,779

- affaires terminées ou réduites
- surstocks achats

évalué par département-- voir détail page suivante

TOTAL ajusté 2: € 1,161,651

moyenne par an sur 8 ans: € 145,206

2

stock passé en historique

- affaire Dornier
- affaire Tornado

€ 1,069,106

moyenne par an sur 3 ans: € 356,369

moyenne TOTALE/ an € 501,575

stock déprécié en 2003-- approx 2,8M

- affaire Dornier
- affaires non-stabilisées

TOTAL ajusté: € 1,702,779

F5	€ 889,440
F2	€ 590,563
F1 + F2 + F3	€ 222,776
TOTAL	€ 1,702,779

- affaires terminées ou réduites
- surstocks achats

F5 analyse faite et les modifs représentent	€ 429,029 =	48% du total pour le département		
F2 analyse faite et les modifs représentent	€ 509,846 =	86% du total pour le département		
F1, F3, F4 pas d'analyse mais on prend le petit %age	48% =	€ 106,932	sur le	€ 222,776
Total	€ 1,161,651			

PROPOSAL FOR ENGINEERING CHANGE COST SUMMARY

EC No.
Dist. Code

COST DATA FOR PROPOSAL

☐ MANUFACTURING COSTS
☐ INHERENT COSTS

TEMPORARILY WAIVED

AUTHORIZED SIGNATURE & DATE

MANUFACTURING COST (IN DOLLARS)					$ INCREASE	$ DECREASE	TOTAL INCREASE	TOTAL DECREASE
CHANGE IMPACT COST								
#	CODE	DESCRIPTION	TYPE OF CHARGE	ACCT NUM.				
1.	A	SHOP PARTS REWORK	LABOR	70710				
			MATERIAL	70850				
2.	B	PURCHASE PARTS REWORK	LABOR	70710				
			MATERIAL	70850				
3.	C	SHOP DURABLE TOOL INITIAL	LABOR	72410				
			MATERIAL	72420				
4.	D	SHOP DURABLE TOOL RR&M	LABOR	72430				
			MATERIAL	72440				
5.	E	VENDOR DURABLE TOOLS	MATERIAL	72500				
6.	F	SPECIAL PERISHABLE TOOLS	LABOR	72410				
			MATERIAL	83070				
7.	G	STD. PERISHABLE TOOLS	MATERIAL	83090				
8.	H	SCRAP OR CANCELLATION	MATERIAL	70850				
9.	**TOTAL CHANGE IMPACT COST (ITEMS 1+2+3+4+5+6+7+8)**							
COST PER ASSEMBLY								
10.	MANUFACTURING COST PER ASSEMBLY							
11.	ASSEMBLY COST PER ASSEMBLY							
12.	ACCEPTANCE TEST COST PER ASSEMBLY							
13.	SUB-TOTAL COST PER ASSEMBLY (ITEMS 10+11+12)							
14.	**TOTAL (SUB-TOTAL ITEM 13 X ASSEMBLIES AFFECTED)**							
	ENGINEERING COSTS (IN DOLLARS)				**INCREASE**	**DECREASE**		
15.	ENGINEERING CHANGE COST				$ 650.			
16.	SPECIAL TEST COST							
17.	DESIGN COST							
18.	DRAFTING COST							
19.	TOTAL (ITEMS 15+16+17+18)							
20.	TOTAL SPARES AND/OR KITS							
21.	**GROSS TOTAL (ITEMS 9+14+19+20)**							
22.	**NET COST OR SAVINGS**							
INHERENT COSTS (IN DOLLARS)								
23.	INHERENT COST CHANGE FOR ENTIRE REQUEST (+ & -)							
24.	NET INHERENT COST INCREASE OR DECREASE							

☐ PROCESSING COSTS ONLY	ORIGINATOR	PROD. CONTROL APPROVAL & DATE

HSF - 505.6B 1/98 ESM3223

Appendix F—Responsibility Matrix for Engineering Changes

		Methodes	BE	Production / Maintenance	Achats	Commercial	
ANALYSE		• cout administratif du changement (design, dessins, dissemination) • couts de production eventuels (reduits et augmentés)		• valeur et nombre de pièces en stock qui deviendront obsolètes	• valeur et nombre de pièces commandées qui deviendront obsolètes • cout de nouvelle matière, pièces à acheter, réqulification sous-traitant	• gains eventuels prix client ou nouveaux marchés • valeur des commandes clients qui affectenteraient la dépréciation des pièces obsolètes	
DECISION							
GESTION	QUAND?	• définir plan de nouvelles versions	• définir catégorie de modification (obligatoire? Faire de suite et laisser de coté autres infos)	• nombre d'ensembles à produire avant épuisement des stocks et commandes	• pièces déjà commandées • contraintes sous-traitance pour changement eventuel à nouvelle pièce	• définir plan de nouvelles versions. • vente de pièces de rechange? quel taux de consommation?	
	DECISION DE LA DATE DE MISE EN PLACE DE LA MODIFICATION						
	COMMENT?	• etre prêt pour mettre en place les modif comprises dans une nouvelle version le jour prévu (plans au poste, nomenclatures mises à jour etc.) • definir dossiers et normes d'inspection pour les FAI (pièces fabriquées)	• definir dossiers et normes d'inspection pour les FAI (pièces achetées)	• gestion physique du stock- définition nouvel emplacement et épuisement du stock obsolète • prendre en note les commandes client pour pièces obsolètes et affecter dépréciation au département simultanément • franchir FAI pour nouvelle pièce avant la dat	• pièces a approvisioner jusqu'à la date de modif et pas plus • changement de gestion achat dans SAP ou SFT?	• renégociation du prix ou négociation nouveaux marchés • faire passer commandes client pour pièces obsolètes et affecter dépréciation au département simultanément	déjà peut-etre défini par d'autres processus

