Process Improvements in Pratt & Whitney's Deficiency Report Investigation Process:

A Case Study of the UTC ACE Operating System

Phech Colatat
Lean Advancement Initiative
Massachusetts Institute of Technology
292 Main Street – Bldg E38 Room 624
Cambridge, MA 02142

pcolatat@mit.edu
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http://lean.mit.edu
Massachusetts Institute of Technology
Cambridge, MA 02139

Lean Enterprise Change Research Case Study Series

This case study provides an example of managerial and organizational changes that have accumulated into significant performance improvements. It is one of a series of case studies undertaken by researchers at the Lean Advancement Initiative (LAI) at the Massachusetts Institute of Technology. LAI focuses on developing, testing and studying the application of lean and other management principles in the aerospace industry. LAI's sponsors, and their improvement initiatives, have created a natural laboratory for studying lean enterprise efforts. The case studies in this series report on effective, interesting and novel applications of lean methodologies at enterprise levels in LAI-sponsoring and other organizations.

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Phech Colatat
pcolatat@mit.edu

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Lean Advancement Initiative
Massachusetts Institute of Technology
Building 41-205
77 Massachusetts Ave
Cambridge, MA 02139

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I. Introduction

This case study describes Pratt & Whitney's process improvement activities on its Deficiency Report (DR) Investigation Process for the F100 engine program between 2004 and 2006. The DR Investigation Process is a customer service function that addresses anomalous, "non-conforming" technical problems discovered in fielded military engines. Investigation of these problems is critical because it produces important operational information for users of the engine. The information may have implications for the way the engine is operated in the future. If the same problem is discovered anywhere else with any other engine of the same model, it can be resolved immediately. Alternatively, it may be possible to take preventative measures so that the problem does not occur in the first place.

Although Pratt & Whitney has many customers for the F100 engine, the largest customer by far is the United States Air Force (USAF) who uses the engine on its F-15 and F-16 aircraft. USAF maintenance staff, upon discovering a technical problem, may decide that it is not well understood and that it warrants further investigation. The investigation may be carried out internally by the USAF and Pratt & Whitney engineers located on-site but, many times, the USAF assigns primary responsibility of the investigation to its contractor, Pratt & Whitney, and the part is shipped to Pratt & Whitney's facilities in East Hartford, CT. For most (non-safety-critical) investigations, the USAF expects Pratt & Whitney to study the problem, take corrective action and issue a report documenting the investigation within 120 days.

In 2004, at the behest of the USAF, Pratt & Whitney began process improvement activity to address the growing number of overdue investigations - investigations taking longer than 120 days. Less than 30% of investigations were being completed on time and the average investigation time was over 300 days. More tangible and troubling to the USAF was the backlog of more than 70 overdue investigations that had resulted.

The problem stemmed from a lack of a robust process for managing investigations coupled with a limited understanding of the investigation process as a whole by the many workgroups operating within Pratt & Whitney. The process is a complicated one, full of conditional steps, and had not been documented in a way conducive to analysis and improvement. It was also a "tightly-coupled" process which meant that isolated changes by individual workgroups would lead to coordination problems between workgroups. An incremental approach to change was not possible and instead multiple changes would need to be made simultaneously. Without a venue for making simultaneous changes, many developed a conservative attitude with respect to change.

In 2004, Military Customer Support, an organization within Pratt & Whitney's Military Engines division, began an effort to drive down the number of overdue investigations and put in place a more robust process for managing DR investigations. Led by Rosemary Farrell, the core improvement team engaged representatives from the multiple Pratt & Whitney workgroups involved in the DR investigation process in addition to representatives from the USAF and the Defense Contract Management Agency (DCMA). They drew on problem solving resources from Pratt & Whitney's Achieving Competitive Excellence (ACE) Operating System, which can be described as the strategic, formalized use of process management techniques like lean

manufacturing and Six Sigma at a corporate level[1]. They made use of prescribed problem-solving approaches from ACE - like value-stream mapping, mistake proofing and standard work - to analyze and make changes to the existing process.

Figure 1: Percent of On-Time Quality Investigations, 2004-2008, (Six Month Moving Average)

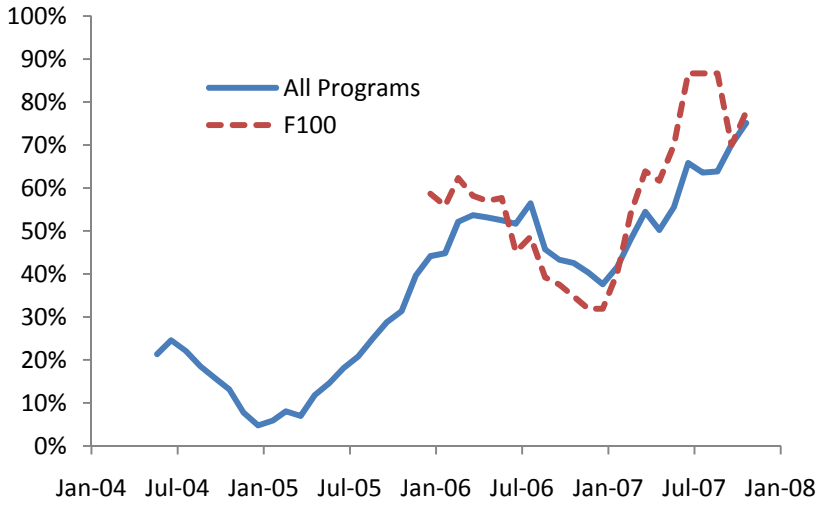
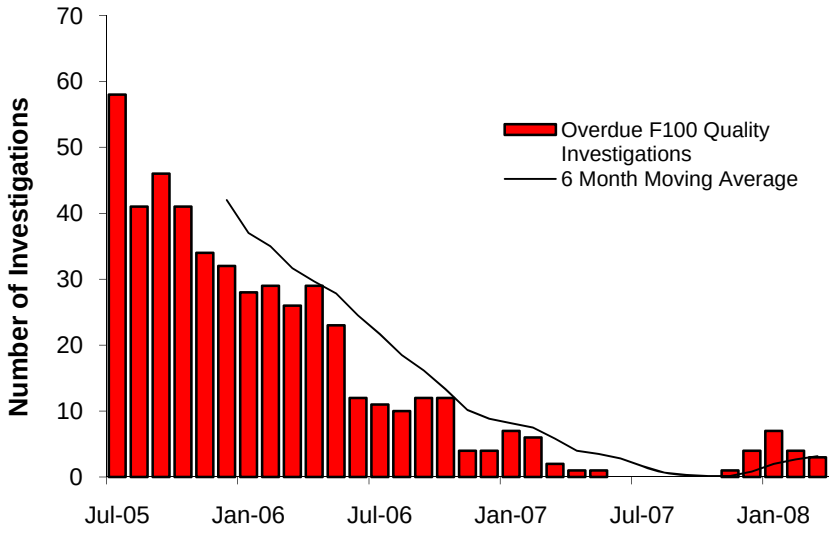


Figure 2: Backlog of Overdue F100 Quality Investigations, 2005-2008



The USAF has been impressed by the level of success that followed. The average percentage of quality investigations completed on time increased from 5% in January 2005 to a high of 75% in November 2007, as shown in Figure 1. Although F100 specific data was not available before 2005, the performance of the F100 was likely highly correlated. As for the backlog of overdue F100 quality investigations, it was eliminated by the summer of 2007 and, while there are still a few investigations that go overdue each month, the overall improvement since 2005 is remarkable (See Figure 2[2]).

In addition to providing description of and insights on DR Investigation improvements, one question this case will attempt to address is: what were the mechanisms that led to improvement in the DR Investigation process metrics and customer satisfaction with the USAF? This question is relevant because changes in the "design" of the

[1] This case study is one in a series of case studies conducted by the Lean Advancement Initiative at MIT (http://lean.mit.edu) that examines Pratt & Whitney's use of the ACE Operating System. Further detail about ACE can be found in those case studies.

[2] The measures presented in Figures 1 and 2 are related, but are not simply mirror images of one another. Figure 1 shows the on-time performance for each month, while Figure 2 shows the cumulative number of overdue investigations. If an investigation is due in month 1, but not completed, then it will count against on-time performance in month 1. Starting in month 2, the investigation will then be counted in the backlog where it will remain until it is eventually completed. Its subsequent completion will no longer be counted against on-time performance.

investigation process account for only part of the improvement; there is still a "residual" level of improvement and customer satisfaction that must be explained in other ways. Understanding the other mechanisms that led to improvement of the DR Investigation process and USAF customer satisfaction and the relationship of these mechanisms to ACE will be valuable to managers at Pratt & Whitney and at any organization using similar programs for process improvement.

This case study is organized in service of answering this question. First, it begins by providing some background on the DR Investigation Process, describing the issues that were being encountered in late 2003, and outlining the improvement actions taken in 2004 and 2005. It then highlights four key features of the DR Investigation Process improvements that set it apart from other improvement activities and provide the requisite understanding for examining the "improvement residual." These features are: (1) engaging multiple Pratt & Whitney workgroups, (2) engaging the customer, (3) a flexible standard for DR investigations and (4) application to multiple programs and customers reflecting a genuine improvement orientation. Next, to bring the question into greater focus, the case will qualitatively compare the process improvement activity from 2004 and 2005 with the process improvement activity occurring in 2008, and it will analyze the design changes made to the DR Investigation Process between 2004 and 2006. The case closes by attempting to explain the mechanisms that contributed to the success of the DR Investigation process improvements and the relationships of those mechanisms to ACE.

Data collection for this case study began in August 2007 and was completed in August 2008 (with the exception of a single follow-up interview in March 2009). The primary data source was a series of 21 interviews conducted with individuals involved in the process improvement activity. In addition to the interviews, data included observation of several working meetings, review and analysis of company documents and data, and informal ongoing communication with employees at Pratt & Whitney.

II. DR Investigation Process Improvements, 2004-2005

Background on the DR Investigation Process

According to Technical Order 00-35D-54, the USAF document that governs Deficiency Reports, the overall goal of the DR Investigation process is to:

> *"identify and correct deficiencies before they impact mission capability. Successful process implementation drives resolution decisions, tempered by total ownership cost, to correct, mitigate, and/or accept the risk of conditions impacting operational safety, suitability and effectiveness (OSS&E).*
>
> *Success is based upon two premises:*
> *1. That the user/operator/maintainer reports deficiencies on their assigned systems and,*
> *2. That program, supply and support system managers establish proactive processes to analyze data and act accordingly to implement solutions."*
>
> (Technical Order 00-35D-54[3]: p A-1)

Having a robust investigation process is not only a USAF requirement, but also provides an important service for the "warfighter" – the ultimate end-user for the USAF and its contractors. Completed investigations provide valuable information that can be used to operate the engines more safely and more reliably. As problems (also known as "deficiencies" and "non-conformances") are identified by users through ongoing operation, they must be solved and the solution must be applied to the rest of the engine fleet.

For Pratt & Whitney, the DR Investigation process is considered part of "Support Products / Services" in the overall company value stream (see figure 3). In general, Pratt & Whitney provides value for end-users by designing, manufacturing, selling and supporting jet engines. The DR Investigation process deals with the support of jet engines already in use. The DR Investigation process is not specific to the F100 engine and the USAF. While there are some differences from engine to engine and customer to customer, the investigation of non-conforming technical problems is a process common to all engine programs[4]. This case study focuses on the improvement activity with respect to one engine program, the F100, and one customer, the USAF[5].

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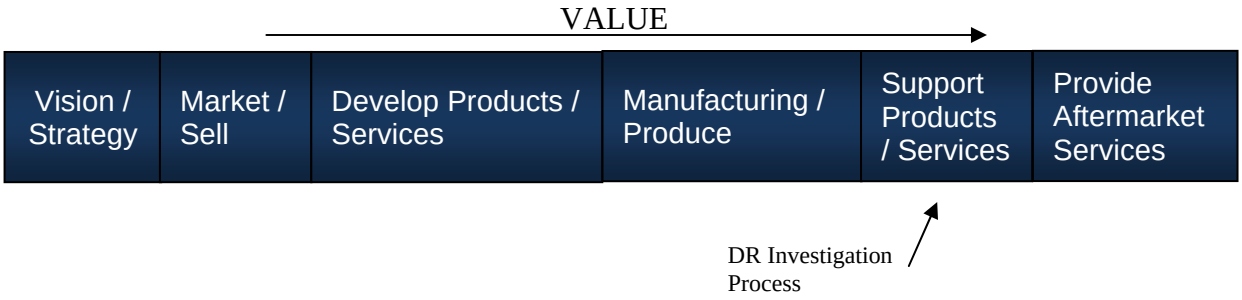
[3]Source: www.tinker.af.mil/shared/media/document/AFD-070517-037.pdf . 2007 revision. Accessed March 9, 2009

[4] Pratt & Whitney sells four major types of military engines: the F100 engine used on the F-15 and F-16 aircraft, the F117 engine used on the C-17, the F119 used on the F-22 Raptor, and the F135 currently under development and will be used on the F-35 Joint Strike Fighter / Lightning II. Other older engine programs include the TF30, TF33, and J52. Across all these programs, the primary customer of military engines is the US Air Force, although other customers include the US Navy, Boeing, and more than a dozen international customers.

[5] The choice to focus on one particular engine program and on one customer was made for several reasons. First, it was the first formal application of ACE tools to the DR Investigation Process. Improvements on the F100 program eventually led to the application of ACE on the F117, F119, and F135 engine programs. Thus, understanding the influence of ACE on the investigation process must begin by understanding the particular case that catalyzed later improvement activity. Second, the DR case was initially identified as a candidate for research specifically because of the involvement of the Air Force in the improvement activity. One objective of the case study is to understand how this relationship worked and how it evolved. Third, because the USAF is Pratt & Whitney's largest military

Figure 3: Location of DR Investigations in the overall Pratt & Whitney Value Stream
(adapted from Pratt & Whitney internal document)



Eight Steps in the DR Investigation Process

The work involved in a DR Investigation can be described as a type of "craft" service work. In general, there are two types of company staff involved in an investigation. First, there are those that manage or help to manage the customer relationship; they are either completely dedicated to customer service or are part of the general program management staff. Customer service staff act as the main point for the customer, read and interpret legal documents and technical specifications, and proactively assist customers in managing their engine fleet. The second type of personnel involved is the engineers that perform technical investigations. They are normally responsible for the design, manufacturing and testing of engine modules. In equipment investigations, the engineers conduct a range of tests to determine the cause of failure and then take corrective action, by either changing the design or the manufacturing procedures.

Figure 4 provides an overview of the F100 DR Investigation process and indicates where the work is carried out. The figure should be read from left to right, and each of the eight steps is described below[6]. Each of the workgroups involved in the DR Investigation process is depicted on the organizational chart in Figure 5.

1. Deficiency report is generated. *Lead time: approximately 2 weeks*
The F100 DR Investigation Process for the USAF begins at an Air Force base where the F100 engine is used. A mechanic conducting engine maintenance discovers a non-conformance – often a part that has failed before its expected design life. He writes a deficiency report and sends it electronically - via a government system, G021/Infocen - to Tinker Air Force Base in Oklahoma City, Oklahoma. Tinker Air Force Base (henceforth, Tinker) is responsible for all technical and engineering issues on the F100 engine, the largest engine fleet in the USAF.

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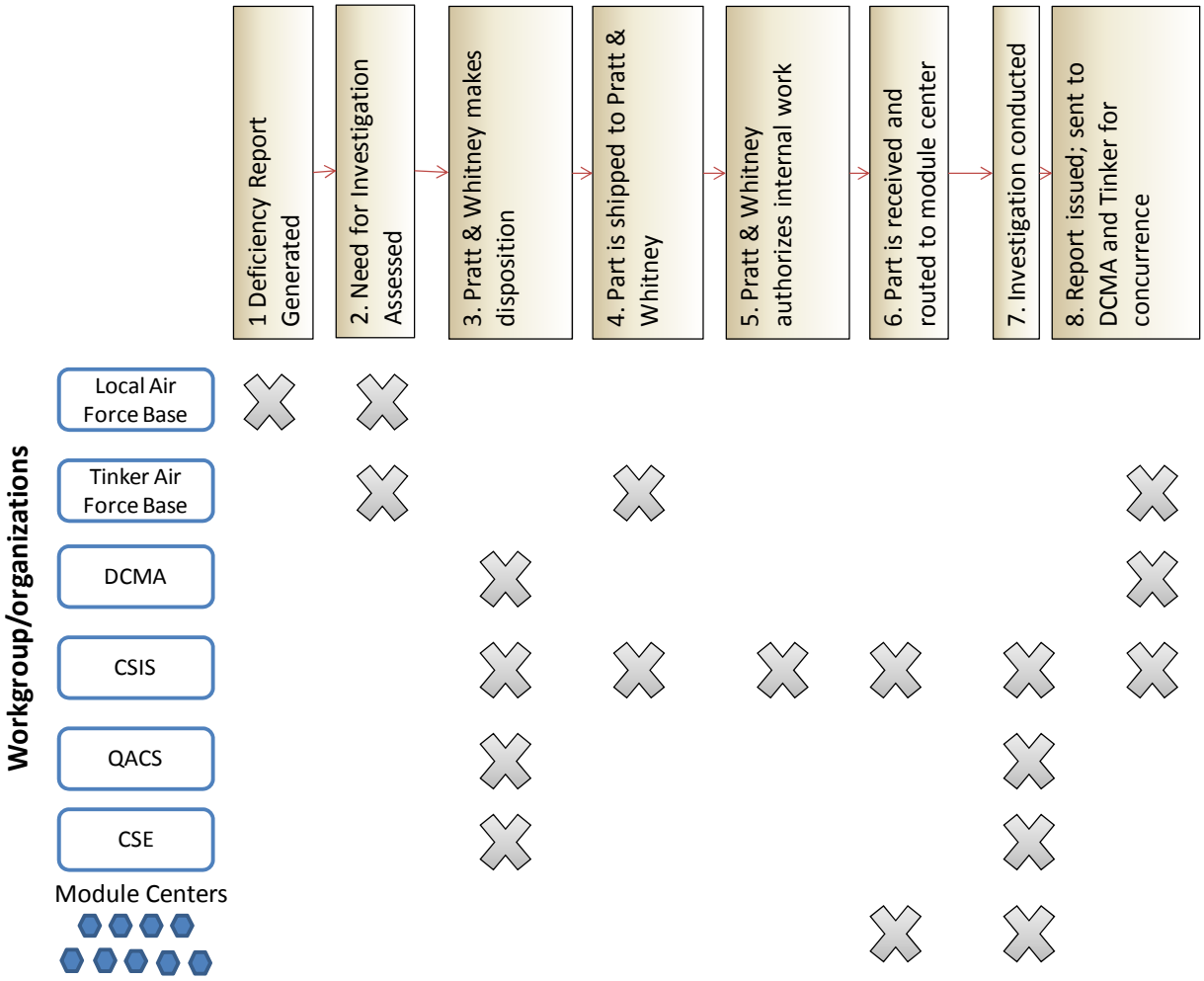
engines customer, the two organizations share the most complex ongoing transactional relationship which has the greatest potential for improvement. Finally, the DR Investigation Process is the least complex in the F100 case. In the F117 and F119 programs, more organizational entities are involved in the investigation process, making them more difficult to study both conceptually and practically.

[6] Estimated lead times are from the value stream map that was drawn in 2004. The origin of the value stream map will be described in the next section.

2. Need for investigation is assessed. *Lead time: approximately 2 weeks*
Equipment specialists and engineers at Tinker compare the problem described in the deficiency report to problems they have encountered before. If the problem is novel, then it is flagged for further investigation. Many times, the investigation is carried out by engineers located at Tinker. Other times, it is passed on electronically to the Defense Contract Management Agency (DCMA) and eventually assigned to a contractor working for the USAF, in this case Pratt & Whitney. If the problem is not novel, then the DR Report will not be passed on to the DCMA and an investigation will not be generated.

Figure 4 - Eight Steps in the DR Investigation Process



3. Pratt & Whitney makes disposition. *Lead time: approximately 2 weeks*
The DCMA acknowledges receipt of the deficiency report and passes it on to Pratt & Whitney's Customer Support and Investigation Services (CSIS) workgroup. CSIS is the main point of contact for the USAF regarding DR Investigations. Depending on the nature of the investigation, CSIS will work with one of two other workgroups in Pratt & Whitney. If the non-conformance is believed to have resulted from a manufacturing process, then it is categorized as a *quality* issue and the investigation is assigned to Quality Assurance Customer Support (QACS). If the non-conformance

is believed to have resulted from a design process, then it is considered an *engineering* issue and the investigation is assigned to Customer Support Engineering (CSE). This case study focuses only on investigations related to quality issues and will therefore include QACS as an integral part of the investigation process.

Working with QACS, CSIS reviews the deficiency report, makes a disposition on the part, and may recommend that the defective part be shipped into Pratt & Whitney for investigation. This recommendation is communicated simultaneously to the DCMA and Tinker Air Force Base.

4. Part is shipped to Pratt & Whitney. *Lead time: approximately 6-7 weeks*
After the disposition is made, Tinker relays instructions to the original Air Force base that discovered the non-conformance. The part is shipped to Pratt & Whitney in East Hartford, CT.

5. Pratt & Whitney takes administrative steps to authorize the investigation work internal. *Lead time: approximately 1.5 weeks (concurrent with shipping)*
While the part is being shipped, CSIS creates a Quality Notification in SAP and develops a statement of work and budget. An internal charge number will be requested. This officially authorizes the investigation work to be conducted by Pratt & Whitney module centers.

