Issue Resolution at a Large Aerospace Manufacturer

by

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B.S. Mechanical Engineering, Columbia University, 2007

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Submitted to the MIT Sloan School of Management and the Mechanical Engineering Department on May 6, 2013 in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Engineering Systems

Abstract

UTC Aerospace Systems has a wide variety of problem solving tools driven by their Achieving Competitive Excellence (ACE) program. One tool that is frequently used to resolve and capture customer escapes is the 8D methodology. It is an eight-step process designed to identify, correct, and eliminate recurring problems and is useful in providing a feedback mechanism between the customers and suppliers. Its goal is to establish a permanent corrective action and focuses on the origin of the problem by determining its root causes.

The objective of the project is to fully understand the cost benefit of implementing the 8D methodology. The initial investigation of the 8D process uncovered that some defects recorded using the 8D tool are omitted in metrics reporting, leading to poor issue resolution and limited feedback between customers and suppliers.

Because the tool requires additional steps that were not required in previous problem solving techniques at UTC Aerospace Systems, it is both more cost and time intensive. To avoid wasteful spending, it is therefore important that the tool be applied only when necessary. A study was performed to identify situations when the 8D tool is used improperly. Two situations were identified: (1) when an 8D investigation is performed unnecessarily and (2) when the 8D investigation is not performed in a situation when it should be.

In the first situation, the unnecessary implementation of the 8D tool results in wasted effort within the organization. In the second situation, the missed opportunity to implement the tool has the potential to allow future occurrences of the same defect that may have otherwise been avoided. Preventing a defect from occurring in the future is often achieved by redesigning a part to eliminate a systemic issue. It is therefore important to use the 8D tool in order to identify systemic issues more quickly and thereby reduce future repair costs. The costs associated with these two situations are further quantified in the project.

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1 Introduction

1.1 UTC Background

United Technologies Corporation (UTC) is a leading provider of high-technology products within the aerospace and building systems industry. With $58.2B in 2011 sales[1], UTC is currently made up of five segments, each of which maintains general autonomy over their products and services. The main product offerings of each segment are described below:

Otis: Elevators, escalators, moving walkways.

UTC Climate, Controls & Security: Heating, ventilation, air conditioning systems, and refrigeration systems, building controls and automation, and fire and security systems.

Pratt & Whitney: Commercial, military, business jet and general aviation aircraft engines.

UTC Aerospace Systems: Aircraft systems, power control and sensing systems.

Sikorsky: Military and commercial helicopters.

In addition to its five business units, UTC maintains a research organization in order to continuously pursue "technologies for improving the performance, energy efficiency, and cost of UTC products and processes"[2].

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[1] Edgar Online. (2012). *United Technologies Corp, Form 10-K.* Retrieved 14 September 2012, from http://files.shareholder.com/downloads/UTX/2157916500x0xS1193125-12-47752/101829/filing.pdf

[2] United Technologies. (2013). *About UTC.* Retrieved 14 September 2012, from http://www.utc.com/About+UTC

1.2 UTC Aerospace Systems Background

Over the past several years, UTC has made several mergers as part of a corporate strategy to "grow through strategic acquisitions in addition to internal growth"[3]. In July 2012, UTC Aerospace Systems was formed through a merger between UTC-owned Hamilton Sundstrand and Goodrich Corporation. Now one of the five segments of UTC, the newly formed UTC Aerospace Systems is a $13B company that represents more than 20% of UTC's revenue with more than 40,000 employees and approximately 170 sites worldwide[3].

The merger was an important acquisition for UTC, allowing them to combine the complimentary product lines of Hamilton Sundstrand and Goodrich Corporation to offer a more competitive and comprehensive system on commercial aircraft. The newly created UTC Aerospace Systems now provides products and services on almost all in-service commercial aircraft and is providing multiple critical systems for the Boeing 787 Dreamliner. UTC Aerospace Systems is the largest aircraft systems provider in the world and is the largest system supplier on the 787, offering systems including: environmental control system; nitrogen generation; electrical power generating and starting; remote power distribution; primary power distribution; ram air turbine; electric motor pumps; fire detection and suppression; electro-mechanical brakes; thrust reversers; proximity sensing; cargo handling; exterior and flight deck lighting; fuel quantity indicators; and fuel management software.[4]