Appendix G—Tool Developed for Engineering Change Cost Analysis

ANALYSE FINANCIERE D'UNE DEMANDE DE CHANGEMENT

N. de la Modif:	Client:	Classification de la modification: (voir processus RF0061)
Avis de diffusion:	Departement:	obligatoire ☐ recommandee ☐ facultative ☐
Article:	# en stock ou commandés*:	*s'il y a lieu, attacher une feuille avec pièces, stocks, et carnet commandes
Date de l'analyse:	besoins mensuels*:	

			Augmentation (Euros)	Reduction (Euros)
Date ou rang proposé de mise en place:		ou interchangeabilité ☐		
COUTS NRC DU CHANGEMENT SUR LES ARTICLES				
n description	*cout unit. fabriq + matiere*	*quantite*		
1 retouches sur pieces				
2 pieces rebutees				
3 outillages de fabrication et contrôle fab.à RF				
4 outillages de fabric et ctrl fab.ST ou achetés				
5 Total des couts NRC sur les articles (1 + 2 + 3 + 4)				
COUTS RECURRENTS DU CHANGEMENT (ARTICLES)				
description	*taux en Euros cout direct*	*Δ temps (h)*		
6 Cout fabr. + controle RF par ensemble	130			
7 Cout fabr. + controle S/T par ensemble	130			
8 Cout achats pièces par ensemble				
9 Cout matière première par ensemble				
10 Sous-total couts recurrents (6 + 7 + 8 + 9)				
11 Total couts recurrents = 10 * nombre d'ensembles affectes				
COUTS ADMINISTRATIFS NRC DU CHANGEMENT				
description	*taux en Euros cout direct*	*temps (h)*		
12 Cout administratif du changement			500	
13 Etude/ modif gamme fabrication/ retouche	40.59			
14 Etude/ modif gamme controle	97.17			
15 Dessin outillage	40.59			
16 Programmation usinage	40.59			
17 Programmation controle	97.17			
18 Mettre à jour la definition (conception, dessin)	47.86			
19 Mettre à jour la justification (calc, RMS, essais)	47.86			
20 Réqualification de la sous-traitance (FAI)				
21 Réqualification pieces achetees (FAI)				
22 Tests et essais internes	64			
23 Service après vente, documentation				
24 Vente de pieces historiques (commerical)	marché de rechange? Oui ☐	Non ☐		
25 Total couts administratifs NRC (12 + ...24)				
26 Total couts non recurrents (5 + 25)				
BENEFICES DU CHANGEMENT				
27 Amelioration qualite (%age amélioration des pièces bonnes)				
28 Profit qualite = rentabil.affaire * 27 * nombre d'ensembles affectes				
29 Nouveaux prix client = augmnt.revenu par ensmbl * nbre d'ensmbls				
30 Nouveaux marches: nombre d'ensembles * rentabilite				
TOTAL (26 + 11)				

Amortissement sur #DIV/0! articles	date ou rang de mise en place:
COMMERCIAL impact sur concurrence du au changements de performance	emetteur
RECHANGE décrire le marché (# par an, etc)	**DECISION** on le fait ☐ refusé ☐ **DATE de décision**
DELAIS impact qualitatif sur les engagements déjà pris avec les clients	**signature** du Directeur technique ou du Chef de Projet

PROCEDURE :

ANALYSER LA RENTABILITE D'UN CHANGEMENT DE DEFINITION

Objet :

Ce document à pour objet de formaliser l'analyse de la rentabilité des changements aux dossiers de définition (modifications des produits) au niveau de l'entreprise.

Cette procédure et ses règles de gestion sont accompagnées d'un outil d'analyse (FOR-DN0162) pour faciliter l'identification des coûts et des bénéfices qui peuvent être entraînés par un changement.

Propriétaire du document :
Sébastien MOUNIER, Responsable Coordinateur des Projets en Développement

Date de mise en application (JJ/MM/AA) :

Langue de référence :
En cas de litige, seule la version française de ce document fait foi, sauf exigences contractuelles contraires.

Confidentialité :

1. DOMAINE D'APPLICATION

Ce document s'applique au matériel de conception DAUGY-NAUDIER

Il entre en application TOUJOURS lorsqu'une Demande de Changement de Définition (DCD) est complétée (cf. PRO-DN-0061) sur le matériel ET les équipements SAUF dans les cas suivants :

a. le changement entre dans le budget d'une affaire nouvelle et que la spécification la plus récente ne change pas (voir définition ci-jointe d'un e « affaire nouvelle »)