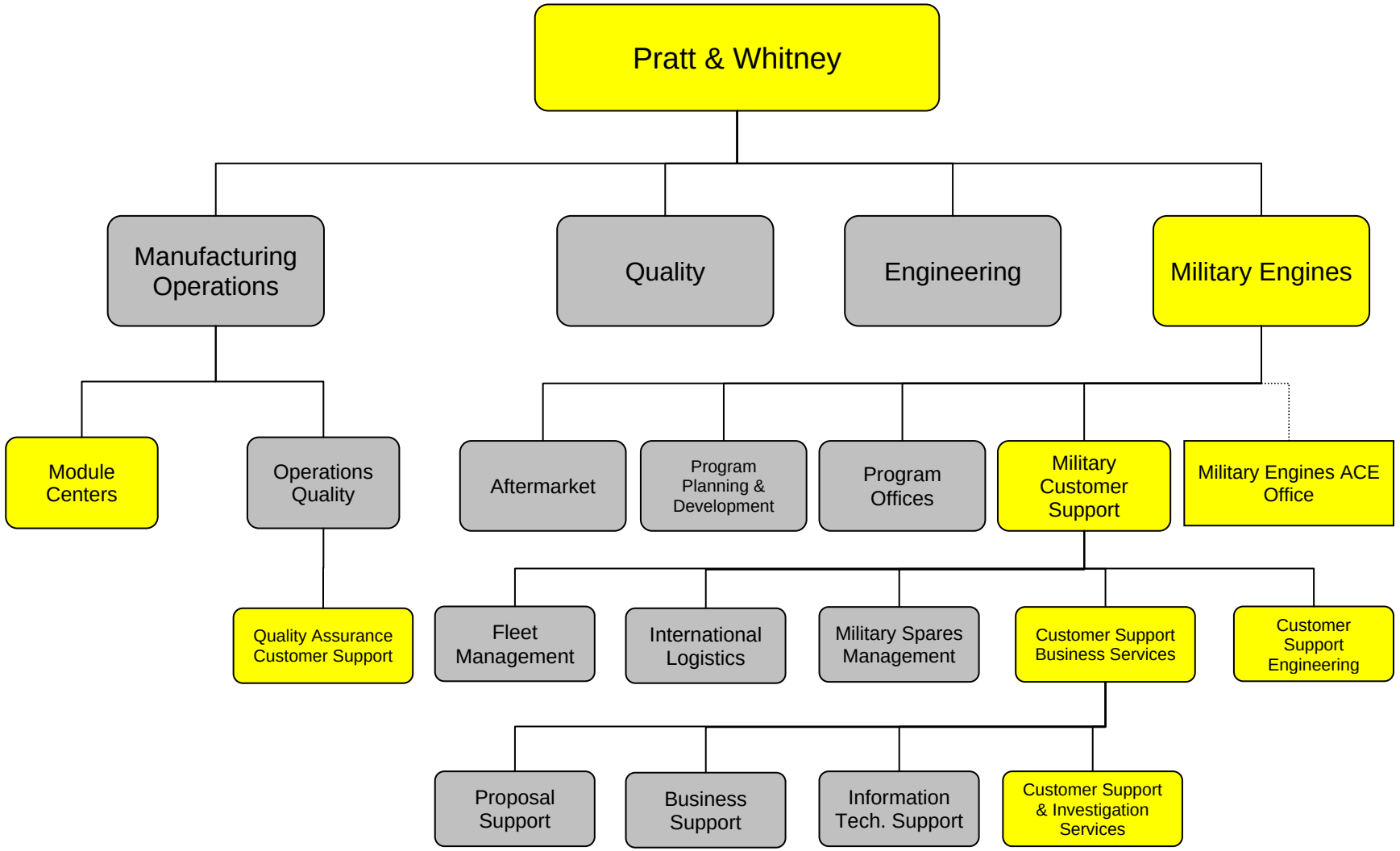
6. Part is received and routed to module center or supplier. *Lead time: approximately 2 weeks*
The part arrives at Pratt & Whitney in the "Bond Room," the location where customer material is received and stored. CSIS and DCMA are notified of its receipt and inspect the part. The Bond Room routes the part to the appropriate Pratt & Whitney workgroup for investigation.

7. Investigation conducted. *Lead time: approximately 10 weeks for a quality investigation, approximately 16 weeks for an engineering investigation*
Investigations are completed by engineers at one of five "module centers," three "parts centers" or even a Pratt & Whitney supplier. Engineers identify the cause of problem and, working with QACS (or, in the case of engineering investigations, Customer Support Engineering), take corrective action to resolve it. QACS concludes the investigation by drafting a report for the USAF that summarizes the investigation findings. This report is reviewed by CSIS, who checks the report for consistency of standard and for any implied legal liabilities.

If the part is assembled outside of Pratt & Whitney, the investigation may be conducted by an outside supplier. In this case, the module or parts center will identify the appropriate supplier, create a purchase order, and send the part out for investigation. This possibility is not addressed in this case study.

8. Report issued, sent to DCMA and Tinker AFB for concurrence. *Lead time: approximately 1 week with 1 additional week for each additional RFAI*
The investigation report is sent to the DCMA and to Tinker for review. Both parties must independently concur with the investigation for the DR to be closed. If either is not satisfied with the investigation report, they may submit a Request for Additional Information (RFAI), in which case Pratt & Whitney continues the investigation.

Figure 5 - Pratt & Whitney Organizational Chart, c.2005



* This is organizational chart is a simplification, since Pratt & Whitney is organized as a matrix organization. It also excludes many workgroups that are not involved in the DR Investigation process.
**Groups that are directly involved in the DR Investigation process are in yellow.

A Storm Begins To Brew

In late 2003, the USAF was not receiving the level of service that it expected from Pratt & Whitney on the DR Investigation process. Sammy Chandler, a 30-year Air Force veteran and 15-year [civilian] equipment specialist at Tinker Air Force Base, had just been promoted to technical management section chief. In this role, he oversaw all the F100 equipment specialists who are each responsible for an individual engine component. The DR Investigation Process was critical to his job, since DRs are the primary mechanism for gathering information about engine problems from the field and determining what corrective action must be taken by the many F100 users throughout the Air Force.

Tinker Air Force Base has the responsibility for the F100 to "establish performance measures for responding to and resolving deficiencies." The Air Force technical manual notes:

> *"As all deficiencies go through some or similar steps to reach a logical resolution, analysis of the timelines associated with these steps will allow a determination of constraints. These steps may include, but are not limited to: initial evaluation, exhibit disposition, in-depth analysis/tear-down investigation, review boards, recommendations, engineering action, engineering change proposal, prioritization, funding, fix verification, and closing."*(Technical Order 00-35D-54: p 4-22)

This need is formalized in the USAF's contract with Pratt & Whitney, which states that routine investigations are to be normally completed within 120 days and, if the problem is safety-critical, the investigation must be completed within 60 days. Safety-critical investigations had not been the problem because they generate an "all hands on deck" response. But routine investigations were a different story however; it seemed that there was little agreement on how they should be prioritized. Chandler explained:

> *"I was waiting 360-400 days before I could get a report back from Pratt & Whitney on DRs. The information was not flowing… We would call whoever they gave it to, and we'd never get the report. It was just a matter of pulling teeth."*

There were two major problems with the way Pratt & Whitney was handling the DR Investigation Process. First, there was a growing backlog of investigations and this was preventing potential fixes from getting back into the field. Chandler explained:

> *"Our DR system is our key to knowing what's going on out there in the field. If we don't get these working in a timely manner, we're never going to get them fixed. At the time, we needed to do something to get these things fixed. We were getting DRs, letting us know we had a problem but we weren't getting anything in a timely manner. We needed that data flowing quicker so we could fix the problem and mitigate the risk."*

From Sammy Chandler's point of view, deficiency reports were being submitted to Pratt & Whitney but Pratt & Whitney was not providing any feedback on the investigations. Chandler wanted to know what these Deficiency reports meant for the way USAF users operated their

F100 engines. He needed to hear back from Pratt & Whitney so that he could determine the corrective action necessary and relay that information to the end users.

Adding to the problem of the growing backlog of investigations was the perception that Pratt & Whitney Military Customer Support was not responsive to USAF requests. What was important was not that investigations were completed within 120 days exactly, but rather that there was good information coming out of Pratt & Whitney based on the DRs. Chandler expected that Pratt & Whitney have a robust process that could complete routine investigations within a reasonable period of time and, when there was a problem with an investigation, that Pratt & Whitney be responsive to USAF inquiries by providing status updates about investigations.

These two issues were not entirely new. The Deficiency Report process has been in place for a long time, ever since the F100 was put into service in the 1970s. It has only become a problem recently because of two changes internal to Tinker Air Force Base. Chandler's position as a supervisor of equipment specialists was a new position and it provided Tinker the opportunity to pay greater attention to the DR Investigation Process. This was a responsibility that did not fit cleanly into the job responsibilities at someone at the equipment specialist level or someone at the engineering chief level. The other change was a greater focus on using process management techniques like lean manufacturing to improve processes at Tinker. To Chandler, the DR investigation process was an obvious target. He explained:

> *"From the time I really got involved in this, the DR Process, I think it was a way of doing business and it was not meeting the requirements. But when I took over this position back in 2003, I realized we had a problem."*

The USAF called Pratt & Whitney to tell them that something needed to be done to eliminate the backlog of investigations and to fix the DR Investigation Process. The Vice President of Military Customer Support, Larry Jones, explained his concerns about USAF dissatisfaction:

> *"In our business, because of its long life cycle, I tell people we and our customers are married… and there's no divorce court. Neither they nor we can succeed without the other. Industrial organizations like the U.S. Government or an airline have long corporate memories and because they are knowledgeable-- if they're unhappy-- when they get a chance, they're going to try somebody else…and the long life cycle means our business and our financials will be impacted for a very long time if they leave us."*

Pratt & Whitney's response took place in February 2004, organized by the manager of the QACS, Susan Roosa, with the help of the Pratt & Whitney ACE Office[7] (see Figure 6 for a full timeline). QACS specializes in understanding and solving quality-related issues. While CSIS interfaces with the customer, QACS's role is to interact with the module and parts centers, coordinate investigation activities and ultimately craft the final report that will be issued to the customer.

[7] See Appendix A1 for a brief description of the ACE Office and other groups involved in the DR Investigation process

Roosa organized a full-day meeting to bring together all of the workgroups involved in the DR Investigation Process which included CSIS and QACS, as well as the Program Offices and the functional departments, Engineering and Quality. The group engaged in "Round Table" discussion to identify the issues, goals, potential barriers, concerns and expectations. They also drafted a basic process map of the DR Investigation Process (later versions of the process map shown in Figure 7 and Appendix A7). At the meeting's end, the ACE Office facilitator, Bill Herdman, called for a volunteer to take charge of the improvement effort from that point forward. Rosemary Farrell, one of the 20 people in attendance, volunteered. Although her group, CSIS, did not control many of the resources necessary to complete them in a timely fashion, she believed that CSIS was a fair choice to lead the improvement activity. According to Farrell:

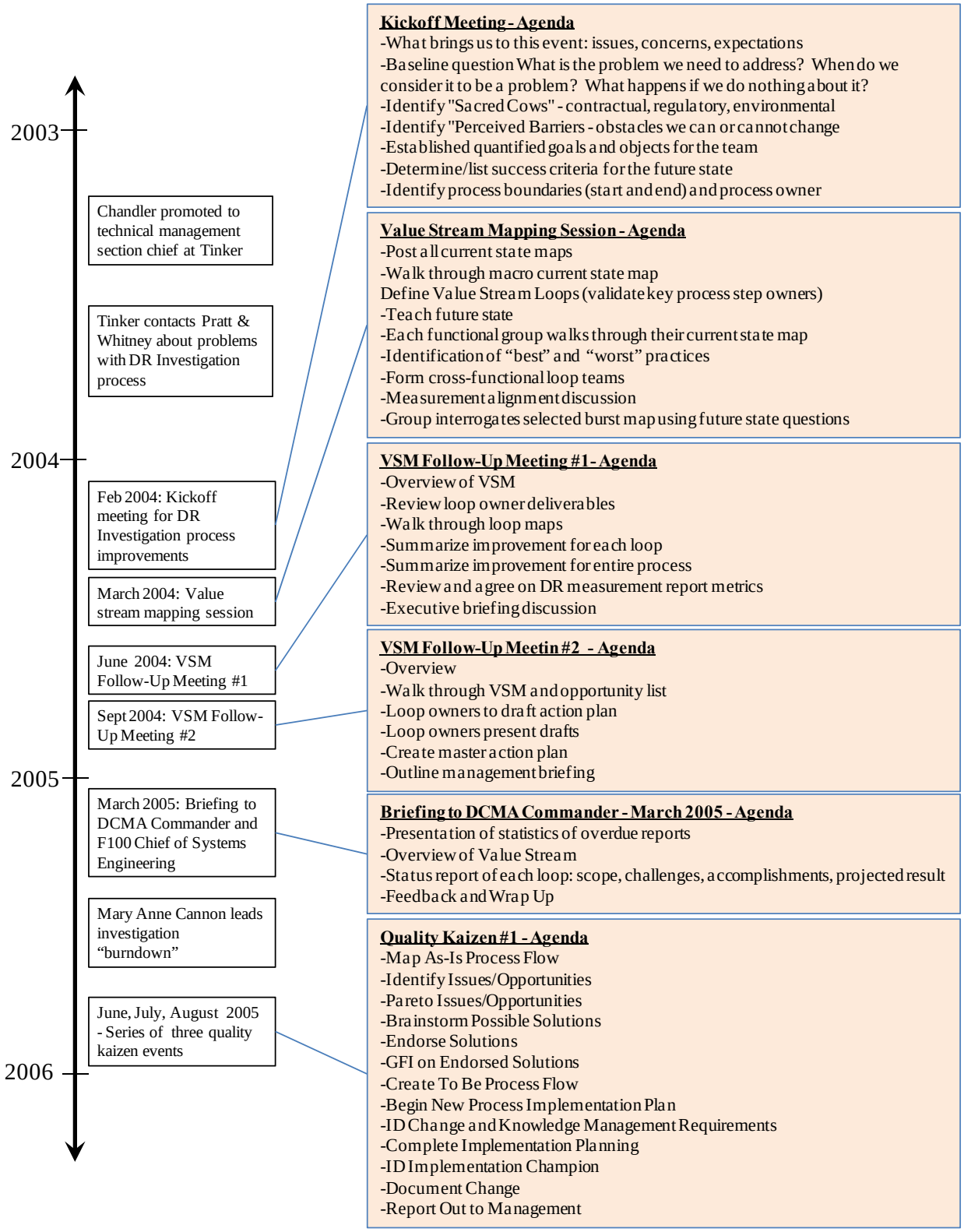
> *"CSIS is involved in the beginning and end of the DR Investigation process. Though CSIS is not the owner of the substance, they are owners of the process. CSIS doesn't do investigations, but does give the report to the customer and deals with them."*

Her motivation came from a general awareness of the problems facing CSIS as well as a progressive attitude towards ACE. Farrell had worked for Pratt & Whitney since 1981, first as part of Pratt & Whitney Canada and now part of Military Engines. As manager of Customer Support Business Services, her day-to-day involvement with DR investigations was indirect. The CSIS manager reported to Farrell, but she did nevertheless occasionally "experience the pain" of the DR process through customer complaints

Despite her willingness to lead the improvement effort, Farrell did recognize the difficulty of such an endeavor. She added:

> *"Nobody wanted to own something so big. We called it 'the beast.' But since I was in the part of the organization that faced the customer, it made sense. I agreed as long as I could get the support of everyone else in the room."*

Figure 6 - Timeline of Key Events Between 2003 and 2006 including Agendas of Selected Events



The Nature of the Beast

The fundamental challenge with the DR Investigation Process was its intrinsic complexity and number of handoffs required. Many of the people and groups involved operated under the belief that the design of the process was sound and, by simply following their own role in the process, investigations would be completed in a timely manner. These groups include the USAF bases were the engines are used, Tinker Air Force Base, the DCMA and the many workgroups internal to Pratt & Whitney. For each group involved, little was known outside their own steps – who they received it from, what they had to do, and who they passed it on to. Someone who attended the February 2004 session noted:

> *"Once it [the DR] leaves here I have no idea what happens to the material, how it gets here, until it gets here, or what they do with the reports, whatever that was, that was like unknown territory to me."*

The way the process had been designed was not adequate. Several people believed that the long investigation times were related to the many handoffs in the process. Steve Ash, from CSIS, explained:

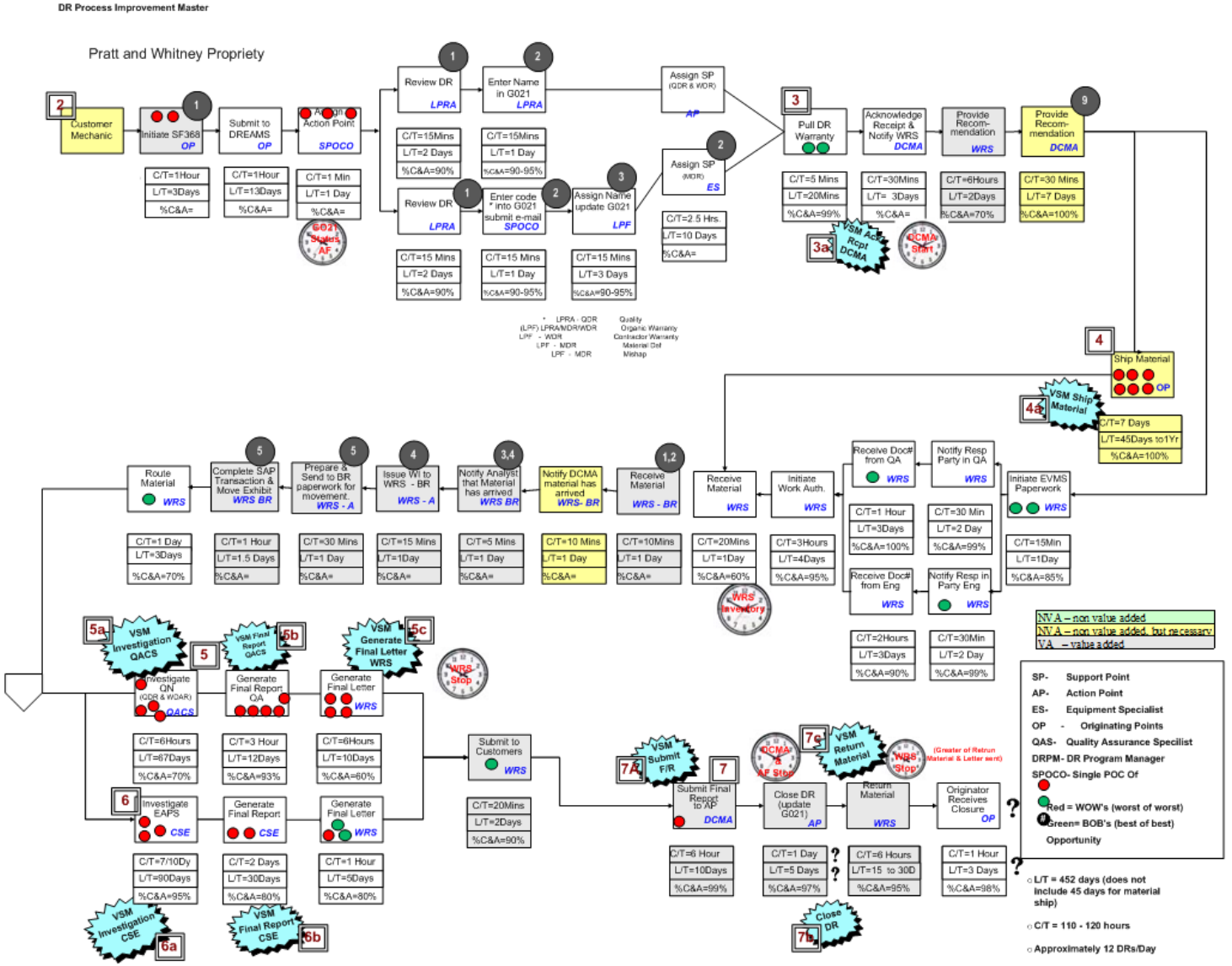
> *"There are two things that I think are driving this [long] lead time. One is the physical movement of the part to different physical locations. It might get moved around from the Materials Process Engineering Laboratory to a module center, from a module center to a vendor, from vendor to vendor etc. Then, there's the paperwork – which has to be routed electronically to many different agencies. There is lot of coordination that is required…there are so many different handoffs in the process."*

Of course, Pratt & Whitney managers and executives know that a process in which work is "thrown over the wall" is far from ideal. However, four factors made diagnosing and solving the problem of systematically overdue investigations difficult. First of all, the data on DR investigations was very poor. Military Customer Support only found out that an investigation was overdue on day 120 when they realized the investigation was not complete. There was no established set of investigation milestones that could be used to tell whether an investigation was on schedule. While they did know the age of investigations and how many were older than 90 days (i.e. at risk of going overdue), there was no automated way to tell the difference between an investigation that would be completed the next day and one that would take another 100 days. Pratt & Whitney could not tell how long each step took, how long each step should take, and how well each step was being executed (in terms of % correct & accurate)[8]. Rosemary Farrell noted:

> *"We were aware that it was taking far too long, but we were not focused on just how long, because there wasn't a reliable source of data. Without regular reports, we weren't reviewing it. Everyone knew we had overdues, but we were having arguments about how overdue they were."*

[8] Poor data was a problem that Farrell and her team members had recognized for some time. At the same time as the DR Investigation Process Improvements, there was a parallel effort to overhaul the legacy information system.