UTC Aerospace Systems provides design, production, and aftermarket services, including spare parts. Within UTC Aerospace Systems, the Customer Service organization is responsible for spare parts, repair services, and training and technical support for its products. The Customer Service division is primarily concerned with providing aftermarket parts (known as spare parts), repair services, and on-site-support

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[3] Edgar Online. (2012). *United Technologies Corp, Form 10-K.* Retrieved 14 September 2012, from http://files.shareholder.com/downloads/UTX/2157916500x0xS1193125-12-47752/101829/filing.pdf

[4] UTC Aerospace Systems. (2012). *UTC Aerospace Systems delivers 100th CACTCS pack shipset for Boeing 787 Dreamliner.* Retrieved 10 October 2012 from http://utcaerospacesystems.com/latest-news/utc-aerospace-systems-delivers-100th-cactcs-pack-shipset-for-boeing-787-dreamliner/

(OSS) at large customer locations. Spare parts are typically provided to customers by distribution centers whose inventory is manufactured either internally by UTC Aerospace Systems or from outside suppliers. Repair services are provided for repairable parts at repair centers whereas broken parts are sent to the nearest UTC Aerospace Systems facility to be investigated and repaired or replaced with the appropriate spare part. The repair process is typically completed within 15 days, though the in-depth investigation into the root cause may take longer.

1.3 Project Motivation

In 2011, the quality organization at the former Hamilton Sundstrand began implementing an issue resolution tool called the 8D methodology. The purpose of the 8D tool is to reduce operating cost and improve performance by providing a methodological approach to problem solving. The methodology requires employees to perform thorough root cause investigations and thereby encourages more accurate and effective corrective action measures. Because the tool requires additional steps that were not required in previous problem solving techniques in place at UTC Aerospace Systems, it is both more cost and time intensive than previous methodologies. To avoid wasteful spending, it is therefore important that the tool be applied only when necessary. This paper first identifies when the 8D should be used, then looks at situations where it can be used incorrectly and the financial impact of doing so.

1.4 Chapter Content

Chapter 2 provides a background on the terminology and techniques discussed throughout the paper. This is followed by a discussion of the current use of the 8D methodology in Chapter 3, as well as the pros and cons associated with 8D implementation. Building on observations made regarding the current state, Chapter 4 outlines three key opportunities for improvement. Finally, Chapter 5 summarizes the main points discussed in this thesis and offers concluding remarks.

2 Background

2.1 Achieving Competitive Excellence

Modeled after the Toyota Production System, UTC has developed a proprietary performance management system, called Achieving Competitive Excellence (ACE). The ACE system is focused on increasing operating efficiency, reducing waste, and improving customer satisfaction. It is built around fourteen well-established tools that help "identify process improvement opportunities, solve problems and assist with decision making processes"[5]. The ACE philosophy integrates these tools with total employee engagement to create and facilitate a company culture focused on continuous improvement. The tools are broken down into three categories: Process Improvement and Waste Elimination Tools, Problem Solving Tools, and Decision Making Tools. To work against the common criticism at many companies that their latest toolset is simply the "flavor of the month", the tools are standardized across the organization. After completing a one-week training course in the ACE system, employees regularly apply these tools in their day-to-day jobs to make quality improvements to products, processes, and working conditions. They serve as the foundation for countless processes and are the backbone of the 8D methodology, as will be discussed later in the paper.

2.2 Cost of Quality

2.2.1 Definition of Cost of Quality

Cost of Quality is an approach developed in order to reconcile the tradeoffs between cost minimization and quality maximization. Juran first defined the cost of quality in his *Quality Control Handbook* as any costs that would disappear if no quality problems[6]. Feigenbaum later separated these costs of quality into

[5] United Technologies. (2013). *Quality.* Retrieved 14 September 2012, from http://www.utc.com/About+UTC/Quality

[6] Juran, J.M. et al. (1999). *Juran's Quality Handbook*. McGraw-Hill, New York. Section 8.

conformance costs or failures costs[7]. Conformance costs are those that are required to ensure a specified quality standard whereas failure costs are those that are necessary to bring a non-conforming part up to the quality standard. These two categories can be further broken down into prevention, appraisal, and failure costs, where failure costs include both external and internal failures.