b. le changement est dans le cadre d'une DCD déjà appliquée

c. le changement ne nécessite pas de DCD et n'a aucun impact sur les stocks

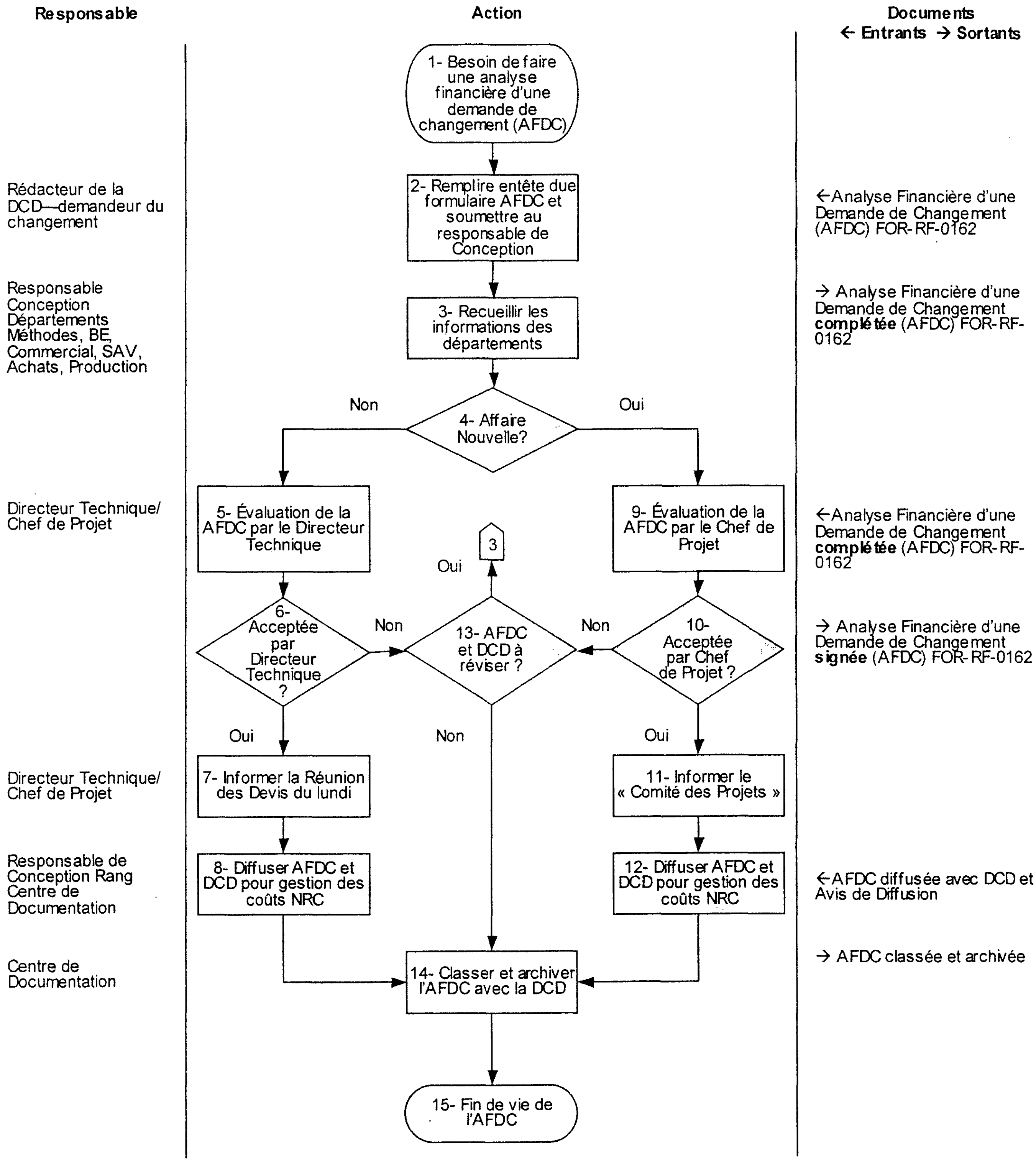
d. dispensation du Directeur Technique

2. PRECAUTIONS ENVIRONNEMENT, HYGIENE ET SECURITE

Ce processus ne nécessite pas de précautions environnement, hygiène et sécurité particulières.

3. PROCESSUS

I. LOGIGRAMME



II. DESCRIPTION DU LOGIGRAMME

Point 1
Le besoin peut avoir pour origine

- le lance ment d'un nouveau dossier de définition (lors d'un changement de matériel)
- la demande de changement sur un dossier de définition existant

L'analyse de la rentabilité se fait TOUJOURS pour les demandes de changement qui ont passé le seuil de faisabilité technique (point 3 de la procédure PRO-DN_0061) et qui entrent en considération, SAUF dans les cas suivants :

a. le changement entre dans le budget d'une affaire nouvelle et que la spécification la plus récente ne change pas (voir définition ci-jointe d'un e « affaire nouvelle »)
b. le changement est dans le cadre d'une DCD déjà appliquée
c. le changement ne nécessite pas de DCD et n'a aucun impact sur les stocks
d. dispensation du Directeur Technique

Point 2

Toute analyse financière d'une demande de changement doit être résumée sur le formulaire FOR-DN-0162, qui permet de recueillir des données de divers départements et de trancher sur la rentabilité à l'entreprise entière. Le demandeur du changement de définition remplit l'entête du formulaire selon le guide GUI-DN-0022 et le soumet avec la DCDE ou la DCDI (Demande de Changement de Définition Interne or Externe) au Concepteur .

Point 3

Le Responsable de Conception contacte les départements concernés pour avoir les informations nécessaires à remplir les cases de l'AFDC (FOR-DN-0062, analyse Financière du Changement de Définition) . Les départements sont tenus à fournir les informations sous peine de responsabilité comptable éventuelle pour les coûts non reportés.

Les documents en support de l'analyse étant éventuellement utilisés à l'intérieur des départements (Devis etc.) peuvent être ajoutées en annexe ou sur les feuilles suivantes du même fichier Excel s'il est électronique.

Point 4

Il est envisagé, lors de la formation du Comité des Projets et de la formalisation des rôles de Chef de Programme, d'avoir deux systèmes de décision parallèles : un pour les affaire stabilisées et un pour les affaires nouvelles. Le système d'acceptation « Affaires nouvelles » permettrait un passage plus fluide (moins lourd) des changements occasionnés par les activités normales de développement.