Figure 7 – Value Stream Map Drawn in 2004



Second, investigations were given a low priority and no one was held accountable for the entire investigation process. One high level manager described them as "a *third tier or fourth tier problem to work on."* A process that cuts across many organizations but is also a low priority overall presents a very challenging organizational design problem. Because the investigation process is not a core process, it did not make sense to organize Military Customer Service around it. The DR Process is only one of three key processes in CSIS, one of many in CSIS's parent organization, Customer Support Business Services, and tiny in the scope of the entire Military Customer Support organization. As shown on Figure 5, the DR Investigation process spans the entire Pratt & Whitney organization and can only be coordinated formally at the highest levels of the organization.

Managing DR Investigations successfully comes down to dividing work responsibilities between many Pratt & Whitney workgroups and setting the metrics to which each workgroup will be held accountable. This is not an easy task. CSIS coordinates, tracks DR Investigations and is the first and last Pratt & Whitney workgroup to be involved. Yet, it does not control the resources necessary for carrying out the investigation and is not held accountable for them. Instead, it is held accountable only for the portion of the process that is within its direct control, five of the 120 days[9].

Third, gathering the support of the other workgroups could be a challenge because executing DR Investigations was not a core process for any other workgroup, and no one was being held directly responsible to a performance metric. While some workgroups are more naturally customer-oriented (e.g. CSIS, QACS), for many workgroups like the module centers, there is a tension between its core mission and the timely completion of DR Investigations. One person described the challenge of working with the module centers which are continually balancing their work demands:

> *"One of the things that we do is we try to highlight the customer's needs within the organization so we can get the priority we need to get our work accomplished. But let's say we have a deficiency report that requires an investigation. You've only got X amount of resources in the engineering community. If it comes down to the wire… we [customer support] will lose."*

The fourth factor that makes diagnosing and solving the DR Investigation problem difficult is that the investigation process is complex. Pratt & Whitney employees must consider the slightly different DR Investigation processes for each of the engine programs[10]. And even

[9] See in the Appendix A3, an example of the "Cell Level" control tower and the "Value Stream Level" control tower. Control towers are a balanced set of performance metrics that are used to assess the overall performance of the organizational unit. It is on the basis of control tower performance and how those metrics are achieved, that a site or cell will achieve its ACE status. CSIS, as part of CSBS, maintains a Gold ACE status on the basis of its cell level control tower, (which measures DR delivery for its five days of the process) despite several non-qualifying metrics on the value stream level control tower.

[10] Although this case study focuses on the F100 engine program, the F100 is not the only program that uses a DR investigation process. Pratt & Whitney employees must consider investigation processes that differ slightly from program to program. An example is the F117 engine program, in which the USAF's primary contractor is Boeing not Pratt & Whitney. Pratt & Whitney is a subcontractor to Boeing, and the investigation process is conducted with Boeing as the direct customer and the USAF as the ultimate customer. Yet F117 investigations are handled by the

within the F100 engine program, there is still an amazing amount of variation between investigations. Each investigation involves one of several types work scenarios that require the coordination of different Pratt & Whitney workgroups. An engineering investigation will involve CSE, while a quality investigation will involve the QACS. And depending on the specific engine component that is being investigated, the investigation will be carried out by engineers in different parts and module centers.

This degree of variability from investigation to investigation makes process standardization difficult. Because there are so many combinations of workgroups that must be called on to work on a given investigation, there are relatively infrequent opportunities for the same combination of workgroups to learn. CSIS handles about five F100 quality investigations in an average month and these five investigations are distributed over nine module/parts centers. Assuming the investigations are evenly distributed, CSIS and QACS have only one opportunity every other month to work with a particular module center. Because the process does not repeat itself frequently, process standardization does not happen automatically.

Formulating a Plan of Attack

In light of these challenges, Farrell's first step was to develop a better understanding of the DR Investigation Process and to share that understanding with all the people involved in the process. At a series of three full-day meetings following the initial February 2004 meeting - in March, June, and September - Farrell brought together representatives from all the Pratt & Whitney workgroups involved in addition to the DCMA and the Air Force. During the March session, they walked through the process step-by-step, with each workgroup describing the tasks that they normally carried out. Together, this would paint a complete picture of the investigation process end-to-end. Describing what took place, CSIS Supervisor, Steve Gagnon commented:

> *"We culled all the people who were involved – customers, engineers, IPTs [Integrated product team], field people, and CSIS. We documented the process from beginning to end in excruciating detail, from when the issue is identified to when the report is developed.*
>
> *We identified areas where we did well and areas where we did poorly. We identified the 'should' time for each step. We asked everyone to identify this time in their areas – the "should' time and the 'actual' time. But since the actual data was not available, we used the judgments of the people there"*

After the process map was drawn, the group identified several process steps that needed to be better understood and warranted a separate mapping session. Participants also voted on those steps that they considered to be the "best" and the "worst" – a best process was marked with a green sticker and a worst process was marked with a red sticker. For some steps, there was great consensus – for instance, the shipment of material from the Air Force base to Pratt & Whitney was considered a major problem. After the voting, the group went through each step

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same people who carry out F100 investigations, and these people must seamlessly switch work processes between investigations.

that had been marked with at least one red or green sticker and they tried to identify specific ways to improve the DR investigation process[11].

Learning about the work required in other parts of the DR Investigation Process was described as a valuable and enlightening experience. Many people were simply unaware or misunderstood the work of other groups. Joe Krajewski, an engineer in QACS, described the value of these sessions:

> *"I've been in many projects, but I don't think we've had as many different people, disciplines like we did over here….to get them together in the same time, in the same room and have them review the process, their part and to even hear what they thought happened down the line. We didn't have that one common link to understand the others - until we had to draw all of this out, and have people answer the questions, and go through the 'best' and the 'worst' practices. This is when we understood that we really have a communications problem."*

At the end of the March meeting, the overall process was divided into six process "loops," shown in Figure 8, and for each loop, a sub-team was formed to focus on mapping the process in greater detail and to dig into the nuances of process shortcomings[12]. Teams were led by individuals from Pratt & Whitney, the DCMA, and the USAF (see table 1). During the June meeting, the emphasis shifted from understanding the current state of the investigation process to developing a strategy for the future state. Individual teams walked the entire group through the work steps in their loop, and then presented a list of improvement opportunities along with a rough timeline for each improvement. Proposed improvements from all the teams were added up to provide a picture of the future state of the DR process.

Whereas the March and June meetings focused on developing a better understanding of the process, the September meeting focused on generating a concrete list of actions to be carried out by each sub-team. Each team was expected to meet individually in smaller, separate meetings to coordinate and carry out plans for improvement. In addition, the plans of all teams were integrated into a coherent master action plan and presented to Pratt & Whitney executives.

[11] This is not the version of value stream mapping, according to Learning to See by Mike Rother and John Shook. The DR Investigation process improvements was one of the earliest ACE events using a process mapping technique in Military Customer Support but since 2007 use of value stream mapping techniques has become more sophisticated.

[12] "Loop" was the term used by Pratt & Whitney, so this case study retains the term.

Figure 8 - Eight Steps in the DR Investigation Process and their Relationship to the Six Loops

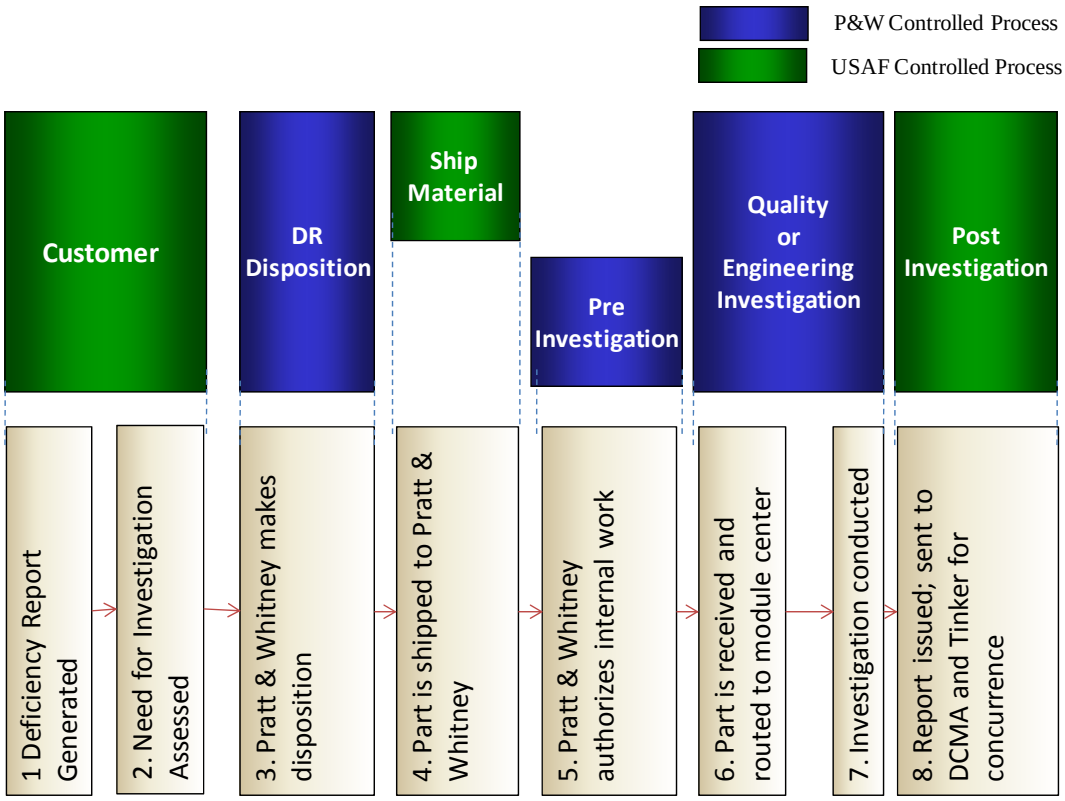


Table 1: Six sub-teams formed and their team leaders

Team	Team Leader
Customer	Bill Folsom (DCMA)
Pre-investigation process	Tara Picard (Pratt &Whitney - CSIS)
Ship material	Chris Szczepan (USAF)
Quality investigation	Joe Krajewski (Pratt &Whitney - QACS)
DR Disposition	Tara Picard (Pratt &Whitney - CSIS)
Post-investigation	Bill Folsom (DCMA)

Developing a Deeper Shared Understanding of the DR Investigation Process

After the September 2004 meeting, while the expectation had been that each of the sub-teams would act independently to follow through on their action plans, activity and progress slowed. In an effort to jumpstart activity, Rosemary Farrell set up an event for March 2005 where she and each of the sub-teams would report progress to USAF and DCMA representatives. She hoped that the session would provide the sub-teams a concrete goal and deadline to work towards. It worked and there was a flurry of activity in February – one month before the March event.

On March 10, 2005, Pratt & Whitney hosted two important customer representatives to whom they made a formal report of their progress-to-date. Attending was the DCMA Commander at Pratt & Whitney and the USAF Chief of F100 Systems Engineering. It was important to gain their approval. The agenda of the session was straightforward. After an introduction by Farrell, each sub-team described the work process in their loop, the improvement opportunities that had been identified, and any progress made so far.

The March 2005 briefing was notable for helping to build consensus on the USAF expectations for Pratt & Whitney. First, after each step in the value stream was explained and its time requirements justified, it was concluded in the meeting that existing USAF expectations for Pratt & Whitney were unrealistic. This was a major revelation, since the USAF complaints were premised on the expectation that DR Investigations should be completed in less than 120 days. In fact, the USAF's expectation had been that DR investigations should actually be completed – from initial discovery to approval of the investigation report - in 100 days!

Table 2: Actual Process Times for Three Steps in the F100 DR Investigations Process, March 2003 and March 2005

Customer Process	35 days
Disposition Process	16 days
Shipping Process	39 days
Total	90 days

To illustrate how difficult it was to complete the entire DR Investigation in 100 days, Table 2 shows the data on three of the six loops that USAF personnel had collected and presented at the briefing[13]. What is notable is that the 90 days it takes for these three sub-processes does not include the time for Pratt & Whitney to receive and investigate the part. Holding Pratt & Whitney accountable to a 100 day standard would mean that, on average, it must carry out the investigation and have it reviewed by the USAF in less than 10 days! This standard is simply infeasible, considering the fact that the problem in an investigation is by definition unknown, and identifying the problem involves an iterative series of tests.

Because this data was collected and presented by USAF personnel it had more credibility with the DCMA Commander and the USAF Chief of F100 Systems Engineering. This was not Pratt & Whitney making a case of why the 100 or 120 day standard was unreasonable; instead, it was unbiased USAF personnel that provided the supporting data. The outcome of this discovery was an agreement that the appropriate time limit will be 120 days, and the 120 days would not start until Pratt & Whitney physically receives the part to be investigated.

[13] Unfortunately, this data is only available for three of the six loops.

Driving Down the Number of Overdue Investigations

While the main takeaway of the March 2005 briefing was a better consensus on the USAF's expectation of Pratt & Whitney, the sub-teams had also made some progress in making improvements in their areas. Their work accelerated after March 2005 when more extensive effort was put into reducing the number of overdue quality investigations and streamlining the DR Quality Investigation process. The F100 Quality Manager, Mary Anne Cannon, led an effort to "burn down" the backlog of over 60 overdue quality investigations. She organized weekly conference calls every Friday with all module centers. During the calls, Cannon would go through every open investigation and the module centers would have to report on the status of each one.

After looking into many of the overdue investigations, it turned out that many of them had already been studied by quality engineers but were just awaiting the write-up as reports. QACS, the workgroup primarily responsible for writing DR Investigation reports, had been the bottleneck. However, given the work expectations on QACS, this was not entirely surprising. QACS was a small group of about five people but it was responsible for coordinating quality investigations for both Pratt & Whitney's military engine programs and its commercial engine programs. The workload from commercial engine programs accounts for most of QACS's total workload (~80%), so only two people in QACS can be assigned to military engines. Military engines, in turn, includes not only the F100 engine program, but also the F117, F119 and other smaller engine programs.

Mike Ghattas, who succeeded Susan Roosa as QACS manager in 2005, described the improvement efforts around this time:

> *"In 2004, I thought that the QACS workload was out of control and we really started looking at how to improve it. One of the main challenges was a lot of the deficiency reports were actually done, but the reports had not been sent to the customer. There was a big effort in getting that stuff out to the customer and working down the backlog of overdue DRs. We really started doing a cleanup of the workload of the group."*

In addition to the "burn down," efforts also shifted to improving certain steps in the DR investigation process itself. This would be a bit more challenging; a QACS employee added:

> "*After that, the improvement challenge became a reality. That's when they started to do kaizens [focusing on the quality investigation loop] and working with the module centers."*

In the summer of 2005, a series of three kaizen events were organized to specifically focus on the quality investigation process. The first two events in June and July focused on better understanding the quality investigation process and analyzing specific problems in the process. The third event in August was oriented towards integrating the DR Investigation process into the new SAP system[14]. The June 2005 kaizen took place over four days and was

[14] For more on the introduction of the SAP system, see Appendix A4.

attended by 15 people. The quality investigation process was mapped to a finer level of granularity. Those attending identified and analyzed 32 problems, attempting to find their root cause.

The second event in July 2005 took place over three days and was attended by 20 people. The thinking behind this event was that major issues in the DR Process would be identified through an analysis of current overdue investigations[15]. Attendees broke up into four groups to review all of the DR Investigations that were overdue (86 at the time) to develop a sense of the process bottlenecks. Each group would confirm where in the process the DR investigation was stalled, and attempt to identify the root cause of the overdue. Where possible, corrective actions were identified and assigned to specific individuals.

The remainder of the July event was focused on integrating the DR Investigation process into the new SAP information system. Until 2005, the information system used by Pratt & Whitney to manage the DR Investigation process was a collection of legacy systems. The initiative to install and use SAP was separate from the DR Investigation process improvements. However, SAP held the promise of better managing a wide range of business processes, including DR Investigations, if work processes were well-integrated into SAP. The third kaizen occurred over one day in August and was attended by 12 people. It continued the emphasis on working efficiently with SAP.

Overall, these improvement activities were successful. The backlog of investigations had been eliminated, the DR Investigation Process was better understood and better documented, and Military Customer Support was more responsive to the USAF. Chandler described his thoughts on the improvements:

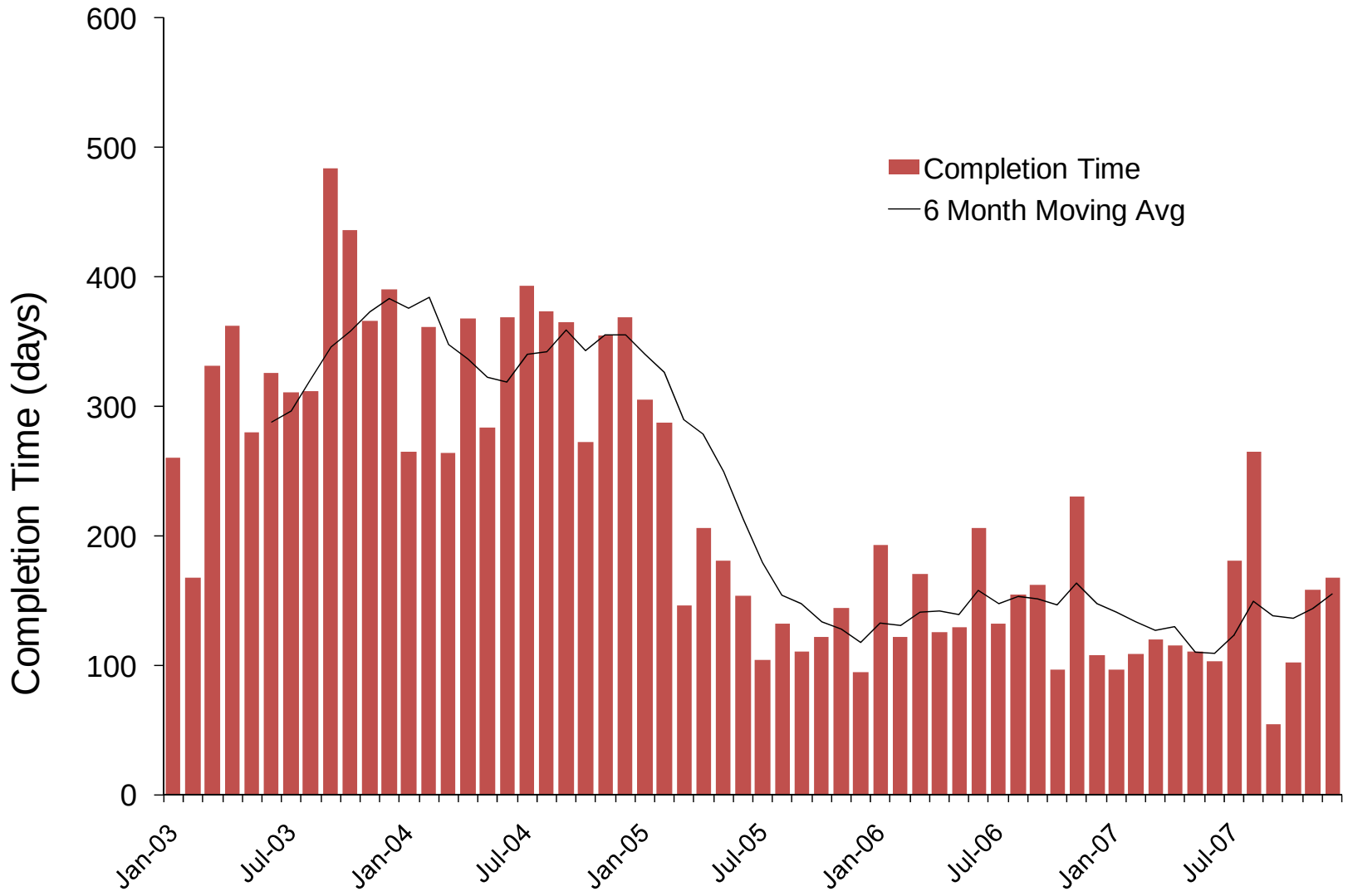
> *"The big thing was that we cleaned up our backlog. That was one of the key things going in. Clean up the backlog that we've got going in there and rectify everything that is open as best as we could. And that all got cleaned up and that's what helped us out more than anything.*
>
> *Then we started treating each one of those with our new process for everything coming in. Our reports started coming back to us as they should have all along. The [new] process was put into place so that it could resolve the issues. By all accounts, right now, the process is working and we're getting good feedback on our DR system."*

Figure 9 shows the changing trend of the average investigation completion time for quality investigations conducted by Pratt & Whitney between 2003 and 2005, continuing into 2007. The average completion time was 335 days in 2003 and 2004. By the middle of 2005, when many of the improvements had been made, that figure had dropped to 165 days. Further incremental improvements have even reduced that number further to 129 days in 2006 which has continued through 2007.

[15] This approach to problem identification relied more strongly on data compared to the initial efforts in 2004, which had been informed by a more subjective assessment of "best of the best" and "worst of the worst" processes.