Prevention costs – All activities designed specifically to prevent poor quality such as employee training and process improvements.

Appraisal costs – All costs dedicated to measuring, evaluation, or testing products or services to ensure they meet quality standards.

External Failure Costs – All costs resulting from products or services that reach the customer that do not meet the quality standards. These costs may include the cost of a replacement product, the cost of the customer service department managing the situation with the customer, and the engineering cost to redesign the product to prevent future external failures. They could even be intangible costs such as sales losses on returns, or cancelled future orders.

Internal Failure Costs – All costs resulting from products or services that did not meet the quality standards and whose defects were caught before being shipped to the customer. These costs could include the material cost of scrapping the product, rework costs, and costs associated with work interruptions.[8]

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[7] Feigenbaum, A.V. (1956). *Total Quality Control.* Harvard Business Review. pp. 93-101.
[8] Juran, J.M., F.M. Gryna. (1980) *Quality Planning and Analysis.* McGraw-Hill, New York. pp. 20-25.

Figure 1 depicts the relationship between these four cost categories.

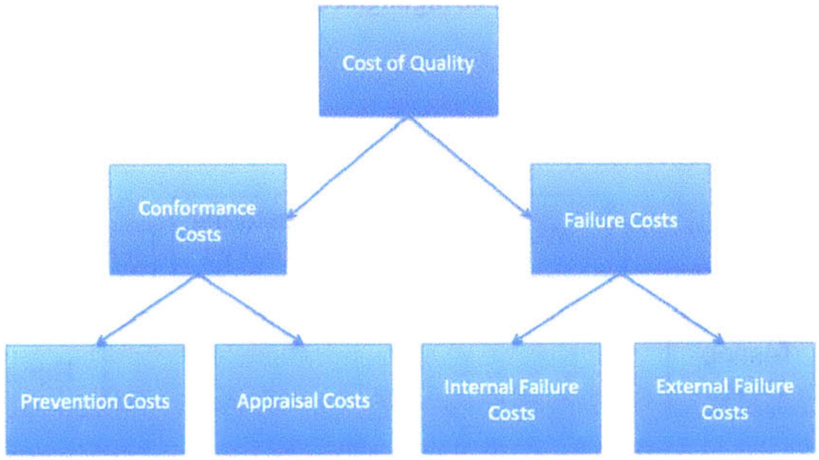

Figure 1: COPQ Costs

2.2.2 Definition of COPQ

While there are many theories on how to reduce costs of quality, many companies focus on reduction of their Cost of Poor Quality (COPQ). UTC Aerospace Systems is among these companies, aiming to reduce their COPQ by 10% each year. Cost of Poor Quality is defined as the sum of the internal and external failures costs described in the previous section. This total represents the out-of-pocked expenses incurred because the quality of the systems, processes, and products is not perfect[9]. Juran argues that while COPQ often accounts for as much as 30% of a company's total cost, only a small portion of these costs is obvious upon initial inspection[10]. As methodologies such as Lean and Six Sigma have focused on COPQ reduction, companies have begun to develop a broader definition of COPQ and have been able to identify less obvious costs as well. The distinction between the obvious and less obvious costs is often

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[9] Campanella, J. (Ed.). (1999). *Principles of quality costs: Principles, Implementation and Use*. American Society for Quality, Quality Cost Committee, Milwaukee, WI.

[10] Juran, J.M. et al. (1999). *Juran's Quality Handbook*. McGraw-Hill, New York.

depicted using an iceberg, where the visible costs are floating above the water and the invisible costs are hidden beneath the surface. Figure 2 gives an example of the COPQ iceberg[11]. Later in Chapter 3, the costs that can be reduced using the 8D tool will be highlighted.