Cependant, Jusqu'à l'établissement formel du comité de changement , toutes les demandes de changement passeront par la branche « gauche », c'est à dire par l'accord du Directeur Technique et le rapport à la Réunion de Devis du lundi.

L'expression « affaire nouvelle », dans le contexte de cette procédure, est définie ci-dessous dans la section Définitions.

Point 5

Le Directeur Technique peut demander des précisions ou d'autres renseignements au niveau technique ou financier lors de son évaluation.

Point 6

Le Directeur Technique peut évaluer plusieurs options de changement qui répondent à un besoin et trancher entre elles, ou en évaluer qu'une seule. Si il y en a qu'une seule, il peut la renvoyer pour des changements techniques ou des changements qui peuvent améliorer les répercussions financières, ou simplement pour approfondir l'analyse financière.

Point 7

Le Directeur Technique est tenu d'informer la réunion des Devis du lundi des changements qu'il a accepté.

Point 9

Le Chef de Projet évalue les AFDC portant sur des affaires nouvelles en tenant particulièrement compte des répercussions sur le coût de développement total de l'affaire, et des stocks de développement qui seront éventuellement rendu obsolètes par ce changement. Ces stocks nécessiteront d'être dépréciés à la fin de la phase de développement.

Un rappel que les affaires nouvelles pour lesquelles

- le changement entre dans le budget déjà prévu

ET

- la spécification la plus récente ne change pas

n'ont pas besoin d'une AFDC.

Point 10

Le Chef de Projet peut évaluer plusieurs options de changement qui répondent à un besoin et trancher entre elles, ou en évaluer qu'une seule. Si il y en a qu'une seule, il peut la renvoyer pour des changements techniques ou des changements qui peuvent améliorer les répercussions financières, ou simplement pour approfondir l'analyse financière.

Point 11

Le Chef de Projet est tenu d'informer le Comité des Projets des changements qu'il a accepté, et peut éventuellement demander au « Comité des Projets » de trancher sur l'affaire.

CLASSEMENT ET ARCHIVAGE DES DOCUMENTS GENERES PAR LE PROCESSUS

Désignation du document	CLASSEMENT (C) / ARCHIVAGE (A)				
	Responsable	**Support et méthode**	**Lieu**	**Moment d'archivage**	**Durée d'archivage**
AFDC	Centre de Documentation	Electronique ou papier	Centre de Documentation	Dès validation du document	Durée de vie opérationnelle du matériel + 3 ans

4. AMELIORATION CONTINUE

DETAILS DES INDICATEURS DE SATISFACTION ET SUIVI

Référence et désignation de l'indicateur	Mode de calcul	Fréquence	Responsable
	Sans objet		

DETAILS DES REVUES DU PROCESSUS

Pilote	Propriétaire du processus
Participants	Représentants du BE, Méthodes Qualité/Production, Production, Commercial, Achats, Support client, Directeur Technique
Fréquence	Annuelle
Points abordés	Difficultés rencontrées lors de l'application du processus Impact des Retrofit (l'évaluation est elle assez profonde sur ce point ?)

CLASSEMENT ET ARCHIVAGE DES DOCUMENTS D'AMELIORATION

Désignation du document	CLASSEMENT (C) / ARCHIVAGE (A)				
	Responsable	Support et Méthode	Lieu	Moment d'archivage	Durée d'archivage
Comptes-rendus de réunions "revues de processus"	Coordinateur processus	Fichiers classés par année et par référence de compte-rendu	Disque partagé V : processus_DN/ archives	Dès diffusion	3ans

5. DEFINITIONS ET ABREVIATIONS

Mot ou abréviation	Définition
Affaire nouvelle	Dans le cadre de cette procédure : Pour un projet court (< 18 mois), le projet est dit en phase « affaire nouvelle » jusqu'à la fin de la qualification interne ET la certification du premier avion. Pour un projet long (>18 mois), le projet est dit en phase « affaire nouvelle » jusqu'à la fin de la fabrication des ensembles de qualification. Après cette date, l'analyse et la décision sur l'AFDC passent par le Directeur Technique.
AFDC	Analyse Financière du Changement de Définition
DCDE/ DCDI	Demande de Changement de Définition Interne / Externe
DN	Daugy-Naudier Naudier

PROCEDURE :

GERER LES STOCKS A LA SUITE D'UN CHANGEMENT DE DEFINITION

Objet :

Ce document à pour objet de formaliser les modes de gestion des pièces lors d'un changement au dossier de définition.

Il vise a faire un bilan sur contraintes de sécurité à observer et les moyens de minimiser les stocks obsolètes. Dans ce but, il définit les modes de gestion et de transition physiques, informatiques et comptables, entre les anciens et nouveaux articles et procédés.

Propriétaire du document :
Didier GAUBERT, Coordinateur Logistique

Date de mise en application (JJ/MM/AA) :

Langue de référence :
En cas de litige, seule la version française de ce document fait foi, sauf exigences contractuelles contraires.

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1. DOMAINE D'APPLICATION

Ce document s'applique au matériel de conception DAUGY-NAUDIER

Il entre en application lorsqu'une Demande de Changement de Définition (DCD) et son Analyse Financière de la Demande de Changement (AFDC) est acceptée et que le changement au Dossier de Définition affecte les stocks et/ou les en-cours de pièces.

Ce document définit des procédures à un haut niveau dans son logigramme principal, et approfondit les détails de la gestion dans les logigrammes de l'annexe A. Il est entendu que ces procédures détaillés évolueront au fil du temps, à mesure qu'évoluent les systèmes de gestion physiques et informatiques ainsi que les politiques d'achats et de sous-traitance de l'entreprise.