This level of improvement was enough to bring Tinker's own internal metrics in order. Just as Tinker holds Pratt & Whitney to a performance standard for DR Investigations, the USAF holds Sammy Chandler to the same 120-day standard. The only difference is that Chandler is held to a standard time for completion of all DR Investigations – which include investigations conducted by Pratt & Whitney and investigations done in-house. In 2003, Tinker's average completion time for total DR Investigations was more than 180 days. After 2005, this fell to 120 days and today the average is less than 90 days.

Figure 9 - Mean CompletionTime for F100 Quality Investigations



*Data from before 2005 is based on warranty claims, while data after 2005 is based on direct tracking of investigations. Warranty claim data in 2003 and 2004 may be biased upwards because of unrelated engine problems in the process of being resolved (i.e. 3rd disk and 4th blade).

III. Four Key Features of the DR Investigation Improvements

Thus far, this case has described the DR Investigation process improvements in only a basic way – what were the major events, who was involved, what were the results. It sounds like the DR Investigation process improvements is just another "textbook" story of process management in which a work process that is underperforming is turned around. But there is more to the story and this is why the case is valuable to understanding the way process management systems like lean manufacturing and Six Sigma are used in practice.

This case points to four features of the DR Investigation improvements that set it apart from other process improvement efforts. These features – interesting in and of themselves – will also help us when considering all the mechanisms that lead to success in this case. First, the DR Investigation process improvements were coordinated by CSIS, although CSIS has no authority over the other workgroups involved in the investigation process. In a sense, the DR Investigation Process is not owned by anyone. This improvement story is not about a department or workgroup applying process improvement techniques to its core process that occurs within its own boundaries; it is about a coalition of several workgroups applying improvement techniques to a process that is secondary to all of them.

Second, improvement of the F100 DR Quality investigation process involved participants from the USAF and the DCMA. This is an instance where Pratt & Whitney took a process of importance to its customer, one that extended outside the boundaries of Pratt & Whitney, and led the effort to make it better. While it may have been more expedient for Pratt & Whitney to focus internally where it has greater organizational control, the customer was actively engaged in the effort to fix a work process that it demanded Pratt & Whitney improve.

Third, the requirement that Pratt & Whitney complete investigations in 120 days was flexible. Meeting the 120-day specification was not absolutely necessary for attaining customer satisfaction; engaging the customer to demonstrate sincere responsiveness and willingness to improve is just as important.

Fourth and finally, during and after the effort to improve the F100 DR investigation process, work began on assessing and improving the DR investigation processes of other programs and for other customers. The initial improvement effort was not simply an isolated project undertaken in reaction to customer complaints. Rather, they provided the impetus for Pratt & Whitney to embark on a series of related improvement efforts and ultimately provide a higher level of service for the customer. This approach is indicative of ACE as "a way of doing business."

1. Coordinating Improvements with Multiple Workgroups

How was the improvement activity organized? Although accountability for the investigation process falls clearly on the shoulders of Military Customer Support (of which Customer Support Business Services is one part, see Figure 5), even Military Customer Support relies on resources outside of its control. But the improvement effort was not led at the Military

Customer Support level; it was led by Rosemary Farrell, manager of Customer Support Business Services, who reached out laterally to other workgroups involved in the DR investigation work.

One potential advantage to forming a cross-functional process improvement team is the ability to pursue improvement opportunities that one workgroup could not pursue unilaterally. Without a cross-functional team, coordinating across workgroup boundaries can be difficult from an information processing and political point of view. When it is not clear what changes are necessary to improve the process, individual workgroups may resist changes that would make their work tasks more difficult. This was not the case here. Because people began to see how the way they carried out their tasks impacts the work downstream in the process, they were more willing to make changes and accept additional responsibilities for the sake of bettering the DR Investigation Process. Here are two examples where workgroups undertook additional responsibilities for the sake of improving the DR Investigation process:

Example 1: CSIS initiates QNs (February 2005)

Identifying and eliminating redundant work processes between QACS and CSIS helped to increase the efficiency of the work process. One of these processes was the initiation of the Quality Notifications (QNs) in SAP. Quality Notifications are electronic documents that allow Pratt & Whitney to coordinate DR Quality Investigations across the multiple workgroups. QNs include a list of investigation tasks which are assigned to CSIS, QACS, and the module centers. Each group records information about the investigation on the QN as the defective part goes through the investigation process. This information will form the primary data source for the creation of the final investigation report.

In the old process, QNs were created in SAP by QACS. CSIS would make a disposition on the part and send shipping instructions to the DCMA and the USAF. To facilitate this, it would "open the claim" in the mainframe system, obtain a charge number from the Earned Value Management System and notify QACS of the upcoming quality investigation via email or phone. QACS would then create the QN. There were at least two problems with this process. First, QACS had to assemble data from several documents to initiate the QN, some of which had just been recorded by CSIS when it initiated the claim. Second, there was a short delay between the time CSIS opened the claim and the time when QACS initiated the QN because coordination was handled via email. This delayed the beginning of investigation work. Through the course of the improvement activity, it was agreed that CSIS, not QACS, would initiate the QN from now on even though it meant CSIS would take on additional work.

Example 2: QACS writes final investigation report (February 2005)

Another process change where one workgroup took on a greater workload for the benefit of the entire process was the writing of the final investigation letter. In the old process, QACS would write the basic report and CSIS would write the final investigation letter addressed to the customer. QACS would create a rough draft of the report by taking

information from the QN and inputting the data into a form that asked for certain critical information.

The problem with this process was that QACS was simply recording data that CSIS would later review to write the final letter. It would be easier for QACS to write the final report by simply inputting the same investigation information, not in boxes on a form, but in a paragraph format. The change made was to merge the report and letter into one document, with QACS as the sole workgroup responsible for authoring. Someone in QACS commented:

"At the end of the DR process, we used to have a crude final report with boxes…CSIS would then take the quality report and create a polished final letter. Now I do the final report/letter and CSIS just checks."

Though QACS no longer has to write the report rough draft, it must now write the final, customer-oriented report and letter. Implementing this change required an agreement to change the work, and additional training for QACS staff. Now, CSIS's only involvement is to review the report and letter for consistency of standard – to make sure it answers the customer's questions.

Process improvement emphasized better coordination between workgroups. The challenge here is that no group has hierarchical authority over the others, and the relationship between any two workgroup is a *mixed motive* one. When Farrell organized the Value Stream Mapping events, the March 2005 briefing, the quality burndown and the quality investigation kaizens, she brought together people and sub-units that had never met as a group before. They had to first agree which problems to solve and then jointly identify the problems' root causes. A new set of opportunities opened up that could only be pursued through the joint effort. When workgroups have resources at stake and the people in them have their reputations and power at stake, defining the problem and assigning responsibility to solve it can be a sensitive matter. Inevitably, some workgroups and individuals will benefit more than others. This, however, did not prevent changes that improved the DR Investigation process more efficient from the company perspective.

People believe that it was the ACE culture that made workgroups willing to take on additional responsibilities. What would normally be seen as a "win-lose" outcome would be reframed as a "win-win." Because ACE is such an explicit priority of Pratt & Whitney and of UTC, it is easy to justify committing time and resources on ACE-related events. Taking on additional responsibilities might stretch resources and strain performance on other work processes but, since this was being done in the interest of ACE, workers and managers were not especially worried. When I asked about the link between the DR Investigation improvements and ACE, one interviewee explained

"ACE demands respect. It helps managers decide to put people to work on ACE projects. They say okay because it doesn't sound like you're saying 'I need some people to do my job better.'"

Another added:

> *"I think it's very helpful to have a corporate operating system like ACE because when we do something like a value stream map or kaizen event, folks know it's not a special project or a one-time thing. It's part of our company's language and culture, and it's a lot easier to rally folks and go get it done because they understand that this is the way that we do business here. Our company management lead by example and are vocal advocates of ACE…everyone in the company understands the importance of ACE to the success of our business. It makes it easier to go accomplish change initiatives when everybody has the same priorities and mindset about doing things."*

ACE also seemed to provide a template for coordination; people are expected to pay attention to and respect data. So long as the data and analysis supports a particular decision, people are likely to seriously consider it and are more willing to take on additional work. The following quotes illustrate the importance of data:

> *"We work very hard on the fidelity and the integrity of the data. And we work very hard to assign them by module center or owning responsibility where those investigations are."*

> *"My approach is that if we are touching it and we're supporting it, then we have some ownership for the results. My team has to move those parts, they have to do the purchase orders in order to pay suppliers, or turn on charge numbers for other entities. So we do contribute to that delivery metric and we do take ownership for those portions of the work that we do."*

2. Engaging the customer on improvement activity

Another key feature was the involvement of the DCMA and the USAF in the process improvements. Understanding what the customer wants can give an improvement project the right focus. In the DR case, Pratt & Whitney went beyond simply understanding what it is that the customer wanted; it created a partnership in the improvement effort. Although it would have been easier for Pratt & Whitney to first define, on its own, a set of customer requirements and then focus its improvement efforts internally, Pratt & Whitney instead formed a cross-*organizational* team. They mapped the DR Investigation Process from beginning to end, encompassing process steps at the multiple Air Force Bases, the DCMA, and Pratt & Whitney.

Because the USAF was concerned with total investigation time and Pratt & Whitney controlled only part of the overall process, it was important to engage the DCMA and USAF in order to understand those steps as well. This was a better problem-solving approach because it opened up the entire DR Investigation process when looking for improvement opportunities. Someone in Pratt & Whitney noted:

"There's only so much that we can do internal to Pratt & Whitney. Part of this process starts outside of Pratt & Whitney, and at the end of the day when we finish the investigation, it goes back outside of Pratt & Whitney to the customer."

To the USAF, the process began when an Air Force mechanic discovers the part non-conformance and concludes when it approves Pratt & Whitney's investigation report. Defined in this way, many of the key steps occurred outside the organizational boundaries of Pratt & Whitney (e.g., writing the initial DR, review of the DR by USAF engineers, review of the final report and letter). Although Pratt & Whitney has no direct influence on work performed by USAF and DCMA, by working together on improving the DR investigation process, improvement areas at all steps in the overall process could be identified and pursued.

One such improvement was the standardization of the shipment process. When an end-user identifies a deficiency, it is submitted on the Infocen computer system where is it received at Tinker. The end-user then waits for instructions from Tinker as to where to send the non-conforming part - either to an USAF contractor like Pratt & Whitney or to Tinker. Errors in the shipping process can lead to extremely long delays. If the shipping instructions were not followed exactly, the part could end up getting sent to the wrong location. And this type of mistake is not difficult to make because there are multiple shipping addresses for a single contractor. For example, a part may be shipped to Pratt & Whitney in Middleton, CT instead of East Hartford, CT. If the item is shipped to the wrong address, it takes more than 45 days (the shipping time) to realize that it has been lost. The original paperwork must be located, someone at the location where the part was shipped must be contacted, and assuming the part can be located, it must be shipped to the correct destination.

Had Chandler not participated in the value stream mapping sessions, he would not have known about this problem on the USAF side of the investigation process. He explained how he valued his participation in the value stream mapping sessions:

"I brought some things back to Tinker…things that we could do on our end, to make sure that they could get the job done better. Like good shipping instructions and identification which has been an ongoing problem. If the user doesn't tag the item properly, then it's not going to get where it needs to go properly.

I took a step back and I sent messages out to the field to let them know…we need to follow the disposition instructions because we're getting parts lost and we don't know where to find them if you don't put the correct disposition on it. I did that after the meetings, and I've followed that up several times and I've briefed it at the worldwide user's conference[16]."

Table 3 is based on the presentation materials from the March 2005 briefing to the DCMA Commander and the USAF F100 Chief of Systems Engineering. It shows the predicted

[16] The Worldwide Users Conference is held every year in May and brings together all the users or customers for F100 engines, including representatives from 17 foreign military users. Current issues and problems with the engines are discussed, and new products or modifications planned for the engines are presented. Attendance has been between 400-500 users every year.

benefits from the all improvements proposed by the sub-teams. Note that more than half of the proposed improvement come from steps carried out by the USAF - customer, ship material, post-investigation[17].

Table 3: Estimated Lead Time and Impact of Proposed Improvements

Process Loop	Estimated Lead Time (days)	Estimated Improvement from Proposed Opportunities (days)
Customer	33	10
DR Disposition	12	N/A[18]
Pre-investigation	20.5	3
Ship material	45-365	35-63
Quality investigation	89	53
Post-investigation	35-50	8
Total	234.5-569.5	109-137

The benefits of working together also went beyond the problem-solving; it helped to build a common understanding of the investigation process and a recognition of issues where there was not agreement. One insight that emerged from the VSM sessions was that each of the three organizations involved - the Air Force, the DCMA and Pratt & Whitney – had measured the DR investigation time differently. To Pratt and Whitney, the 120 days begins the day the part has arrives on its loading dock and ends the day they submit the investigation report to the DCMA. From the DCMA's point of view, the 120 days begins the day the DR appears on its electronic system and ends the day the investigation report is approved. To the USAF, the 120 days begins the day the mechanic discovers the issue and concludes the day Tinker signs off on the investigation report. These different start and stop times for the DR Investigation Process are shown in Figure 10. It is of little surprise that the Air Force believed that too many investigations were overdue; in some cases, the investigations were "overdue" before Pratt & Whitney even received the part.

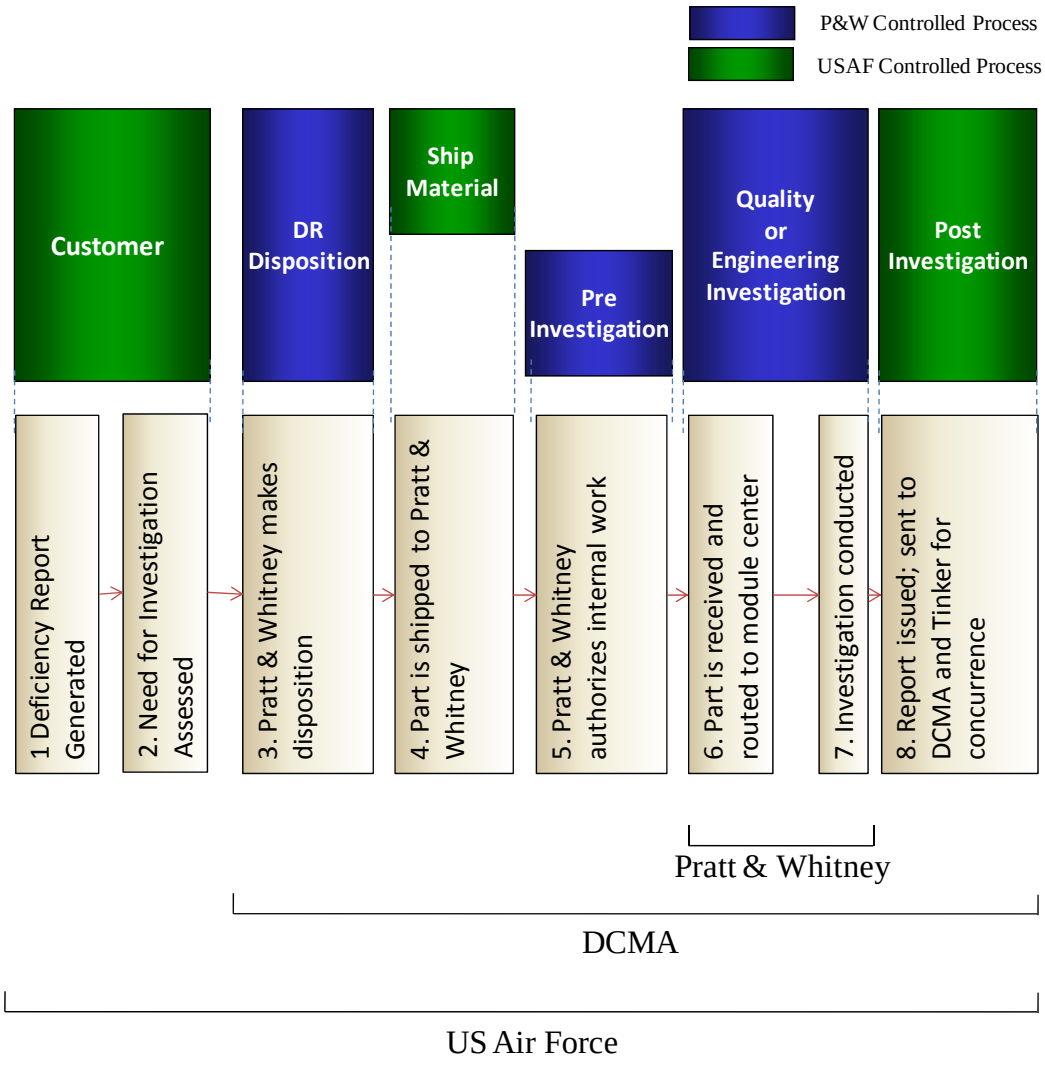
Confusion and disagreement on the standard expected for Pratt & Whitney was the result of contractual agreements that left ample room for different interpretations. The Air Force requirement, as outlined in Technical Order 00-35D-54, specifies that Tinker must strive for resolution of routine investigations in 120 days. The contracts with Pratt & Whitney refer to the Technical Order, but do not specify to whom the 120 days applies. One interpretation is that, since Tinker must resolve investigations in 120 days, then Pratt & Whitney must be able to conduct their own investigation in less than 120 days. Another interpretation is that Pratt & Whitney could take up to 120 days to provide a response to Tinker.

But after the meetings in 2004 when the entire DR Investigation process was mapped out, there was recognition that a debate over legal details would be moot. It became clear that it was

[17] It may be helpful to review Figure 4 or Figure 10.
[18] This information was not available.

a challenge for Pratt & Whitney to complete investigations on-time even under the most favorable interpretation of 120 days. In fact, the process of shipping the part from an Air Force base to Pratt & Whitney in East Hartford takes 45 days. Expecting a 75-day investigation completion time (120 - 45 = 75) is unrealistic, considering the challenge of completing investigations in 120 days. The implicit agreement after the 2005 briefing was that Pratt & Whitney would apply the 120 day standard[19].

Figure 10 - DR Investigation Process, with start and stop times as defined by Pratt & Whitney, the USAF, and the DCMA



This type of understanding was only possible after the Air Force, DCMA and Pratt & Whitney worked together in jointly documenting and understanding the process. One person involved described the usefulness of the value stream mapping process:

[19] Clarifying the expectation through contractual language is still a work in progress, even in 2009.

> *"When you do the map, you get a great opportunity to get everyone together in a non-hostile environment and everyone's trying to see where all the boxes and pieces go. And a lot of times, they think that they see a box on a flow diagram and they didn't realize how the process worked or who had responsibility. So just aligning those expectations for performance is really valuable. It's a byproduct that you don't get to capture in the tool, but you certainly see the benefit to the working relationship that you develop."*

Another participant noted the effect of jointly analyzing the process:

> *"It took away a lot of the blaming…all the... 'You're overdue.' ' Well I'm not overdue because you didn't send me the part yet.' There was a lot of learning on both sides, we got the chance to see what their world is and what their systems are. We understood shortfalls in IT systems, different language, how we measure things [metrics were different, who owned it, accountability... all those things that make a process work well."*

Overall, engaging the customer on the improvement activity helped to identify more opportunities for improvement, and helped to establish an agreed-upon performance standard for the DR Investigation process.

3. A Flexible Standard for Deficiency Report Investigation Process

Having an inconsistently-defined performance standard for Pratt & Whitney begs the question of how exactly Pratt & Whitney achieved customer satisfaction with the USAF. With no clear target time for completing investigations before the value stream mapping and an "agreement to disagree" over the current standard, the line between a "good" and a "poor" level of performance is fuzzy, leaving room for multiple interpretations and negotiation.

Although reducing the time to complete DR Investigations is certainly important, what seems equally important was the signal that it sent to the US Air Force. Pratt & Whitney and the USAFare in a long-term relationship; there are only a small number customers in the world for military engines and only a handful firms that can produce high performance jet engines. Keeping the relationship on good terms is in the interests of both parties, and improving the DR Investigation Process was one way for Military Customer Support to strengthen their relationship with the USAF. In 2003, the Air Force was dissatisfied with the number of overdue investigations and, over the next few years, Pratt & Whitney was able to reduce the number of overdue investigations. While this was important at a pragmatic level (i.e. providing a stream of information to Tinker and F100 users), it was also important at a relational level. The number of overdue investigations is only one measure of how well Pratt & Whitney was performing investigations.

The way a customer interprets the service being provided is critical to customer satisfaction and a strong ongoing relationship. It is often not obvious what is important to the customer, making it even more difficult to set up a quantitative measure of the customer relationship. In the case of the DR Investigation process, it may be tempting to focus single-mindedly on meeting the magic number of 120 days. However, even meeting the 120 day

standard may not have been enough to ensure customer satisfaction. USAF complaints in 2003 were premised on the belief that DR Investigations – from mechanic discovery to USAF approval of the investigation report – should take 100 days. Even if Pratt & Whitney were completing investigations in 120 days (of course, it was not), the USAF would probably still have been dissatisfied.