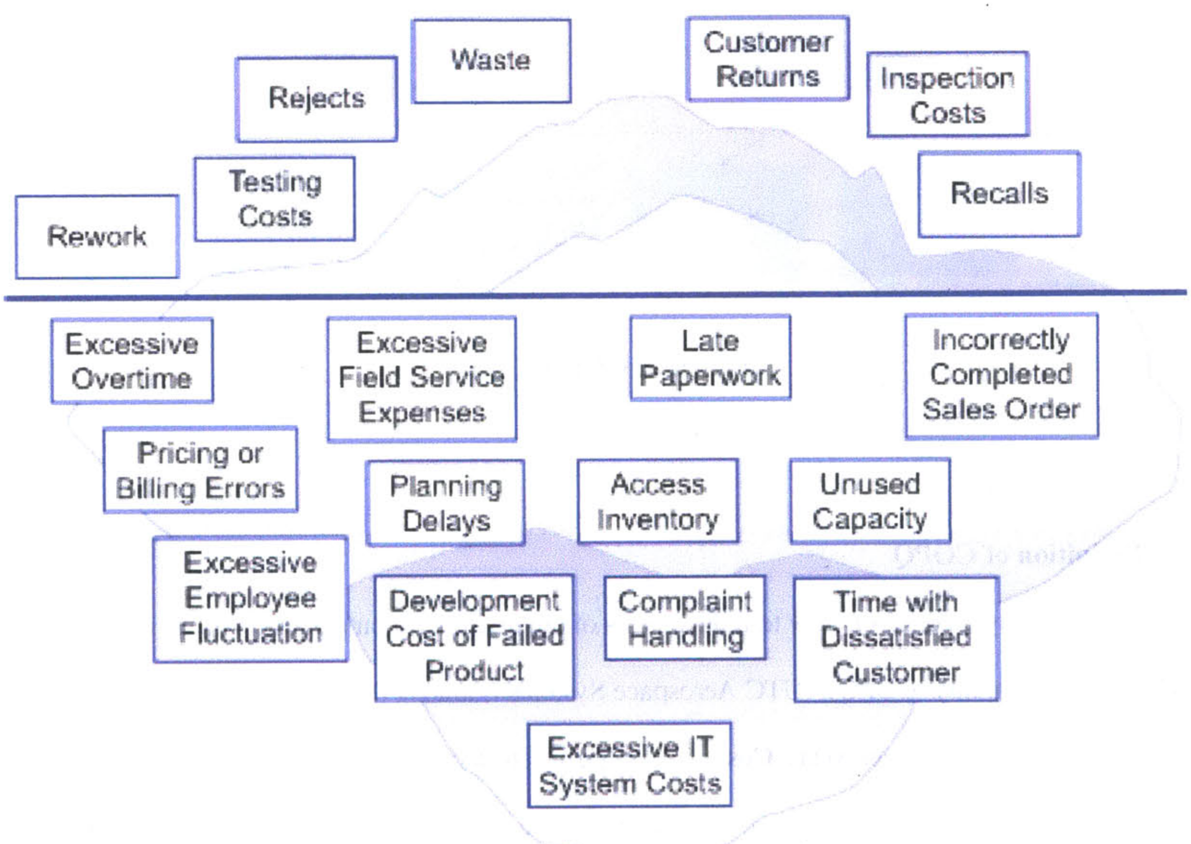

Figure 2: COPQ Costs

[11] iSixSigma. (2011). *Cost of Quality: Not Only Failure Costs.* Retrieved 22 November 2012 from http://www.isixsigma.com/implementation/financial-analysis/cost-quality-not-only-failure-costs/

2.2.3 COPQ at UTC Aerospace Systems.

Within UTC Aerospace Systems, COPQ costs are broken down into three main types: (1) Scrap, Rework, and Repair, (2) Product Improvement Engineering, and (3) Warranty. The distinction between these costs is based upon the point they are incurred in the product lifecycle. Once a part's design is complete, the manufacturing phase begins. During manufacturing, if there are any discrepancies in the part that differ from the specified design, the part must either be scrapped (and manufacturing must begin again) or reworked or repaired until it meets the design. The additional costs of the scrap or the rework are captured under the "Scrap, Rework, and Repair" bucket and are considered internal failure costs, as described in section 2.2.1.