2. PRECAUTIONS ENVIRONNEMENT, HYGIENE ET SECURITE

Ce processus ne nécessite pas de précautions environnement, hygiène et sécurité particulières.

3. PROCESSUS

I. LOGIGRAMME

Responsable

12- production
11- méthodes + production

13- production
14- méthodes

Méthodes: préparation gammes

15- production
18- achats

16- gestionnaire production

19- gestionnaire production avec achats et éventuellement Directeur Technique

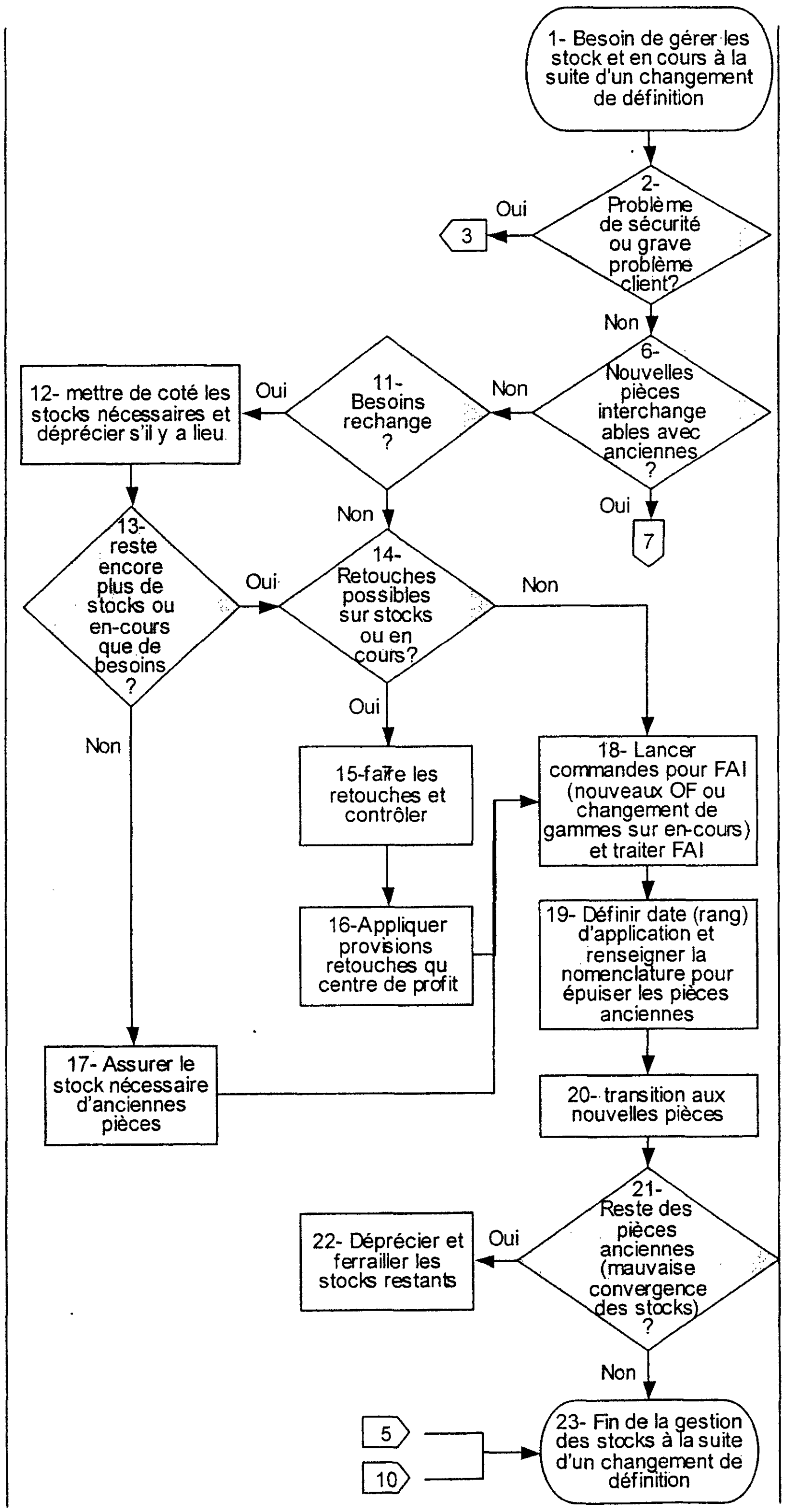
17- gestionnaire production

19- gestionnaire production avec achats

20-production/ magasinière

22- Gestionnaire

Action



Documents
← Entrants → Sortants

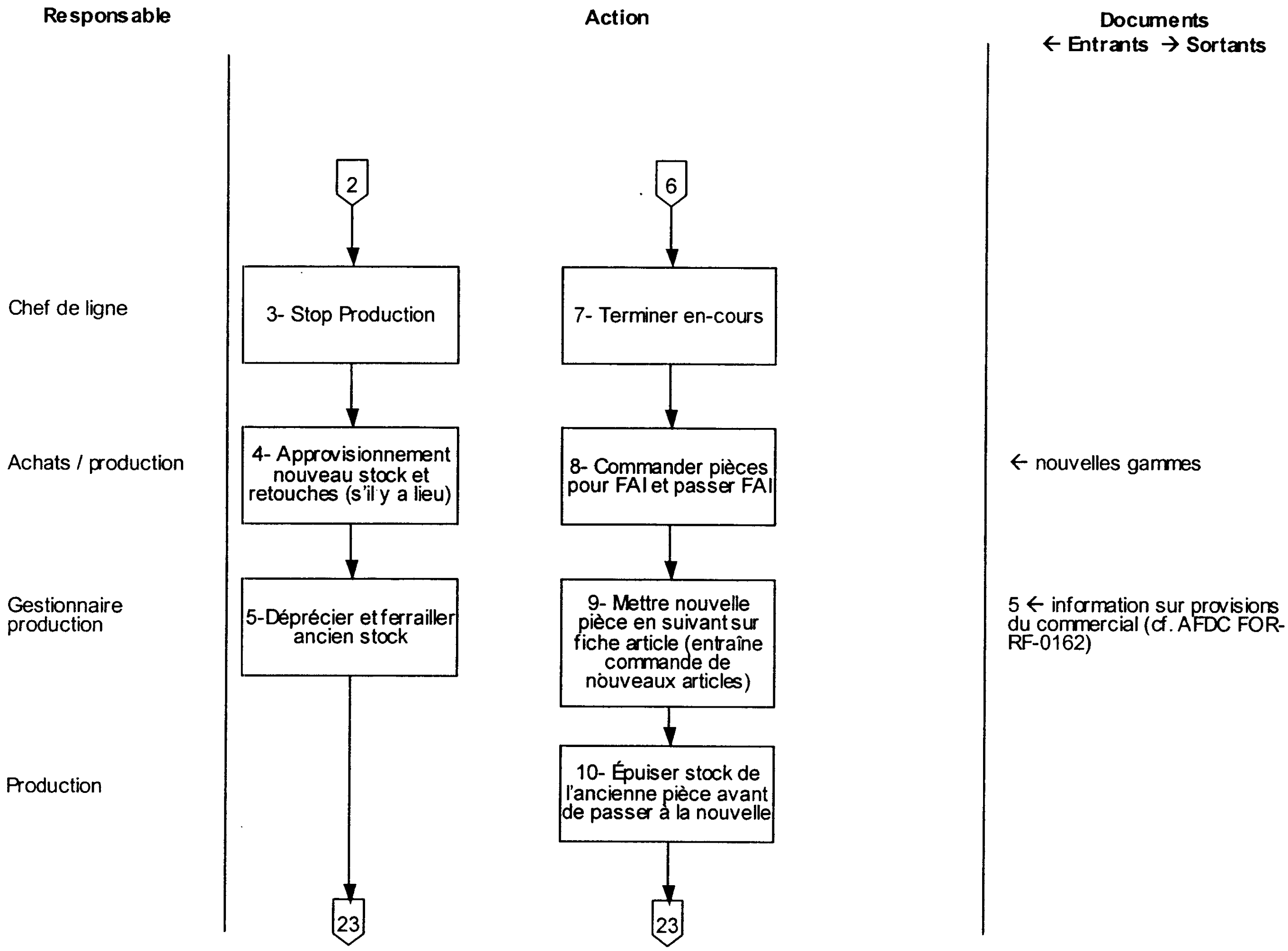
← DCD (FOR-RF-0049 ou 0050) / AFDC (FOR-RF-00162)

6 ← DCD (FOR-RF-0049 ou 0050) / AFDC (FOR-RF-00162)

← nouvelles gammes ou gammes retouche

16, 19 ← AFDC (FOR-RF-00162)
16 ←confirmation provision du commercial

16, 19 ← AFDC (FOR-RF-00162)
16 ←confirmation provision du commercial


Responsable
Action
Documents
← Entrants → Sortants
2
6
Chef de ligne
3- Stop Production
7- Terminer en-cours
Achats / production
4- Approvisionnement nouveau stock et retouches (s'il y a lieu)
8- Commander pièces pour FAI et passer FAI
← nouvelles gammes
Gestionnaire production
5-Déprécier et ferrailler ancien stock
9- Mettre nouvelle pièce en suivant sur fiche article (entraîne commande de nouveaux articles)
5 ← information sur provisions du commercial (cf. AFDC FOR-RF-0162)
Production