Adding to the ambiguity of this standard is that fact that even the 120-day standard to Pratt & Whitney's portion of the investigation is not a "hard-fast" rule on any single investigation. Because the time to complete an investigation is, by definition, unknown, the DCMA and USAF can be accommodating if the circumstances warrant it. Larry Jones, Vice President of Military Customer Support, explained the inherent variability of the DR Process:

> *"Production facilities make widgets. Widgets may not be easy to make but they are easy to count. At the end of the day I was supposed to produce six, I made five, I failed. If I made seven, then I excelled. In the case of the DR process, the widgets are not all the same. One of the investigations may take you two years. You may need to run cycles on an engine to understand the problem. You have to get access to a test bed. You have to get the Government to say it's OK to borrow one of their assets to test. You have to get the funding aligned to run the test. It could take you two years, and the next one could take you 2 days.*
>
> *So there's no way to exactly quantify how much work there really is… so the 120 days is a standard that has to be adjustable to the specific issue. If I say, 'just go do this for a fixed period of time, what does that mean? Will I have provided too little time or have I taken 2 days of work and forced it into 120 days of elapsed time? How do I tell your boss, how long I need you?"*

To some extent, the USAF does recognize the inherent variability carrying out investigations. Many investigations, in fact, are given extensions from the USAF which grants Pratt & Whitney some reprieve for that particular investigation[20,21]. What is just as important as Pratt & Whitney's turnaround time for investigation, if not more important, is the quality and quantity of the information coming out of the DR investigation process. Rosemary Farrell noted that the backlog of investigations, though problematic as a measure of the speed of DR investigations, could have other far-reaching implications:

> *"If we have many overdue quality investigations, what does that imply about the population that might be affected by that quality investigation? It's in the customer's interest to quickly understand the root cause of quality problem and bound the population so that we can take action as quickly as possible."*

[20] Its completion time however is still factored into the monthly average, and Pratt & Whitney will still be held accountable to that monthly average.

[21] Based on all claims between 2002 and 2006, approximately 25% of investigations were given extensions. This percentage has remained constant over the 2002-2006 time period, though there is some variability from month to month.

It may be useful to think of the DR Investigations as part of an ongoing quality process. Pratt & Whitney is alerted to quality non-conformances which leads to an investigation and the generation of new information. This information is useful to the rest of the engine fleet since it is also at risk for the same nonconformance; a problem found on one part is likely to be found on other parts. Because of the implications of an investigation on the entire engine fleet, the USAF values an accurate and insightful investigation. DCMA Manager for the F100 program, Bill Folsom, explained:

> *"They're [USAF at Tinker Air Force Base] willing to let an investigation go on a little bit if they're going to get a good response – if it's going to keep bad stuff from getting to the field or it's going to help them find out something about other engines that they're going to have to remove. They would rather have a good product than a quick product…they don't care if the investigations go on as long as I regularly let them know what's going on."*

In a process where performance expectations are fluid, the key to satisfaction is that customer expectations and the delivered level of service match. As the USAF expectations on Pratt & Whitney relaxed to reflect the infeasibility of their original standard, it became more likely that Pratt & Whitney could meet customer expectations based on a new understanding. Pratt & Whitney would hold itself accountable to 120 days for its portion of the overall DR Investigation process and the 120 days would apply not to any single investigation, but would be the expected average[22]. Since then, the USAF has been satisfied with the level of service. According to Sammy Chandler at Tinker, the process is "pretty well fixed now." In jointly engaging in the improvement activity, the USAF and Pratt & Whitney were negotiating and redefining the terms of success.

Perhaps the lesson that can be drawn is that an organization that provides a service is more likely to satisfy its customer and build a long-term relationship if they jointly negotiate the standard for success. But jointly defining the standard for success may not be possible in all cases, particularly if one side seems self-interested. One issue that seemed important in the DR Investigation case was a perceived mutual interested in supporting the ultimate end-user, the "warfighter." One participant in the DR Investigation improvements explained:

> *"We have to support the warfighter in all the efforts we do. Some folks don't look at that that way but that was one of the goals that we established up front when we started the process. The better we are, the better our product is going to be for our users. We're here to make sure that warfighter has what he needs to do the job. That [goal] kept everybody focused."*

[22] Interestingly the expected turnaround time for DR investigations is still a point of some confusion. Although it is well established that 120 days is the appropriate performance standard, the USAF DCMA expectation has been that investigations be completed in 120 days *on average*, while Pratt & Whitney's expectation has been a 120 day *maximum* standard. In practice, this works out well because Pratt & Whitney's interpretation is more restrictive; if Pratt & Whitney meets its standard, then it automatically meets the DCMA standard. For Pratt & Whitney, thinking of 120 days as a maximum makes managing their internal processes easier since it sets an unambiguous standard.

To some extent, every organization pursues its own interests, but by demonstrating a level of commitment to goals of mutual interest – supporting the warfighter – Pratt & Whitney gained the legitimacy to participate in the negotiating and defining the standard of success for DR Investigations.

4. A genuine improvement orientation: Improvements continued beyond the F100

Although this case study focuses on the improvement efforts for DR investigations on the F100 engine program, it is insightful to place these events in their wider context. A common concern about continuous process improvement is that it risks becoming nothing more than a "check-the-box" activity. When people and organizations are not genuinely motivated, they may do what is required of them because they are concerned with how others might interpret their lack of action, but they have little motivation to do much more. This was not the case here. The DR Investigation Process improvements stretched well beyond where they had started – for the USAF quality investigations on F100 program.

The key piece of evidence is that, after the bulk of the F100 DR process improvements had been carried out by late 2005, improvement activity shifted from the F100 program, where the work originated, to other engine programs including the F117, F119 and F135, as well as to other customers. Although the DR Investigation process is slightly different in each case, the basic steps of disposition, investigation, and root cause and corrective action are consistent across other programs and customers.

Experience from the original F100 efforts provided leverage into improving these other processes. One goal was to standardize, as much as possible, the investigation process across programs and across customers. People were not thinking of the F100 DR Improvements as an isolated project, but as part of an ongoing process that included other engine programs. Rosemary Farrell explained why the initial focus was on F100 quality investigations:

> *"At the very beginning I was focused on the USAF who happened to be focused on the F100 and our problem area was quality. But my perspective was the company perspective. I was looking at quality and engineering way from the get-go. All those people were in the same room when we started mapping. I was looking at performance, and for a while quality was the problem."*

To illustrate how the DR Investigation improvement spread to different areas, Figure 11 lists all the value stream maps that have been created in CSIS from 2004 to 2008. While this does not capture all the improvement activity that occurred in CSIS and Military Customer Support, the list of value stream maps provides an indication of the location and magnitude of the improvement activities. The figure is organized into swim lanes, with the original DR Investigation improvements at the top lane. Arrows show how value stream maps evolved for a particular process; multiple listings connected by arrows at the same row show multiple revisions of the process map. As shown by entries in Figure 11, a significant amount of activity

occurred after 2005 in areas beyond the F100 program – in Support Equipment, the F119, the CSIS Crib, the F117, and international customers[23].

When I asked interview respondents about this trend, it was explained to me as follows: The DR Investigation Improvements began in 2004, mainly because of the complaints and prodding of the USAF. As progress was being made in the 2004/2005 timeframe, the Military Engines organization was undergoing a shift with respect to ACE. As Military Engines was becoming more mature with ACE, it started developing an independent desire to achieve ACE Gold levels of performance. Improvement activity started as reaction to the demands of a key customer, but evolved into more than that. Pursuing process improvement is a proactive way to increase the company's capabilities.

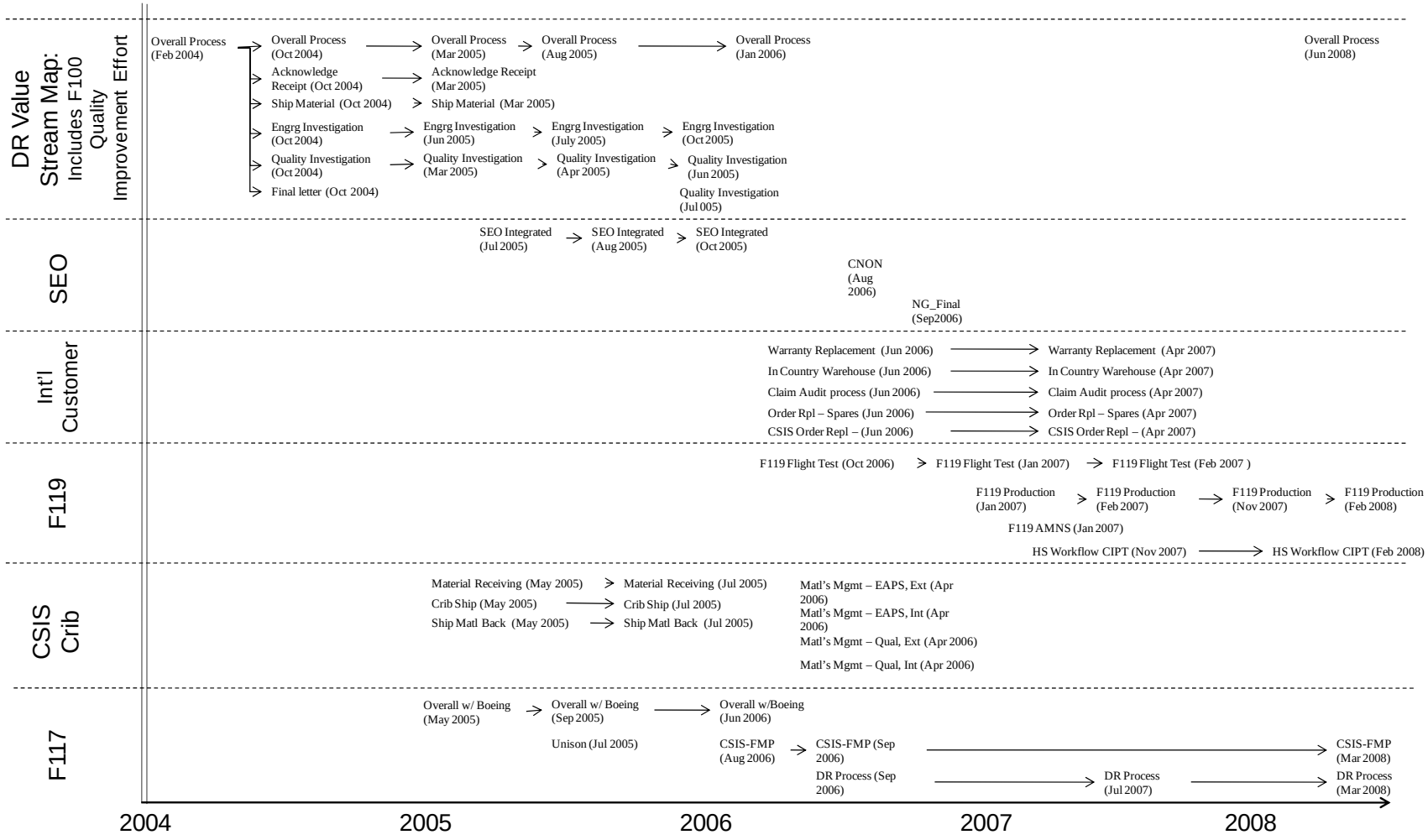
Recapping the Four Features

Discussion of these four features is intended to highlight what separates the DR Investigation process improvements from other improvement projects. Instead of being focused on improvement within a single organizational unit, the DR Investigation improvements involved a coalition of Pratt & Whitney workgroups. Instead of focusing on the processes internal to the organization, these improvements involved - and benefitted from the involvement of - external organizations, the DCMA and USAF. Instead of having to meet an objective goal, like a certain production or defect rate, the DR Investigation improvements were oriented towards customer satisfaction. Each side believed it had a clear 120-day performance standard but they later discovered that their interpretations of the standard differed. What was once thought of as an "objective" 120-day standard was shown to be negotiable. And instead of reaching the project goal and concluding improvement activity, the improvement efforts in this case continued, likely because of the improvement-orientation instilled by ACE.

The image of the DR Investigation process and Pratt & Whitney's effort to improve it is one that is different from a traditional engineering problem. In the idealized engineering problem, the goals and relevant criteria are known, rich data on the process are available, and the objectives of individuals, groups and organizations are aligned in wanting to solve the process. Many problems in organizations lack data with this level of precision and the DR Investigation Process improvements are no exception. In this case, improving the process meant dealing with and overcoming behavioral and political challenges in addition to technical challenges.

[23] A description of some process improvement activities can be found in Appendix A5.

Figure 11 - CSIS Value Stream Maps Created Between 2004-2008



IV. Reflecting on the past, looking to the future

While Section II provided a basic description of the events that occurred in the DR Investigation process improvements, and section III highlighted four features that set these improvement activities apart from a more conventional improvement project, this section will take a step back and focus on examining the link between the improvement activities and the improved performance on investigations.

There are two goals for this section. First, it will describe the state of the DR Investigation process several years later in 2008. This will provide a lens with which to better view the of the DR Investigation process improvements in 2004 and 2005. Second, it will discuss the mechanisms that led to improved performance metrics and success with the USAF. As mentioned earlier in the case, changes to the way the DR Investigation process was designed do not account for all the success that was observed.

The DR Investigation Process in 2008: In the Midst of Second Round of Improvement

There are ambitious ACE goals for the DR Investigation process and, while there have been some major steps forward in improving the process, there is still room for further improvement. Despite a drastic improvement of on-time investigations and the average completion time for investigations, the metrics are still not at ACE Gold standards. The percent of on-time investigations is still far from the ACE Gold standard of 100%, and the average completion time is still over 120 days[24]. A review of the 2007 value stream control tower shows that quality investigations did not make the ACE Bronze standard (80% on-time) for seven out of twelve months[25] (see Appendix A3). On one hand, this case study has described the significant improvements that have been made to the DR Investigation process. Yet on the other hand, there is still a chasm between the current levels of process performance and the standards set out by ACE. This begs the question of where the improvements to the DR Investigation Process are today, and what are the plans for further improvement.

ACE improvement activities continued in Military Engines and CSIS between 2006 and 2008, yet its focus shifted to other programs and other processes. This included: the investigation processes for the F117, F119, and Support Equipment Organization; material management processes; standard work and training materials. But it was mid-2008 when improvement focus returned to the F100 DR Investigation process as part of an attempt to create a standard investigation process for all engine problems.

[24] Note that, even if investigations were completed in 120 days on average, it would not mean that Pratt & Whitney would meet its on-time delivery requirement. Completing every investigation on time is equivalent to meeting a 120 day *maximum* standard, instead of the 120 day *average* standard.

[25] Engineering investigations did not meet the 80% on-time ACE Bronze standards for eleven of twelve months. Given the inherent variability and uncertainty in the investigation process, this is a difficult target to achieve.

This renewed DR Investigation improvement effort began with another value stream mapping session. Following the analysis of the value stream map, a new set of improvement activities were planned, some of which will be discussed below. Although the focus of this case study is on the DR Investigation Improvement in 2004 and 2005, examination of this second round of improvements is insightful because of the contrasts it draws with the 2004-2005 activities. Compared to the first round, the second round of improvement activity involves a more disciplined use of ACE tools but also a greater internal orientation.

VSM Event in CAN Module Center

On June 16th 2008, Rose Farrell kicked off a new effort to map the DR Investigation Process value stream, hosting the three-day event at the CAN (Combustor, Augmentor and Nozzle) Module Center. Until this latest event, the module centers had essentially been a black box in the investigation process. Farrell had hoped that by publishing performance metrics of each module center and with the increasing company focus on ACE, the module centers would organize their own improvement activities focused on the DR Investigation Process. But in April 2008, she had commented:

> *"The major piece of this process is just a black hole….We've asked the module centers if they have any data that they can share with us….one of the module centers said that they had maps but no data. They used our data. Another module center had no maps and no data. This has not been on their radar screen at all. I think the only reason we've gotten the performance we've seen is because of the pressure we have brought to bear on the organization through CIPT's. That's not a healthy process. That's just a muscle job."*

The original intent had been to map the investigation process internal to the module centers, since that is where the majority of Pratt & Whitney's investigation time is spent. Though the session began with a focus on the process in the module center, it eventually widened its scope to encompass the entire Pratt & Whitney process. This was because activities in the module center relied on information generated early in the investigation process and had implications for work steps later in the process.

This latest value stream mapping session was facilitated by the two members of the Military Engines ACE Office and by Randy Buckingham, one of Pratt & Whitney "ACE Masters[26]." Buckingham worked for Pratt & Whitney for 30 years, first starting off as a machine operator then getting involved with the company's early lean activities in the early 90s and now part of the Military Engines ACE Office. He is a classic example of Pratt & Whitney's investment in people; the company has helped to support his education at the associates, bachelors and masters degree levels.

Buckingham was able to contribute a deep knowledge of lean techniques. This Value Stream Mapping event closely adhered to "textbook" techniques (e.g. Learning to See[27]) and

[26] ACE Masters are the top group of Pratt & Whitney's lean and ACE experts.
[27] Rother, M. and Shook, J. (1999). Learning to See. Lean Enterprise Institute: Brookline, MA

reflected a more mature use of lean techniques[28]. Unlike the earlier process maps, the map included information flows and lead time ladders (compare Figure 12 with Figure 7). Once the current-state map was drawn, Buckingham and the other ACE facilitators analyzed it using the Seven Steps of Lean - takt time, finished goods strategy, continuous flow, pull systems, schedule at one point, interval, and pitch. In drawing the future state map, the ACE facilitators were instrumental in the helping to set an aggressive target. For a quality investigation, the targeted lead time in the future state map is less than one-quarter of the lead time in the current state map[29].

Three of the highest leverage improvements identified in the event were called: process gating, shared resource at the Materials Performance Engineering (MPE) Lab, and virtual cells. The strategy for process gating is to set up four or five gates along the investigation process which will provide a series of more immediate process goals and provide feedback as to whether the investigation is progressing on-schedule. If the investigation is not making adequate progress, it will signal the need for additional resources. The MPE lab performs structural analysis and is one of the final "ivory towers" in Pratt & Whitney not organized for process flow. Improvement in the MPE lab should be high impact, since it serves all module and parts centers. Virtual cells will involve employees from the module center, QACS, and CSIS jointly working on an investigation rather than passing it from one workgroup to another.

Rosemary Farrell excitedly described the future state as "radical" and pointed to better understanding of and support for ACE climate as enabling the bold agenda. Since the first improvement activity in 2004, Pratt & Whitney has become more sophisticated in its use of process management tools including value stream mapping. The Military Engines ACE Office, formally established in 2007, provides workgroups like CSIS technical support for ACE-related activities. Since as late as 2007, there has also been greater acceptance and interest of people in applying ACE methods beyond manufacturing processes to business processes. This second round of DR Investigation Improvement activity is taking place in a cultural environment more supportive of change[30].

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[28] Of the 28 ACE events labeled as "value stream mapping" events, Buckingham estimated that only six or seven were "true" value stream maps. The rest were more simple "process maps."
Up to this point, I have used the term "value stream map" interchangeably with "process map" but if we take the narrow definition of the former term, than only the 2008 map was a "value stream map" and maps drawn before then do not fit the strict definition.

[29] Buckingham conceded that this would not be a realistic goal for the next 3-6 months, but would provide an ultimate vision for the DR Investigation process.

[30] ACE has been used in Military Customer Support as far back as 1999 when CSBS became an ACE Qualifying cell (under its old name, Business Management Warranty & Repair Services, it became ACE Bronze in 2000, ACE Silver in 2001 and ACE Gold in 2006). Although there was a transition from using cells to sites as the unit of analysis for ACE assessments in 2002 throughout UTC, CSBS was not assessed as part of a site until September 2008. It was awarded ACE Silver at a site-level as part of the Military Support Center of Excellence.

The delay in shifting from cells to sites can be attributed in part to the questions about how to structure the Pratt & Whitney Military Engines organization to best provide customer support. Cell and site boundaries are drawn on top of the business unit structure, so unless the business unit structure is known, then there will be uncertainty on the appropriate cell and site boundaries. However, since the DR Investigation process improvements of 2004 and 2005, Pratt & Whitney Military Engines has been restructured. Within Military Engines, Military Customer Support and the Program Offices were separate organizations. The Program Offices had primary responsibility for maintaining the overall relationship with the customer, while Military Customer Support executed to the expectations of the relationship. These two business units were combined to form a single unit - Military

The first major follow up event occurred in August 2008 and its goal was to develop the process gates for the investigation process. This three day event brought together 15-20 people to not only map out the process, but also to lay out five process gates along the process. Process gates would be used as a way to track DR investigations in progress, and provide a benchmark. By recording when investigations pass a certain gate, managers will know whether investigations are at risk of going overdue and whether additional resources will be necessary.

This was a new capability for managing DR investigations. Before this event, while Pratt & Whitney could track how long investigations were taking and how many investigations were of a certain age (e.g. 0-30 days old, 30-90 days old, 90-120 days, 120+ days), they did not know whether an investigation was on the verge of going overdue, say 119 days old, was just about to be completed or whether a lot more work had to be done. In other words, they could not tell whether an investigation was proceeding on-schedule.

Another major change that was announced was that CSIS would step down as the lead workgroup in coordinating improvement in the DR Investigation process. In its place, CSE will take the lead in ACE improvement activities in addition to coordinating all investigations, including quality investigations. According to Rosemary Farrell, this change made a lot of sense. CSE is more knowledgeable about the content of investigations than CSIS, and engineers in CSE maintain ongoing relationships with customer engineers. When a customer engineer encounters a problem, the person they naturally contact is the CSE engineer, not the CSIS analyst.

The change from CSIS to CSE as lead workgroup was not without controversy. QACS objected, arguing that CSE engineers do not have the same level of expertise on quality investigation as quality engineers. CSE may raise unfounded objections on the thoroughness of quality investigations. In the end, the debate was settled by a compromise. All groups agreed that they would carry out a trial with CSE as coordinator, and they would re-evaluate the change after that.

The contrast with the 2004-2005 improvements in which CSIS led the improvement activity is striking. CSIS has never been involved in the content of the investigation - not in 2004, 2005 or 2008. So it would seem that the rationale for CSE leading the DR improvement activities was equally applicable then as it is now. So why then did CSIS, not CSE, lead the improvement activity in 2004-2005? One possible explanation is that having CSIS lead was the simplest arrangement politically. CSE and QACS share the same "jurisdictional area," that is, they solve similar problems and perform similar roles for Pratt & Whitney. Although one focuses on quality issues and the other focuses on design issues, they have a functional similarly that can lead to tension. Because CSIS has no stake in the content of the investigation, it could take the lead of improvement activity without arousing that tension. In the early tenuous stages

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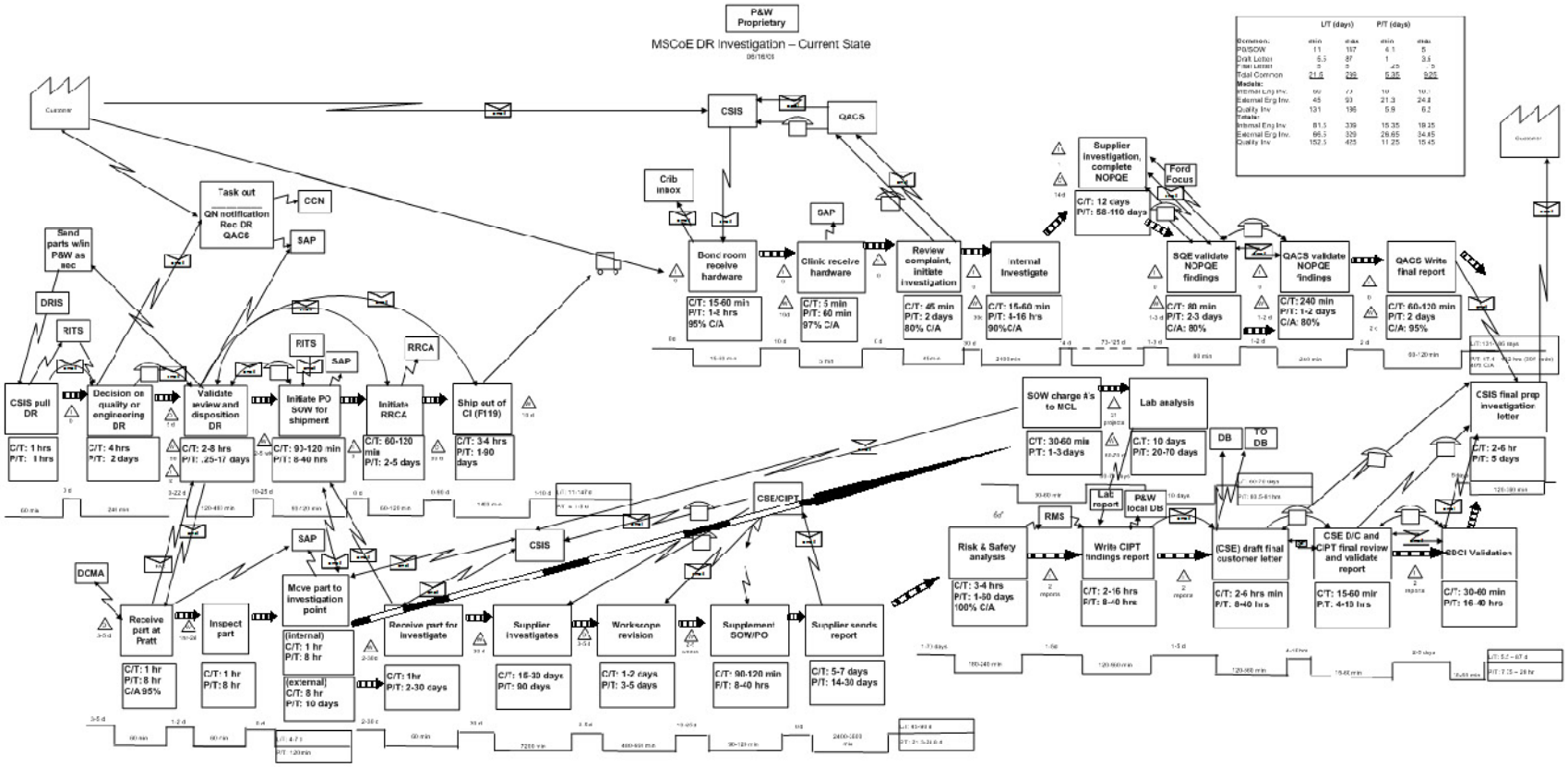
Programs and Customer Support. One part of Military Programs and Customer Support is the Military Support Center of Excellence which includes the Business Services, CSIS, Customer Support Engineering and the Spares organization.

Despite the changes in the Military Engines organization, I use the business unit names from the 2006 time period throughout the case study for consistency.

of the improvement effort, internal conflict might have derailed the overall improvement effort. This early decision was a wise political choice. However, now that the DR Investigation Process improvements have become more established, CSE can take the lead and leverage its substantive expertise.

Figure 12 – "True" value stream map drawn in 2008 – includes information flow and lead-time



An Internal Orientation for the 2008 Improvements

Although DCMA and USAF involvement had been beneficial in improving the DR investigation process, USAF involvement began to drop off after the March 2005 briefing. As a result, Farrell turned her focus on the internal processes at Pratt & Whitney. Explained by her boss, Larry Jones:

> *"Rose's job was to try to get people, internal and external to [Pratt & Whitney], to do things who didn't work for her. Part of the problem with us getting this done in a timely fashion, as I recall, was Rose couldn't get the government to respond. It was hard to get the right person from the government to show up because he was very busy with other priorities."*

On the USAF side, the drop off of involvement was a sign that they were satisfied with the work that had been done. The backlog of investigations that had built up before 2004 had been eliminated, and Chandler was receiving a steady flow of information from investigations being conducted by Pratt & Whitney.

> *"Once they implemented, I basically stepped back out of it because I haven't had an issue."*

Although he added:

> *"If they would like my assistance, I would be more than happy. And my boss…if we can make it better, we would be more than glad. The better we are, the better our product is going to be for our users."*

While this latest round of progress is exciting, it has taken a different tack from the earlier round of improvements in 2004 and 2005. Improvement activities are now largely focused internally, whereas they had once involved the DCMA and USAF. Meeting customer (i.e. DCMA,, USAF) requirements has been and is still the starting point for improvement activity, but customers have not been directly involved in the improvement activity itself. The DR Investigation process is important only because it provides value to the ultimate end-user, the warfighter; and Tinker, DCMA and Pratt & Whitney each consider themselves to be supporting the warfighter. Yet, from the warfighter's perspective, it should not matter that the investigation process spans the Pratt & Whitney and the USAF; any organization that is involved in the DR Investigation process should also be part of the effort in improving it. For Pratt & Whitney, an internal focus may make sense as a business, but it may not be the optimal focus to support the overall mission.

There are, of course, important practical constraints to what Pratt & Whitney can do. Pratt & Whitney can only control work that takes place within its own walls, yet working with the DCMA and USAF requires that they place the same priority on DR Investigations. It also requires paying "overhead" costs like coordinating work between Tinker in Oklahoma City, OK and Pratt & Whitney in East Hartford, CT. In the future, Randy Buckingham believes that re-

engaging the customer starts with first doing an extraordinary job internally, and then "pulling" the interest of the Air Force:

> *"The whole idea with an event is to come up with an idea to delight the customer. It would've been great to have seen the customer there, to show them what we could actually do…but my hope is that they become so pleased with our process that they want to understand how we do it. And maybe it will set the standard for all DR investigations throughout the Air Force. I'm hoping that if our performance gets that much better on DRs, then it will get their attention."*

Considering Chandler's general interest to help in improving the DR Investigation process, a joint effort may emerge in the future. It should not be surprising that there are still opportunities for further development of joint processes and expectations. For example, in September 2008, Pratt & Whitney had been contacted with a message calling for inquiry into 39 overdue USAF investigations. When the 39 investigations were looked into, it was discovered that 18 were assigned to Pratt & Whitney and the other 21 were assigned to other suppliers or to groups internal to Tinker Air Force Base. Of the 18 investigations assigned to Pratt & Whitney, four were overdue as of that month. CSIS looked into the 39 investigations and sent a manager from Hartford to visit the USAF at Tinker and explain their findings. Responding to the USAF request, CSIS demonstrated a continuing desire to work with the USAF to ensure high attention to detail and to strengthen their relationship - which can only improve the process in the future.

However, despite the desire and improvement potential of re-involving Tinker, a focus on Pratt & Whitney's internal processes, instead of the joint USAF-Pratt & Whitney processes, may actually make more sense. Though fully involving the DCMA and USAF in ongoing improvements may be ideal, the level of effort necessary to coordinate a multi-organizational improvement effort must be weighed against the relative priority of the DR Investigation process. It could be argued, since Sammy Chandler at Tinker is meeting the performance measures expected for the investigation process, that further improvements are less valuable or unnecessary. For a process of secondary importance, perhaps the required level of performance should be "good enough" in order to allow additional organizational resources to be allocated to processes of central importance.

From this perspective, Pratt & Whitney's current approach seems reasonable. With greater maturity in their use of ACE techniques, the DR Investigation process will almost certainly improve over the next year or two. And because Pratt & Whitney must perform DR Investigations for many engine programs, the current improvement activity exploits natural economies of scope. Assuming it is possible to coordinate the USAF, DCMA and Pratt & Whitney in an effort to improve the F100, it would not be an efficient division of labor considering the fact that there would be similar multi-organization process improvement efforts for every other engine program. Much (though not all) of what is learned with one engine program can be applied to other engine programs. An internal focus for Pratt & Whitney may be the right step for now - until more can be learned about the priority of the DR Investigation process and about the scope economies of the process in Pratt & Whitney[31].

[31] The other direction for Pratt & Whitney engagement is one that I do not have space to fully discuss. It is the involvement of suppliers in process improvement. Suppliers typically become involved in the DR Investigation

What improved? What led to the success of the improvement effort?

By and large, the DR Investigation Process improvements have been considered a success: the USAF was not satisfied with the process Pratt & Whitney responded using ACE tools, the USAF became satisfied, and Pratt & Whitney Military Customer Support continues to improve the investigation process in pursuit of ACE Gold. But the story is more nuanced than this. Certainly, improvement activities were organized and people were brought together to examine the process and plan changes. But what were the mechanisms that lead to improved process performance and USAF satisfaction?

The facts are that, in July 2005, there were 58 overdue DR Quality Investigations and, in July 2007, that number was reduced to zero (see Figure 2). Within 24 months, the 58 DR Investigations were completed - over and above five new DR Investigations per month (five is average number of new investigations per month). This means that Military Customer Support was completing about 7.4 investigations per month (5 + 58/24 = 7.4) for a two-year period to eliminate the backlog. Pratt & Whitney's throughput of DR Investigations increased by almost 50% above the required average monthly rate! Looking at the average completion time for investigations, the time dropped precipitously between 2004 and 2006 from 335 days to 129 days, a difference of 206 days (see Figure 9). These figures beg the question: what accounts for the 206 days?

Contributing to the mystery is the fact that little data exists about the DR Investigation process. As evidenced by the Process Gating event in August 2008 mentioned earlier, there was no automatic mechanism for collecting data about investigations as they were being processed. The data that was available (that has been used to generate the graphs in this case study) is at the level of the investigation – how long it took and whether it was on-time. Almost nothing is known about the duration of each step within the overall DR Investigation process as well as the variance around the average duration[32]. Of the described process changes that were proposed and completed, we do not know which ones – if any - led to the decreased processing time.

Perhaps the most natural expectation for process improvement based on techniques from lean manufacturing is that drastic improvement was the result of a radically redesigned DR Investigation process. The rationale would be that by eliminating non-value added work,

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process if the part under investigation is assembled by a supplier, not in-house. In this case, a module center will send the part out to the supplier for investigation and the supplier will return an investigation report back to the module center.

Thus far, Military Customer Support has not integrated the supplier investigation process with the Pratt & Whitney one. Evidence of this is the response time Pratt & Whitney expects from suppliers. The formal requirement is that suppliers complete the investigation within 10 days, though in reality suppliers take between 55 and 100 days to respond (and they do this with impunity). What's more is that, if the part were investigated in-house, Pratt & Whitney would expect a turnaround time of 30 days from the workgroup running tests. Since the work is essentially the same, there should not be two different standards. While little progress has been made on this front to date, it has been identified as a potential frontier for ACE in Military Engines.

[32] The exception is the data that has been presented in the first section of this case study. However, this data collection was work-intensive and - compared to what the data would ideally be – not complete. It would neither be sufficient nor practical to collect data by hand.

reducing handoffs, performing work in parallel, and/or changing information flow, the overall processing time can be reduced?

Interestingly, this explanation is not sufficient in this case. Examination of DR Investigation Process maps from 2004, 2005, and 2006 suggests that the overall design of the process was essentially unchanged (see Figure 13)[33]. Although the 2006 process map was certainly more detailed than earlier versions, it shows an underlying process with the same steps and the same precedence relationships[34,35].

The conclusion that the process had not been dramatically redesigned leaves two generic possibilities for explaining the performance improvement. Under the first possibility, process times were decreased because of increased pressure on workers to perform. People simply *work harder*. This might take the form of greater incentives for carrying out work quickly, of penalties for not carrying out work quickly enough, and/or more performance reviews. If true, this possibility would be unsettling since the fundamental motivation of ACE is to increase the organizational efficiency of every work process within Pratt & Whitney by using lean and quality management tools. The belief implicit in ACE is that problem solving helps to increase the quality of processes, reducing wasteful rework and other non-value adding work. Using the same amount of resources, only more efficiently, means a greater process throughput.

In the second possibility, the work process may have improved at more of a "micro" level such that changes to the process may not have been captured by structural changes to the DR Investigation value stream map. These are the types of changes that were proposed in the first round of DR Investigation process improvements in 2004. However, more than these proposed changes is necessary to explain the level of improvement. Recall from Table 3 that the estimated

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[33] To be sure, several structural changes were made to the process, but many of them were intended primarily for better material tracking, fewer mistakes, and documentation of turnbacks – not for reducing lead time.

[34] Figure 7 shows the 2004 value stream map. A photo of the map used in 2004 can be seen in Appendix A7. The 2006 process map can be seen in Appendix A6.

[35] We should be careful not to conclude, based on this insight, that the underlying process that was represented by the maps was also unchanged.

To understand why many of the maps looked the same, one has to look at organizational process for creating the value stream maps. Between 2004 and 2006, there were three iterations of the overall DR Investigation process map, and three iterations of the quality loop process map. The work process was not well documented in a manner conducive to process improvement; developing the process maps was the first rigorous approach to documenting the process. Early maps outlined the basic DR Investigation process and estimated times for many steps. These early maps were incomplete and later maps were meant to create a more complete picture of the process.

The conclusion is consistent with the content of meeting records and interviews. Use of the process map in the 2004-2005 timeframe aided in mutual understanding of the process and in generating consensus about the problems in the process. As mentioned earlier, the types of drastic changes that might be expected by the value stream mapping technique only began to occur in 2008 under the guidance of ACE Master, Randy Buckingham.

An alternative expectation might be that each map was created anew, and documented changes to the process as improvement activity proceeded. In this case, each map would reflect the process "as-is" at that point in time and an analysis of the 2004, 2005 and 2006 maps would reflect changes to the way work was carried out. This was not the case. Farrell and the rest of the improvement team believed they were able to identify major problems in the process and take action in fixing them without a detail "as-is" process map – one which would include all work steps, conditional loops, percent correct and accurate at each step, and the process and lead times of each step. This level of detail was believed to be unnecessary to identify the major problems in the DR Investigation process.

amount of improvement from the proposed changes accounted for only 109 to 137 days, while the observed improvement is 206 days (see Figure 9). A complete explanation must explain this difference.

Figure 13 - Comparison on 2004, 2006 and 2008 value stream maps[36]

	2004 Map		2006 Map		2008 Map**		
	Step	Lead Time (days)	Step	Lead Time (days)	Step	Process Time (days)	Wait Tme until step begins (days)
Customer Loop	Initiate SF368	3	Initiate SF368	3			
	Submit to DREAMS	13	Submit to DREAMS	13			
	Assign Action Point	1	Assign Action Point	1			
	Review DR	2	Review DR	2			
	Enter name in GO21	1	Enter name in GO21	1			
	Assign SP	10	Assign SP	10			
Disposition Loop	Pull DR Warranty	20 min	Pull DR Warranty	20 min	CSIS Pull DR	0.041666667	
	Acknolwedge Recpt and Notify WRS	3	Acknolwedge Recpt and Notify CSIS	3	Determine if quality or Engrg DR	2	
	Provide Recommendation	2	Create notification	10 min	Validate review and disposition [	0.25-17	0-22
			Provide Recommendation	2			
Ship Material Loop	Provide Recommendation	7	Provide Recommendation	7			
	Ship Material	45-365	Ship Material	45-365			
Pre-Investigation Loop	Initiate EVMS Paperwork	1	Initiate EVMS Paperwork	1	Initiate PO SOW for shipment	8-40	10-25
	Notify QACS	2	Open QN and Notify QACS	2	Initiate RRCA	2-5	
	Receive Doc # from QACS	3	Initiate Work Authorization	4	Receive part at Pratt	0.3333	
	Initiate Work Authorization	4	Issue Instruction to Bond Room	1	Inspect part	0.3333	1-2
	Receive Material	1	Receive Material, notify DCMA	1	Move part to investigation point (	0.3333	
	Receive Material - Bond Room	1	Store material in SAP	1	Bond room receive hardware	.04167-.333	
	Notify DCMA that material arrived	1	Complete SAP Transaction & Move Exh	1.5	Hardware received in clinic	0.04167	10
	Notify Analyst that Material arrived	1	Notify Analyst that Material arrived	1	Review complaint	2	
	Issue Work Instruction to Bond Roon	1	Update WCMS	1			
	Prepare & send paperwork to Bond R	1	Route Material	4			
	Complete SAP Transaction & Move E	1.5	Mod center notifies bond room of receip	30			
	Route Material	3	Bond Room updates SAP, notifies analy	30 min			
Investigation Loop	Investigate QN	67	Quality Investigation	67	Internal Investigate	30	30
	Generate Final Report	12	Generate Final Report	1	QACS Validate findings	1-2	1-2
	Generate Final Letter	10	Generate Final Letter	12	QACS Write Report	2	2
					CSIS review	5	
Post-Investigation Loop	Submit to customers	2	Submit to customers & AP	2			
	Submit final report to AP	10	Close DR	0.5			
	Close DR	5	Return Material	15-30			
	Return Material	15-30	USAF read and review report	1-3			
	Originator Receive Closure	3	Summarize report	1-3			
			Read final letter	3			
			Forward QAS to module Center	1			
			Review final letter	1			

*the 2008 Process Map includes only portions of the process conducted internally by Pratt & Whitney

Totals of each map, for each loop

	2004 Map	2006 Map	2008 Map
Customer Loop	30	30	
Disposition Loop	5.01	5.02	2.29-41.04
Ship Material Loop	52-372	52-372	
Pre-Investigation Loop	20.5	17.52*	34.08-85.37
Investigation Loop	89	80	71-73
Post-Investigation Loop	35-50	24.5-43.5	
TOTAL	231.51-566.51	209.04-228.04	107.37-199.37

* One 30-day step was not included because it is not on the critical path

[36] To generate this table, I followed each process map and listed each step for a quality investigation, completed in-house. I grouped the steps into the basic six process loops, to allow for comparison of each process map at the same point in the process.

Comparison of the 2004 and 2006 maps shows that many of the steps and process times are the same. The 2008 map was generated separately only includes portions of the DR process internal to Pratt & Whitney, and separates lead time into process time and wait time. Although the names of the process steps are different, the overall process in the 2008 map is similar to the 2004 and 2006 maps.

Drawing Greater Attention to the DR Process

It is the second possibility finds more support than the first. The proposed changes to the DR Investigation process led to some decrease in completion time (though we cannot tell how much of what was initially estimated actually came to fruition), while the remainder of the improvements can best be explained as the result of increased priority of level of DR investigations throughout the Military Customer Support organization. This had the effect of reducing waiting time at many steps in the process which reduced the DR Investigation time overall. This possibility can be described as *Pareto superior* – it makes the DR Process better off without making other processes worse off.