10- Épuiser stock de l'ancienne pièce avant de passer à la nouvelle
23
23

II. DESCRIPTION DU LOGIGRAMME

Point 1

Le besoin peut avoir pour origine

- L'acceptation d'un nouveau dossier de définition (lors d'un changement de matériel)
- L'acceptation d'un changement au dossier de définition

Cette procédure peut aussi servir de guide pour la gestion des stocks en fin de programme.

Point 2

Cette question s'adresse à la désignation du changement définie dans la PRO-DN-0061, dans le cas d'un changement dit « OBLIGATOIRE ». (« Un changement obligatoire a pour but de pourvoir à une configuration interdite de vol pour des raisons de sûreté ou réglementaire »). Si c'est le cas, ou éventuellement dans le cas d'un GRAVE problème client (selon acceptation du Directeur Technique sur l'AFDC), on passe directement à l'étape 3.

Dans ce cas, les stocks de l'ancienne pièce sont passés sous régime MRP et les stocks de la pièce remplacente seront gérés aussi sur MRP jusqu'à la stabilisation de la nouvelle pièces/ nouvelle source.

Point 4

L'approvisionnement du nouveau stock peut comprendre une requalification des nouvelles pièces ou de la nouvelle source. Les délais d'approvisionnement en MRP devraient donc être réexamines pour assurer l'arrivée ponctuelle des nouvelles pièces. (Sans changement, le délai serait égal au cycle d'approvisionnement stabilisé. Les commandes, passées au jour du besoin – le cycle trop court, arriveraient en retard).