The process improvement activities helped to draw a new, higher level of attention on the DR Investigation Process. As DR Investigations became a higher organizational priority, each workgroup became incrementally more responsive to investigation work demands. This sort of responsiveness can have a significant impact because a large component of an investigation is coordination between Pratt & Whitney workgroups. Consider that while the US Air Force requirement is 120 *days*[37], the estimated processing time for a DR Investigation is about 120 *hours* (according to the 2004 process map, see Figure 7). Handoffs and waiting in between work steps account for the vast majority (120 days – 120 hours = 115 days, or ~95%) of the investigation lead time, so managing this time is potentially a powerful means of improving process performance. Larry Jones explained:

> *"It was key to get people to acknowledge that what we were working to accomplish was important before we could get them to focus on the process. It took some cajoling and eventually it took more than just Rose. It took getting US Air Force propulsion leadership and Warren Boley, the vice president of Operational Military Engines, to put their weight behind the effort to get their people dedicated to success. You sometimes have to go pound on peoples' doors to get them to pay attention because they have other important things occupying them."*

Higher prioritization, even if not explicit, means that when a DR Investigation crosses the desk of a manager or engineer, she shifts her attention from other work tasks to the DR. If everyone involved in the DR process puts in the same amount of work, but simply gets to it sooner, then the overall DR investigation time will be reduced though the work time for each step is unchanged. At the "micro" level of the DR Investigation process, non-value adding steps – waiting time – is being removed from the process. The ability of individuals to attend to DR investigations sooner may also be enabled by standard work, which specifies work expectations and reduces variability in the work that is passed from one individual to another. A comment made by Steve Ash supports this explanation:

> *"The customer requested better performance and hence the collective Pratt & Whitney organization focused more energy on completing investigations on time to meet customer expectations. We are always working with competing demands and limited resources. Priorities change over time."*

[37]The process lead time is frequently longer – 452 days on the 2004 process map.

Several mechanisms for communication and coordination have helped to increase the visibility and priority of DR Investigations. In 2004, weekly conference calls were organized by Mary Anne Cannon. During these calls, each module center reported on the number of investigations in process and the status of each one until the investigation backlog was eliminated. Today, there is a similar weekly conference call for reviewing investigations and, in addition, Rose Farrell uses a monthly report that tracks the number of investigations by engine program, by module center, and by age. This is distributed to other workgroups as well as company executives.

There is of course a fine line between reminding people of the importance of a DR Investigations and pressuring them into working harder. In the DR Investigation case, work intensification still seems unlikely. First, CSIS has continuously had 10-15% of its staff positions open. Staffing levels did not increase in response to an increased workload, and staffing levels did not decrease as might be expected if pressure to perform had become burdensome. Second, most of the time and work in carrying out an investigation is done in the module centers. CSIS has little influence over the allocation of resources in the module centers, and has only been modestly successful in getting the attention of module centers and high-level company executives who might use their authority to allocation more resources to DR Investigations

To summarize, the most likely explanation is that, on top of specific proposed "micro-level" changes, the efficiency increased through small improvements at many steps in the process through increased prioritizations. This is resulted in a *Pareto superior* outcome. To those who study process management technique like lean manufacturing, this conclusion may be unsatisfying. Process management seeks to replace *working harder* with *working smarter.* The improvements made in the 2004-2005 timeframe resulted from a smarter prioritization of activities, but not from a clever redesign of the overall process. The DR Investigation process had not been rigorously managed before and left ample opportunity for a subtle behavioral change like increased prioritization to make a significant impact to process performance[38]. However, as improvement activity continues beyond 2008, Pratt & Whitney may be approaching the limits to benefits from smarter prioritization and is turning to redesigning the overall process using process management techniques.

[38] There are limits to this of course. Increased prioritization was sufficient to complete the 60+ overdue quality investigations in 2004 and drop the process time to about 130 days but, since then, has not significantly improved the monthly average investigation completion times.

People are certainly more educated about the process – who is involved and approximate time frames for each step but there has not yet been a systematic approach to drastically changing the DR Investigation process, at least until the 2008 value stream mapping session.

V. Closing Remarks

The DR Investigation Process improvements were successful in decreasing investigation completion time, increasing the proportion of on-time investigations, building a common set of expectations about the process, and strengthening the relationship between the USAF and Pratt & Whitney. The effort had started off as a response to a customer need, but transformed into one where those in Military Customer Support would pursue subsequent improvements on their own. Multiple workgroups were coordinated horizontally, with little guidance from above. Pratt & Whitney also engaged with the DCMA and the USAF, which permitted a wide scope of improvement activity - from mechanic discovery to USAF approval of the final report. It also allowed a shared set of expectations to develop between Pratt & Whitney and the USAF, having the effect of reducing the level of tension and increasing the level of satisfaction in the relationship.

Nonetheless, as investigation metrics are not at the ACE Gold standard, there remains space for further improvement. To meet this challenge, more work – exciting work – is ongoing. Whereas the first round of improvements took important first steps and laid the groundwork for later work, this latest round of improvements, by taking greater advantage of the lean methodology, strives for a radical rethinking of the process and could cut process lead time by 50%-75%. The next year should be an exciting time for the DR Investigation process.

This case study is intended to provide a description of the activities that were part of the DR Investigation process improvements. This sort of description is useful in and of itself, hopefully illustrating the organizational and behavioral complexity of successful process improvement and suggesting we maintain a more critical eye towards process improvement "success stories" which may be decontextualized.

Going beyond description and beginning to abstract from what was observed, we can glean some insights that may be relevant for systems for process management like ACE. This case will leave three points for the reader to consider:

1. The application of prescribed ACE tools was immature in the 2004-2005 time period, but given the state of the DR Investigation process, the immature application ACE tools was not a major constraint to improvement. Systems for data collection had not been put in place, and there was disagreement over the priority of DR Investigations both within Pratt & Whitney and between Pratt & Whitney and the USAF. When the process being improved is not mature, then simple approaches to process improvement may be most expedient.

2. It may be especially helpful to slowly build consensus among people - even if the process management tools are not used to their fullest extent – if the process cuts across many organizations and workgroups. Workgroups were willing to take on additional work responsibilities if it meant improving the overall process, and this willingness was built on a shared understanding of the DR Investigation process. In addition prioritization on ACE and on the DR Investigation process likely played a significant part of the observed improvement in the form of many individual decisions to attend to investigations more

quickly. Of course, building consensus about the priority of a certain work task will only improve a process to a limit, but it does establish a more stable environment in which ACE tools can later be used to their full extent.

3. There were two important outcomes in the DR Investigation process improvements that are related but also independent: improved process performance, and a positive relational outcome with the USAF. Although it may be tempting to focus on improving objective direct measures of performance, those measures cannot capture the full meaning of customer satisfaction and a strengthened relationship. Both outcomes must be considered simultaneously. Better performance on objective dimensions like completion time and percent on-time may lead to customer satisfaction and a strengthened customer relationship, or it may not. In fact, while ambiguity about the appropriate performance standard had initially been a source of conflict, once Pratt & Whitney demonstrated a commitment to improving the process, ambiguity also provided a large space for negotiation and compromise.

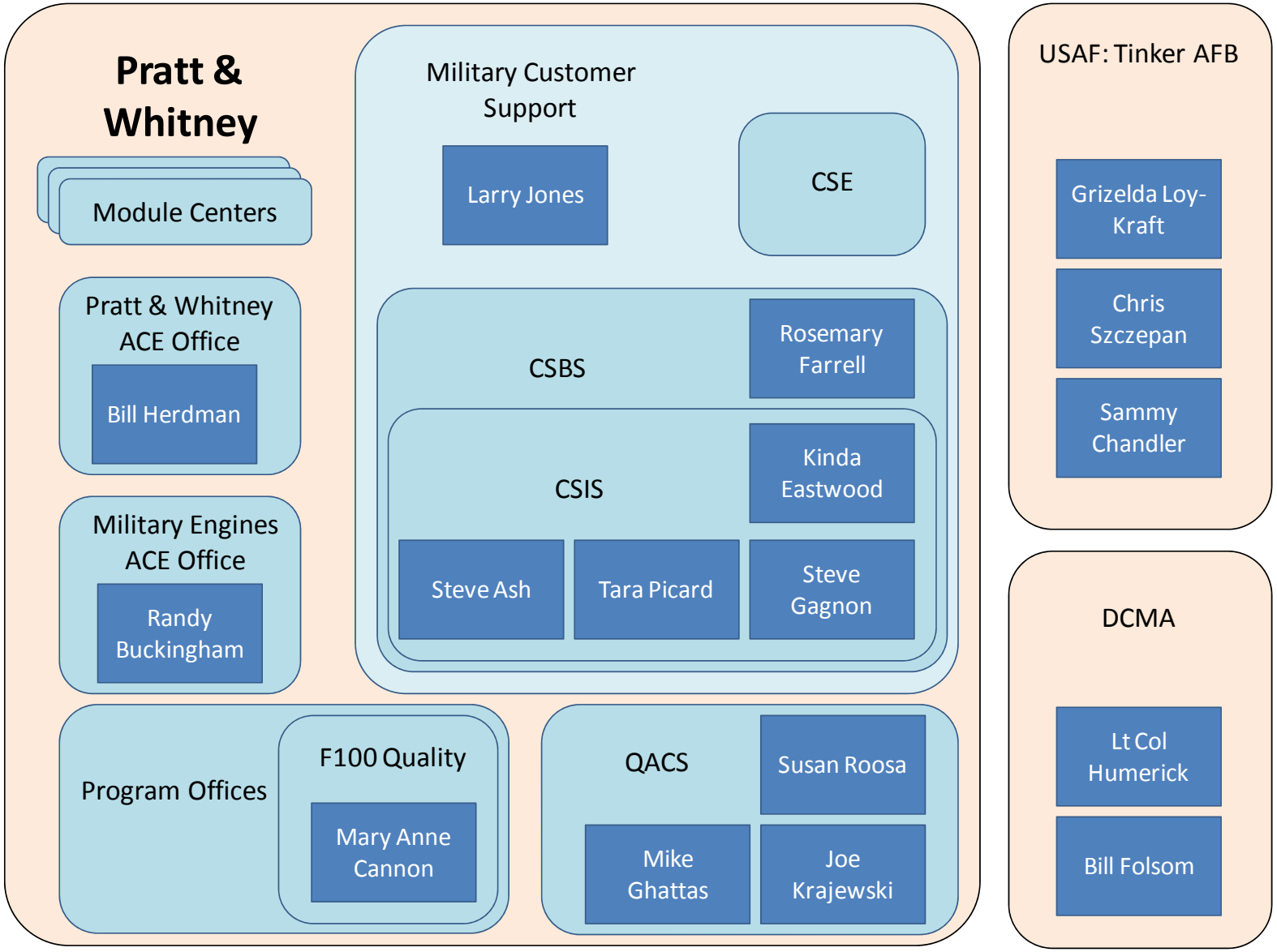
VI. Appendix

A1. Programs and Organizations within Pratt & Whitney Military Engines

F100	• Engine used on the F-15, F-16 • Entered service 1974 • USAF is the primary customer, but there are also a number of other international customers • Tinker AFB in Oklahoma City is the central depot for F100 engines in the Air Force. If an Air Force base has a problem with their F100 engine, it contacts Tinker. • The Air Force management of the F100 DR Process resides at Tinker AFB. It was their concerns about overdue Quality Investigations in 2003 that became the primary motivation for the DR Investigation Process Improvements.
CSIS	• Customer Support and Investigation Services • Handles warranty claims, repairs & the deficiency report process • On the DR Process, coordinates engineering and quality investigations
CSE	• Customer Support Engineering • Responsible for engineering investigations, work with engineers at module centers to conduct investigations. • Engineers in CSE are associated with specific engine programs
QACS	• Quality Assurance Customer Support • Responsible for quality investigations, the disposition process • Ensure investigations are completed in a timely and thorough manner, but do not conduct the investigations • Review investigation data from the module centers, and writes the final investigation report and accompanying letter for the customer
Engineering	• A functional organization in Pratt & Whitney. Individual engineers in module centers report to the engineering function in addition to their module center.
Quality	• A functional organization in Pratt & Whitney. Individual engineers in module centers report to the quality function in addition to their module center.
Module & Part Centers	• Sub-units that specialize on the purchasing, engineering, production, delivery and service of specific engine components. • Includes: Electronic and mechanical systems module center, compression system module center, controls and externals module center, turbine module center, combustor augmentor & nozzle

	(CAN) module center, mature engines parts center, small hardware parts center, or the international parts center.
Military Engines ACE Office	• Group of ACE specialists formed to provide support for workgroups in Military Engines • Separate from the core Pratt & Whitney ACE Office
Pratt & Whitney ACE Office	• ACE office that confers Gold, Silver and Bronze status to Pratt & Whitney sites and cells • Each Pratt & Whitney site has a "client manager" who provides limited process improvement support and coordinates ACE certification
Military Engines	• One of nine divisions within Pratt and Whitney headed by Tom Farmer.
DCMA	• Defense Contract Management Agency • The DCMA is a quasi-governmental agency that acts an intermediary between the US Department of Defense (DoD) and its contractors. About 75 DCMA staff are located in at Pratt and Whitney's East Hartford campus managing DoD contracts.
CSBS	• Customer Support Business Services • Comprised of four smaller workgroups: CSIS, Business Support, Proposal Support, IT Support • Headed by Rosemary Farrell

A2. Relevant Organizations and People Involved in the DR Process Improvements



A3. CSBS/CSIS Control Towers, 2007

Value Stream Control Tower - 2007

CSBS Value Stream	Customer Satisfaction		Quality			Delivery				Financial	
	CPAR Average			Escapes		Investigation		CNON Disposition			
	Ease of Doing Business	Cost of Ownership	Investigation on RFAI	Significant Customer Escapes	Other Customer Escapes	Quality	EAPS	Other	F119	F100 Monthly Liquidated Damages	SSR Compliance
Gold											
Silver											
Bronze											
Baseline 2003											
GOAL 2004											
January-04				NEW METRIC	NEW METRIC						
February-04											
March-04											
April-04											
May-04											
June-04											
July-04											
August-04											
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November-04											
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Baseline 2004											
GOAL 2005											
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June-07											
July-07											
August-07											
September-07											
October-07											
November-07											
December-07											
Cumulative Performance											

Cell Level Control Tower - 2007

CSBS Cell Level	Customer Satisfaction	EH&S		Employee Fulfillment										Quality						Delivery				Financial								
	MFA / Annual Survey													Escapes						EAC												
	Overall	Recordable Incident Rate	Lost Time Incident Rate	Overall MCS Survey Response	Skills Matrix			Leadership Training	PFT Objectives Set	PFT Closed	IDP Update	Staffing Level		Significant Customer Escapes	Other Customer Escapes			Compliance	Avg. Turnback per Warranty EAC	Avg. Turnbacks per Proposal	BS EACs On-Time	PS SOX Letters On-Time	BS & PS EACs On Time	Final Investigation Letter On-Time	Overall			w/o IT			IT Only			
																									Financial	Plan	Overhead Budget ($ K)	Actual	Plan	Overhead Budget w/o IT ($ K)	Actual	Plan	Overhead Budget IT only ($ K)
Gold																																
Silver																																
Bronze																																
50																																
2004 Goal																																
January-04																																
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October-07																																
November-07																																
Cumulative Performance																																

History of BMWRS/CSBS ACE Certification

1999 – Qualifying Cell
2000 – Bronze Cell
2001 – Silver Cell
2004 – Silver Cell Recertified
2005 – Silver Cell Recertified
2006 – Gold Cell
2008 – Gold Cell, as one part of a newly formed Silver ACE site
2009 – Cell-level recertification assessment planned for May 2009

Key To Control Tower Colors

100% of ACE Standard	Gold
90%<X<100%	Silver
80%<X<90%	Bronze
x<80%	Below Standard
Actual Value or Data missing	
Target value	

A4. Challenges with Data and Information Technology

One key hindrance at the beginning of the improvement effort was the lack of clean, reliable data. Without detailed process data, it was difficult to establish the right level of urgency in the organization and to identify the best improvement projects. Data quality and quantity has gradually improved since 2004, but more work is needed.

In 2004, a separate, but related initiative was underway to upgrade the IT system - not just for managing DR investigations, but also other aspects of CSIS's business. CSIS had been using a disconnected IT system for managing DR Investigations and its two other primary value streams: warranty claims, and repairs. The IT system had been pieced together from several legacy and "homegrown" systems and, although Farrell did not find the data reliable, it was the best data they had for managing their business.

> *"I called our system back then 'a box sitting on a lot of matchsticks.' Because we were using a mainframe system as a repository for data, we took a snapshot of it regularly and managed our entire warranty and investigation process through [Microsoft] Access. So we were using Access to manipulate data and manage the day-to-day business. And of course what would happen is that it would crash regularly. We had a lot of Access experts in the department - out of necessity. The [CSIS] manager back in those days would end up staying until 10 or 11 o'clock at night repairing the problems so we could be back up and running the next morning."*

In managing the DR Investigation Process, data integrity was a major concern since different customer service workgroups often did not agree on how long the DR investigation had been in any given step. Each had its own system for recording data, with fields that were defined in different ways.

> *"We have a legacy based claim management system called WCMS that is being phased out and replaced by our new SAP based system. One of the biggest issues with WCMS is the lack of system-driven data integrity. In other words, if I put in the wrong serial number part number combination, the system allowed it. WCMS would not flag the data as suspect." "The new SAP claim management system does, which in turn ensures data integrity."*

Reconciling the data was not only "a nightmare," but it was also wasteful. Former CSIS Manager, Tara Picard, explained:

> *"Another thing is when you start asking the analysts, they say that they have to go to this computer than that computer. In addition to the databases for contract interpretation and recording of customer DRs, we had to go to two different systems for financials."*

It was only by July 2005, when CSIS began a concerted effort to reconcile and clean data, that data on the DR Investigation Process became more reliable. Rose Farrell said:

"Finally we said, enough of that. The one source of data will be in CSIS, so we can stop with this reconciliation business. And Rita [employee in CSIS] essentially took on the responsibility for cleaning the data and getting it to the point where we could believe that we could rely on. So that's why much of the data begins in July 2005"

Since then, new types of data has been collected and tracked. Before 2004, CSIS used to track investigation times by the amount of time a "claim" remains open in the WCMS system. A claim is simply a mechanism with which to track material and authorize work in Pratt & Whitney. But because claims are not necessarily closed when investigations are complete, and multiple claims can be resolved by a single investigation (if they relate to the same quality problem), this was an imprecise measure of investigation times.

Now CSIS tracks investigations themselves, not claims, on its control tower. In addition, more detailed reports are used to better manage investigations. The data includes investigations by module center, and investigation by time elapsed (Investigations are grouped into one of four "age buckets" – 0-30 days, 31-90 days, 91-120 days, and 120+ days). Other workgroups in the DR Investigation process regard the new CSIS data as the official data, and populate their own metrics charts and control towers based on the CSIS data.

Still, the data is not perfect. For one, when the data was cleaned in July 2005, "*we reconciled the data with CSE and with QACS but didn't reconcile the data in quite the same way. That's why we still have some challenges with the data today to marry up those final letter dates and so on.*" The true data of course is "out there" somewhere, but since it is not automatically collected, it is work intensive to collect and reconcile it with other data sources. Steve Ash commented:

"The problem is that presently all the systems are disjointed and you just can't capture the transactions and automate this process. So it requires manual management by people to capture the data. That's the main challenge. So is data accuracy, and so is the additional workload in an environment where people can't take on additional work."

The quality and level of detail of data is expected to improve in the future. CSIS is in the process of switching over from their legacy information systems to the SAP. Blueprinting of the electronic transactions began in 2004 and, in 2005, the slow transition to SAP began. And although the transition accelerated in 2006, it still continues in 2008.

Future plans call for the creation of several "gates" along the DR Investigation process. This will be useful because, although CSIS is fairly confident on the start and finish date for each investigation, it cannot assess the progress of an investigation underway (except on an ad hoc basis). With process gates, it would be possible for Military Customer Support to know where along the process an investigation should be 30, 60, or 90 days into the process, and whether it is on track to be completed on-time.. Process gates would serve as natural data collection points along the investigation process, and would help Military Customer Support identify critical process bottlenecks.

A5. Description of improvement activity in the F117 and F119 engine programs.

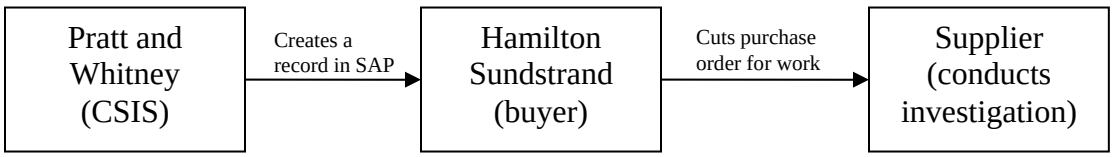
Improvements on the F117 Engine Program

In June 2005, Rose Farrell and her team kicked off improvement efforts for the F117 program. Like the F100, it was agreed that the process for the F117 was unclear and inconsistent; there was likely to be a lot of non-value added work in the form of inefficient processes and redundant work steps. Yet the differences in the F117 also led to some issues not found on the F100. On this program, Pratt & Whitney is a subcontractor for Boeing who, in turn, provides complete C-17 aircraft to the USAF. When conducting investigations, Military Customer Support responds to Boeing, not the DCMA and the Air Force.