Dans le cas d'un changement obligatoire, il risque d'y avoir un programme de rétro-fit. Ces besoins seraient aussi à prévoir avec le Commercial et le SAV en planifiant l'approvisionnement..

Les anciennes pièces en stock ou en cours peuvent être éventuellement modifiées avec des retouches. Voir le logigramme de retouches détaillé dans l'annexe A.

Point 5

Voir le logigramme de dépréciation et ferraillage détaillé dans l'annexe A.

Point 6

Si les nouvelles pièces ne sont pas interchangeables avec les anciennes, les anciennes devraient passer en gestion MRP, et les nouvelles devraient être démarrées en MRP avant de passer éventuellement en Kanban lorsque la nouvelle production ou source est stabilisée.

Si les nouvelles pièces sont interchangeables avec les anciennes, les stocks peuvent rester en gestion Kanban. Sur la Fiche Article, la date prévue d'application de la nouvelle pièce est renseignée, ce qui permet de déclencher le commandes de la nouvelle pièce.

Point 8

L'approvisionnement du nouveau stock peut comprendre une requalification des nouvelles pièces ou de la nouvelle source. Les délais d'approvisionnement (nombre de lots kanban dans la boucle) devraient donc être réexamines pour assurer l'arrivée ponctuelle des nouvelles pièces.

Point 9

Sur la Fiche Article, la nouvelle pièce est passée en « suivant » ce qui permet au montage d'assurer l'écoulement des anciens stocks avant d'entamer les nouveaux.. Au niveau physique, les nouvelles pièces sont stockées au même emplacement que les anciennes.

Point 12

S'il y a des besoins rechange pour l'ancienne pièce (qui n'est pas interchangeable), assurer un stock suffisant de ces pièces. Si le stock existant est très grand par rapport au besoins prévisionnels, ou si ces besoins sont incertains ou éloignés dans le temps, le stock devrait être déprécié par rapport au coût de possession et au risque d'obsolescence.

Point 15

Voir le logigramme de retouches détaillé en annexe A.

Point 18

L'approvisionnement du nouveau stock peut comprendre une requalification des nouvelles pièces ou de la nouvelle source. Les délais d'approvisionnement en MRP devraient donc être réexamines pour assurer l'arrivée ponctuelle des nouvelles pièces. (Sans changement, le délai serait égal au cycle d'approvisionnement stabilisé. Les commandes, passées au jour du besoin – le cycle trop court, arriveraient en retard).

Point 19

Dans le cas des pièces non-interchangeables, il y aura souvent plusieurs pièces qui doivent être appliquées à la même date ou au même rang. Voir l'AFDC pour le rang proposé et accepté d'application, tout en reconnaissant que la date sera à préciser selon l'entrée des nouveaux stocks et l'écoulement des stocks anciens. Le Chef de Ligne gérera cette transition pour optimiser l'écoulement des anciens stocks.

Dans le physique, la gestion de la transition comprend la création des nouveaux emplacements en bord de ligne et l'enlèvement des stocks obsolètes après la transition.

Point 22

Voir le logigramme de ferraillage en Annexe A.

CLASSEMENT ET ARCHIVAGE DES DOCUMENTS GENERES PAR LE PROCESSUS

Les documents générés au cours de l'administration de cette procédure (ou qui peuvent servir à instruire cette gestion) consistent en un Dossier de définition, une DCDE ou DCDI, une AFDC, et un Dossier de Justification e le Définition. Quatre procédures s'adressent plus particulièrement à la création et l'archivage de ces documents :

PRO-DN-0112	Analyse la Rentabilité d'un Changement de Définition	AFDC
PRO-DN-0061	Demander un Changement de Définition	DCD
PRO-DN-0043	Maîtriser le Dossier de Définition	Dossier de Définition
PRO-DN-0058	Concevoir un Produit	Dossier de Justification

Désignation du document	CLASSEMENT © / ARCHIVAGE (A)				
	Responsable	Support et méthode	Lieu	Moment d'archivage	Durée d'archivage
Cette procédure ne génère pas de documents, mais se réfère aux quatre autres mentionnées ci-dessus, et à d'autres documents ou sources éventuels qui peuvent instruire les décisions de gestion.					

4. AMELIORATION CONTINUE

DETAILS DES INDICATEURS DE SATISFACTION ET SUIVI

Pour que le suivi ait de la valeur, il est impératif que les pièces soient dépréciées par rapport à leur consommation « passive » ou envoyées en historique lorsque l'horizon de consommation des stocks se voit allonger par rapport à une consommation « active ».

Référence et désignation de l'indicateur	Mode de calcul	Fréquence	Responsable
Pièces dépréciées ou envoyées en division historique, non-attribuables à une fin de programme.	Sortir la liste sur SAP des pièces envoyées en historique (et des pièces dépréciées) avec la désignation de l'affaire (ensemble livrable, centre de profit, client). Trier par affaire et enlever manuellement celles qui correspondent à des fins de programme.	1 fois par an au moins.	

DETAILS DES REVUES DU PROCESSUS

Pilote	Propriétaire du processus (devrait se revoir en même temps que PRO-DN-0112)
Participants	Représentants du BE, Méthodes Qualité/Production, Production, Commercial, Achats, Support client, Directeur Technique
Fréquence	Annuelle
Points abordés	Difficultés rencontrées lors de l'application du processus A créer éventuellement : processus « jumeau » qui servirait a améliorer la gestion des stocks en fin de programme

CLASSEMENT ET ARCHIVAGE DES DOCUMENTS D'AMELIORATION

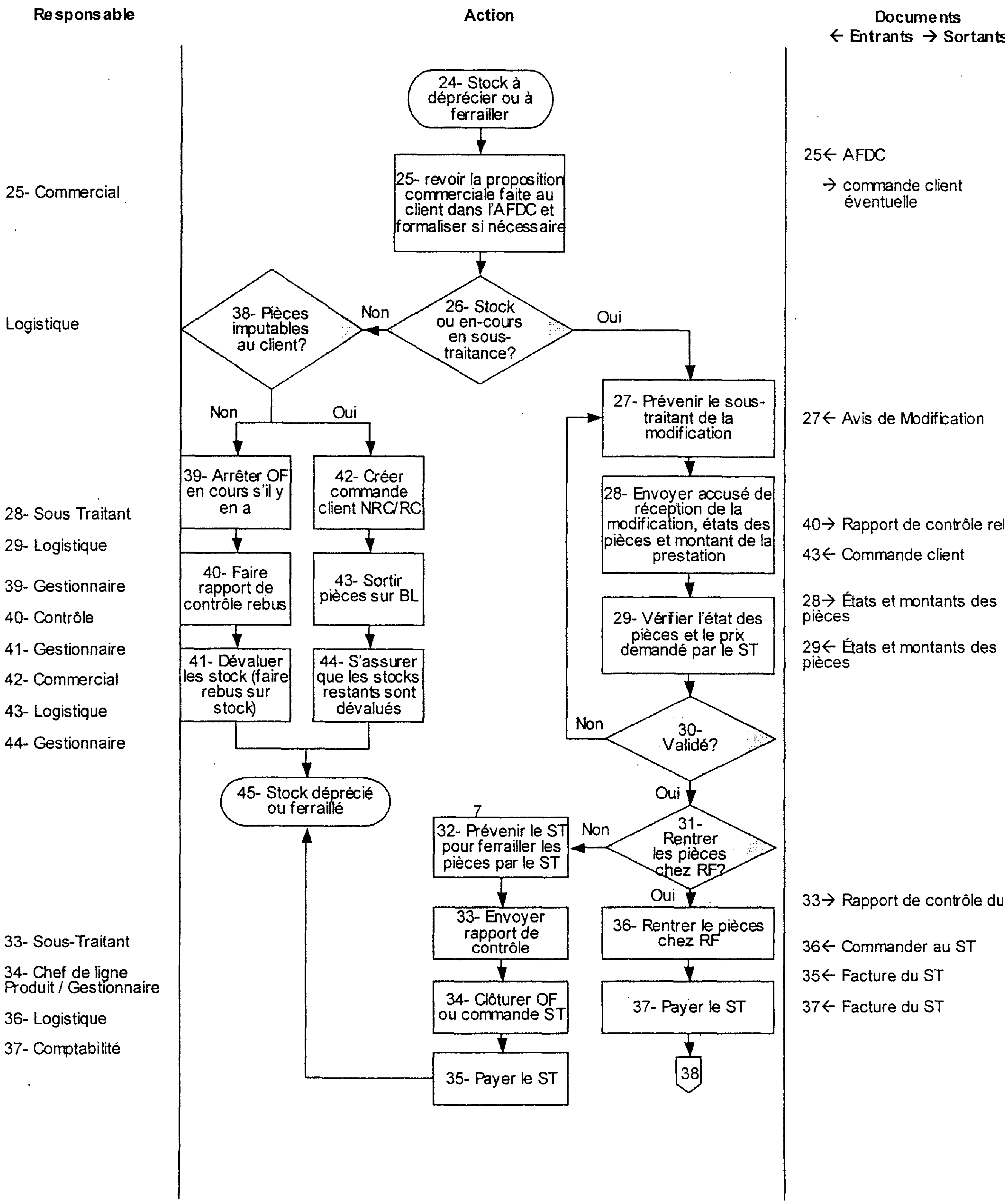
Désignation du document	CLASSEMENT © / ARCHIVAGE (A)				
	Responsable	Support et Méthode	Lieu	Moment d'archivage	Durée d'archivage
Comptes-rendus de réunions « revues de processus »	Coordinateur processus	Fichiers classés par année et par référence de compte-rendu	Disque partagé V : processus_DN/ archives	Dès diffusion	3ans

5. DEFINITIONS ET ABREVIATIONS

Mot ou abréviation	Définition
Affaire nouvelle	Pour un projet court (< 18 mois), le projet est dit en phase « affaire nouvelle » jusqu'à la fin de la qualification interne ET la certification du premier avion. Pour un projet long (>18 mois), le projet est dit en phase « affaire nouvelle » jusqu'à la fin de la fabrication des ensembles de qualification. Après cette date, l'analyse et la décision sur l'AFDC passent par le Directeur Technique.
AFDC	Analyse Financière du Changement de Définition
DCDE/ DCDI DCD	Demande de Changement de Définition Interne / Externe Demande de changement de Définition
DN	Daugy-Naudier Naudier
Consommation « active »	L'article fait l'objet de besoins bruts pour la production, les rechanges et la réparation
Consommation « passive »	Seuls les besoins de rechange et de réparation font l'objet ou devraient faire l'objet d'une expression de besoin.
Pièces en Historique	Il n'y a pas de consommation production et les consommations en réparation ou en rechange sont ponctuelles. Ces articles sont dépréciés à 100%
MRP	Système de gestion Manufacturing Resource Planning
SAV	Service Après Vente

ANNEXE A. DETAIL DES LOGIGRAMMES

TRAITER LES PIÈCES À FERRAILLER



TRAITER LES PIECES A RETOUCHER