One of the first major improvements on the F117 was in the purchase order process. Purchase orders are necessary when the investigation is carried out by a supplier, not by an internal center at Pratt & Whitney. When the investigation is conducted internally, the process is fairly straightforward; a statement of work is created, a budget estimated and a charge number provided. But when the investigation is conducted externally, a CSIS analyst contacts a buyer in Hamilton Sundstrand, a UTC sister company, who is responsible for purchasing certain types of parts. Hamilton Sundstrand, in turn, generates the purchase order which is sent to a supplier and authorizes the investigation work to be conducted. Garry Frost, a supervisor in CSIS, explained:

> *"There's a multi-step process that takes place when cutting a purchase order…We (CSIS) generate a 'memo ID in the SAP system which goes to the buyer via workflow [in Hamilton Sundstrand].' The buyer then creates a purchase order based on the information in the memo ID and sends it to the supplier."*

Figure 5: Overview of the Hamilton Sundstrand Purchase Order Process



Driven by Kinda Eastwood, a joint team of five people from Pratt & Whitney and four from Hamilton Sundstrand was formed to study this process. Previously, because the work process and expectations of the CSIS analyst and Hamilton Sundstrand buyer had never been formally defined and were often confused, the purchase order process would be delayed as a result. To improve the work process, the team defined the process and created standard work for communication between the Hamilton Sundstrand and supplier, and between CSIS and the supplier The Hamilton Sundstrand team also created standard work for their side of the process once they receive a "memo ID" from CSIS. Garry Frost explained:

"Within our Standard Work, we created standard text templates that the analyst puts into the memo ID. This simplified the process and shortened the time required to create a memo ID. The standard text also ensures we are providing instructions we can hold the supplier to. That was part of our success on that team."

Another key event in the F117 improvement effort was a value stream mapping event with Boeing that helped to improve their working relationship. Prior to the improvement efforts, the relationship between Boeing and CSIS had been described as less than ideal. Another person from CSIS noted:

"They were very dissatisfied initially. Our failure to deliver parts…every part that is involved in an investigation is an asset that is being held up from being returned to the field for use. It creates strain on the logistics system and in an FMP [Fleet Management Program] environment. That strain is picked up in one of two places – either Pratt & Whitney or Boeing."

Part of the problem was the lack of a clear DR investigation process and a clear set of expectations on both the Boeing and Pratt & Whitney sides. This person continued:

"Boeing would send us an email and say that this part is coming in for an investigation. Well, we didn't give them a disposition, we didn't agree to that [an investigation]. So they would start the clock. That is just one example of misalignment of expectations, role, and responsibilities."

CSIS gathered together a team of Pratt & Whitney and Boeing representatives to create a process map of the F117 process. Some people believe that the process of jointly creating a VSM helped improve their working relationship.

"Initially, they were very unhappy but we had done some prework prior to meeting with them. We had mapped the entire process, from the time when we received the part. And we did that specific to the F117 process. We asked them if they would help us map the front portion of it. When they saw the map and the work that we had done in putting it together, I think that it showed that we recognized the need to hear them and that we were committed to improving."

One new shared understanding that emerged from the value stream mapping process was that Pratt & Whitney should not release the material until the final customer – the US Air Force – concurs on the investigation findings. This was necessary because, if the USAF disagrees with an investigation finding, Pratt & Whitney engineers may need to reinvestigate the part and it is important that the part be in a controlled environment. Boeing had frequently complained about this problem because although the DR investigation may essentially be completed, Boeing cannot get the part back and cannot alleviate the logistics strain resulting from the tied-up part.

Improvements on the F119 Engine Program

Designed for the F-22 Raptor, the F119 engine program is the newest military engine in production. Like the F117, the F119 is a "Fleet Management Program" which means that the Air Force has a contract with Pratt & Whitney for the maintenance and management of the engine fleet. The main challenge on the F119 program is to complete DR Investigations as quickly as possible, so that engineers can learn as much as possible, as quickly as possible. This allows the program to climb the experience curve as corrective action and design changes will improve the performance of existing and future engines. The first DRs for the F119 program arrived in 2001 when three were submitted. In 2006, the number received was up to 685 DRs which yielded 120 investigations.

Value stream mapping of the F119 DR Investigation process began in February 2005. Building off the F100 value stream, several changes had to be made to the process. Jim Beaver, representing CSE on the F119, described it as:

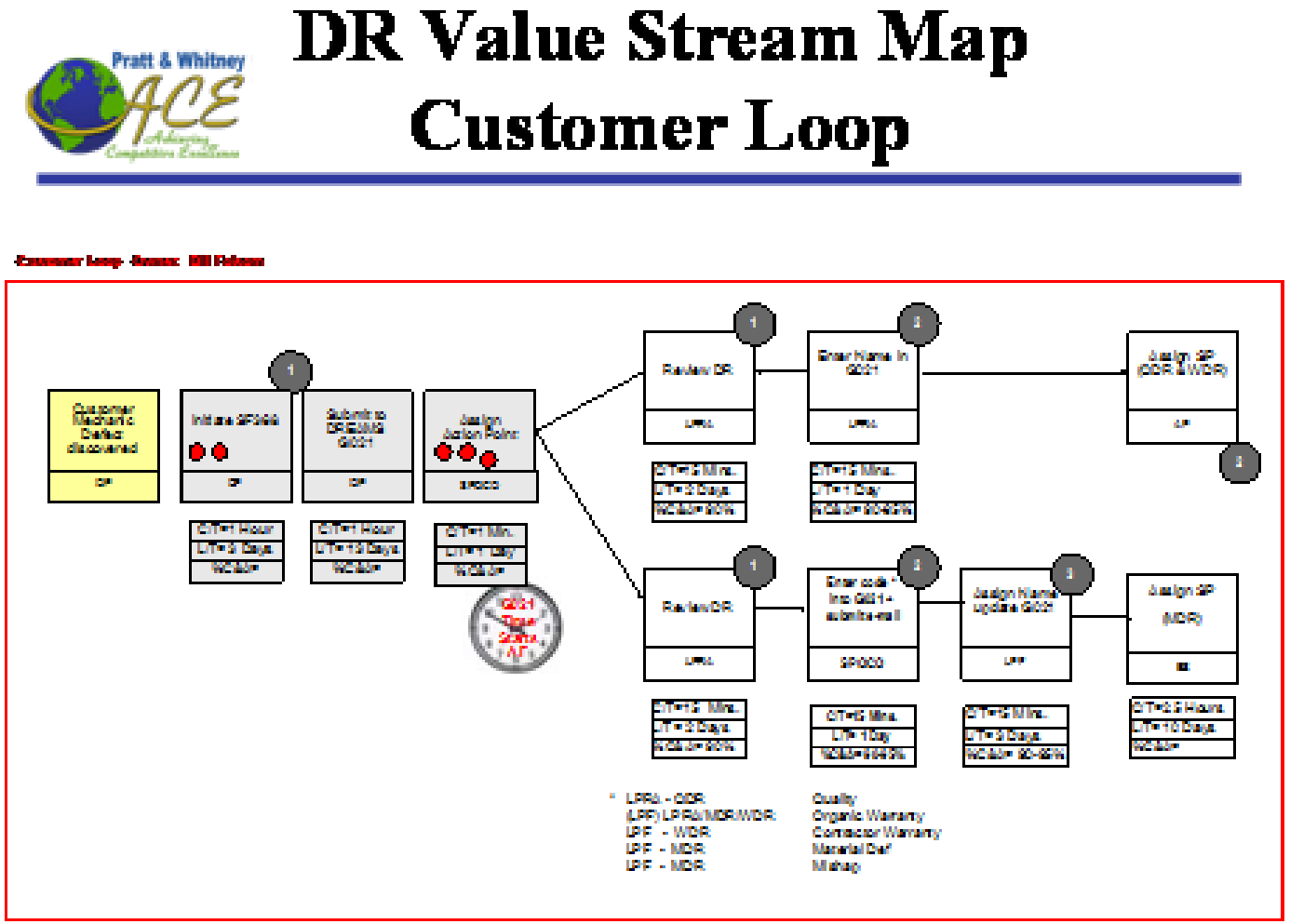
> *"I remember going into a meeting room and she [Rose] had the value stream up there and I said, Whoa! The F119 is not quite like that. We ended up drawing a separate parallel path of certain areas to show the F119 process."*

Although the F119 value stream was mapped out as early as 2005, improvement work did not begin until late 2006. Finally, in November 2006, 44 overdue Engineering Investigations provided the impetus to dig deeper into the F119 Investigation process. In January 2007, 12 representatives from Hamilton Sundstrand, CSIS, CSE and the Pratt and Whitney fleet management program (FMP) office met to review the DR Investigation process. It was discovered that most of the overdue investigations were from the Controls and Externals module center. They, in turn, purchase many components from suppliers like Honeywell or Parker Hannifin. Jim Beaver discussed the challenges of this arrangement:

> *"It was no simple matter of getting the part in and doing the investigation We had to get the part in, determine what needed to be done, cut a purchase order, give the supplier a not-to-exceed, and then get the supplier interested in doing an investigation since it usually takes the same engineer off of the production line to go do the investigation. The span of control in this operation is huge because it goes down to our suppliers and their suppliers and sometimes their suppliers. That was really where a lot of the holdup was."*

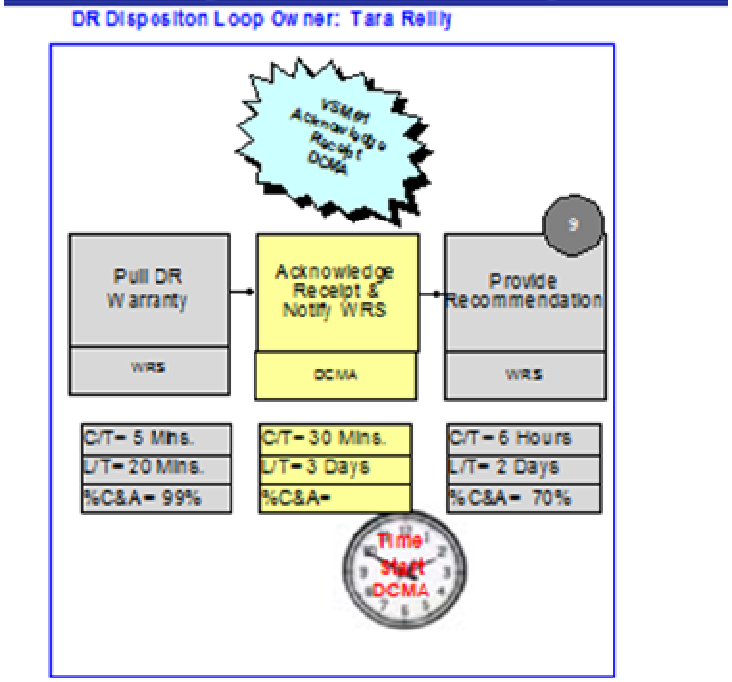
In the summer of 2007, a series of working meetings - kaizen events - were organized to: define roles and responsibilities of various Pratt & Whitney workgroups, identify "worst of worst" practices and decide on corrective action, and to develop a procedure for investigation extension requests. Many of the problems centered on the supplier involvement in the investigation process. How should Hamilton Sundstrand hand off the report to CSE? How to streamline the purchase order process, which was delaying the shipment of the defective equipment? What are the work procedures that a supplier must take when it receives the part for investigation? Four sessions were held between July 2007 and September 2007 to resolve these issues.

A6. DR Investigation Process Map, 2006[39]

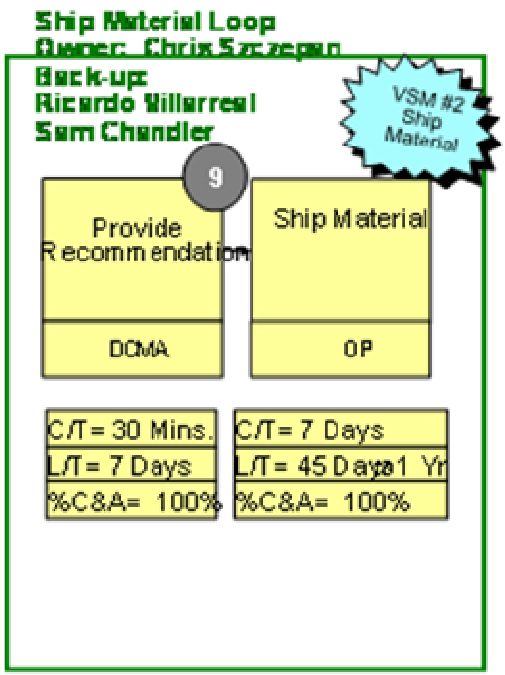


[39] Would not fit on a single page, so is broken into separate "loops." See Figure 8 to see the relationship between loops

DR Value Stream Map Disposition Loop

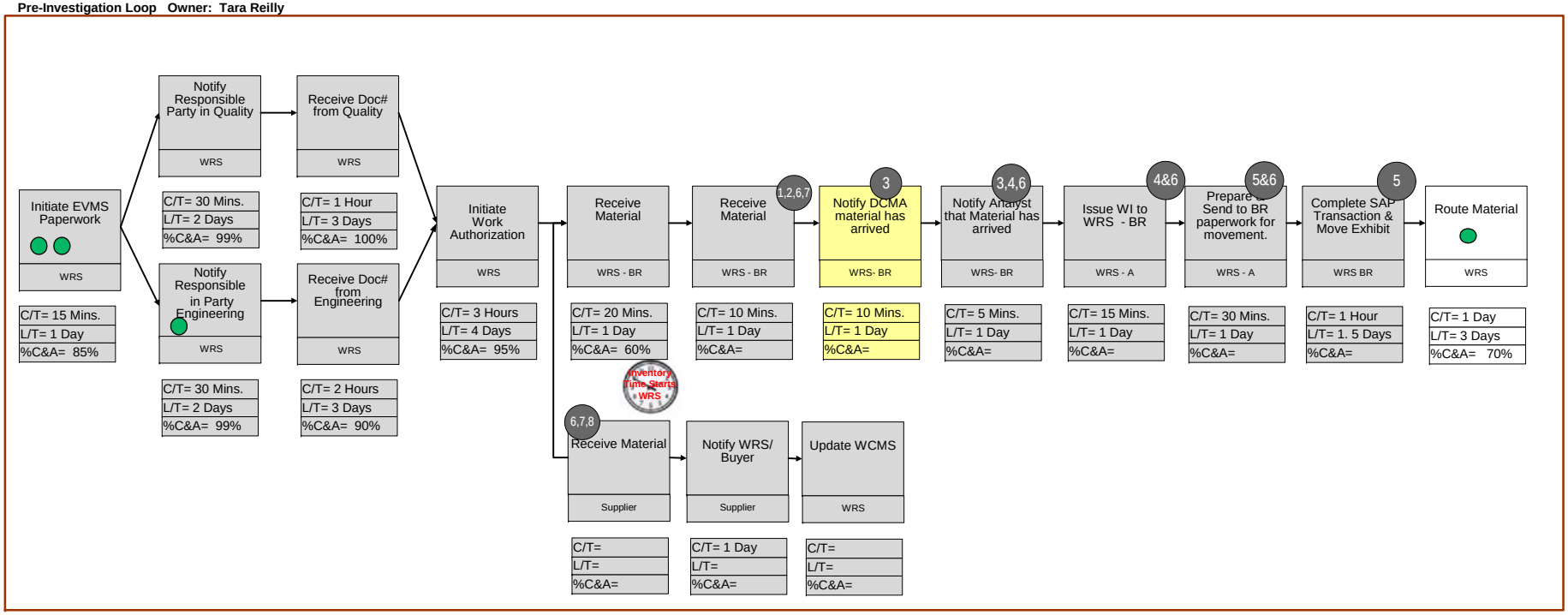


DR Value Stream Map Ship Material Loop



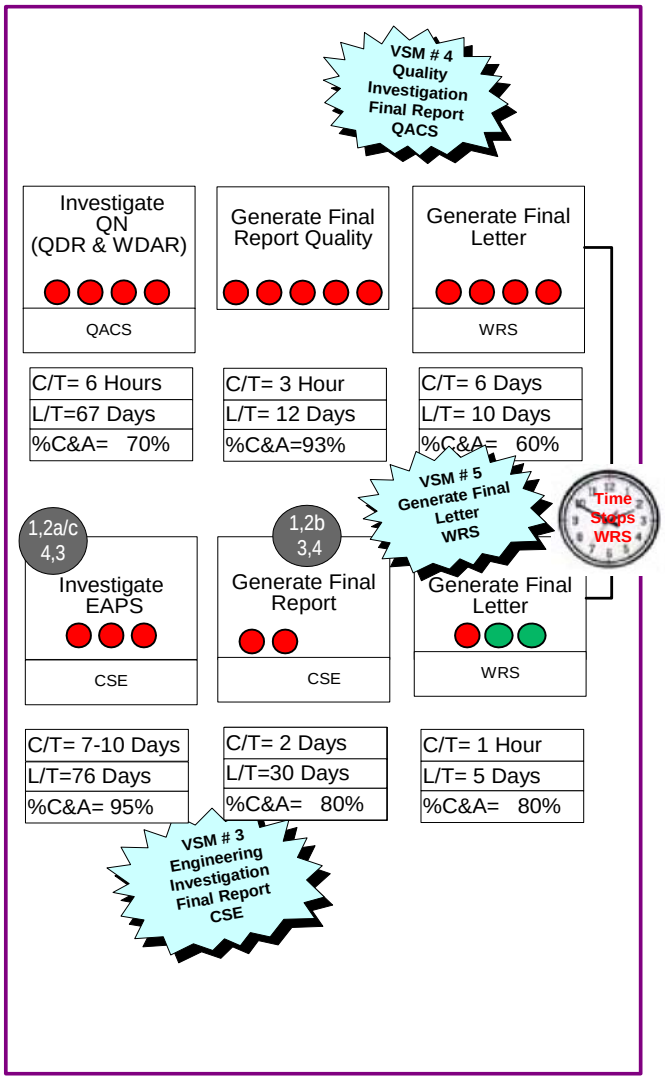
DR Value Stream Map
Pre-Investigation Loop

Pre-Investigation Loop Owner: Tara Reilly

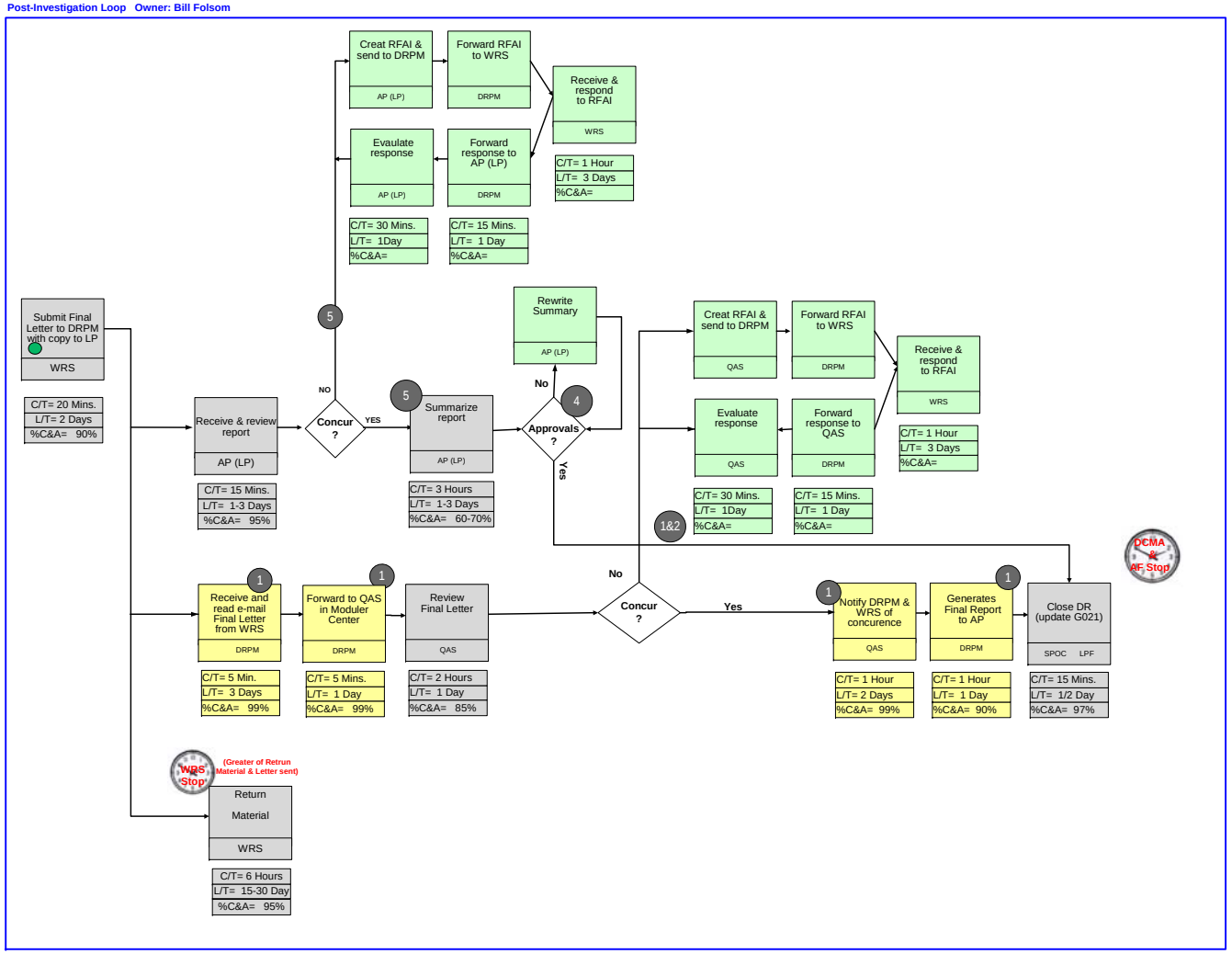


DR Value Stream Map Investigation Loop

Engineering Investigation Loop Owner: Chuck Brown
Quality Investigation Loop Owner: Joe Krajewski



DR Value Stream Map
Post Investigation Loop



A7. Photo of the DR Investigation Process Map, 2004