Once manufacturing is complete, the part is delivered to the customer where any subsequent failure is considered an external failure. If a defect is found and returned by the customer that can be attributed to UTC Aerospace Systems' engineering, manufacturing, or shipping processes, any costs resulting from this defect are captured under the "Warranty" bucket. These costs may include the cost of a new part, the time spent by customer service working with the customer to resolve the issue, the excess paperwork created by the issue, or the cost of the investigation that resulted from the failure.

If UTC Aerospace Systems discovers a systemic issue with the part, it may be redesigned to prevent future failures. The engineering effort to develop the redesign is captured under "Product Improvement Engineering" cost. Once the redesign is complete, UTC Aerospace Systems may choose to upgrade other existing parts to the latest redesign. Any upgrades as well as any future defects on that part are captured under the "Warranty" bucket. Figure 3 shows the breakdown of these costs over the lifetime of a part.

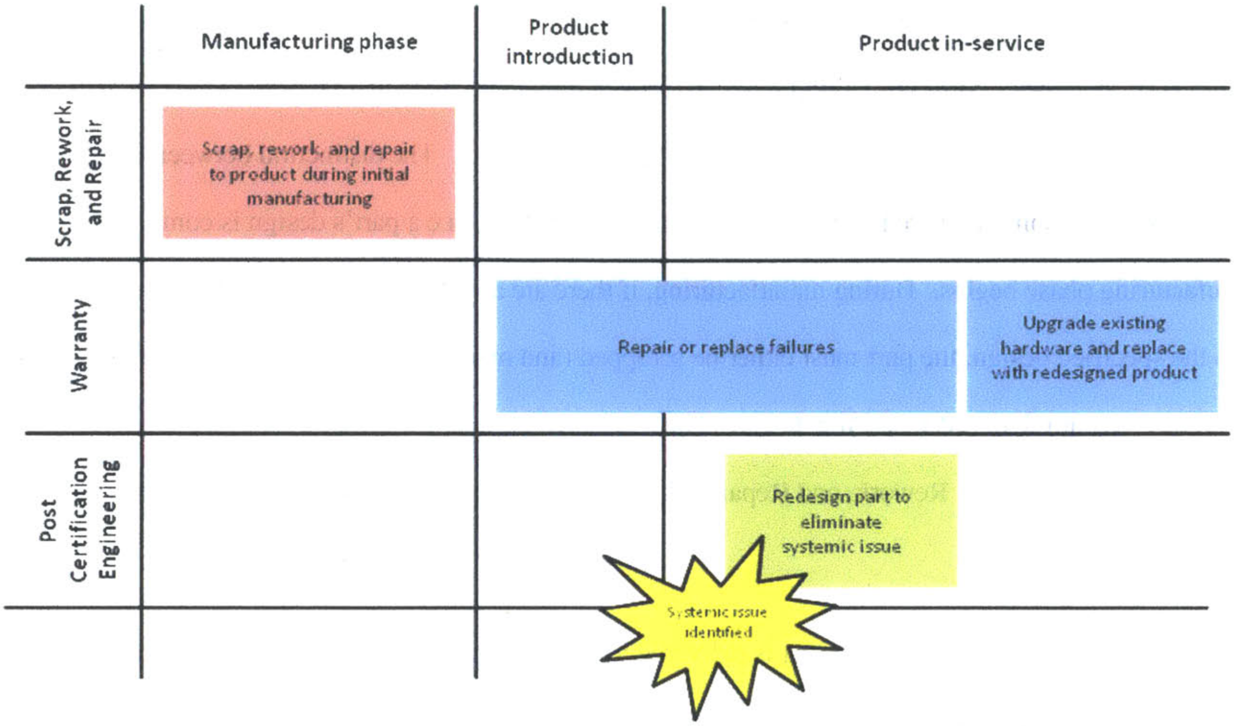

Figure 3: COPQ Over Product Lifetime

The overwhelming majority of COPQ costs at UTC Aerospace Systems are incurred in the Warranty phase. In 2011, almost 90% of COPQ costs were warranty costs. This thesis will therefore focus on impact to warranty costs, as a reduction in warranty costs would result in the greatest reduction in total COPQ.

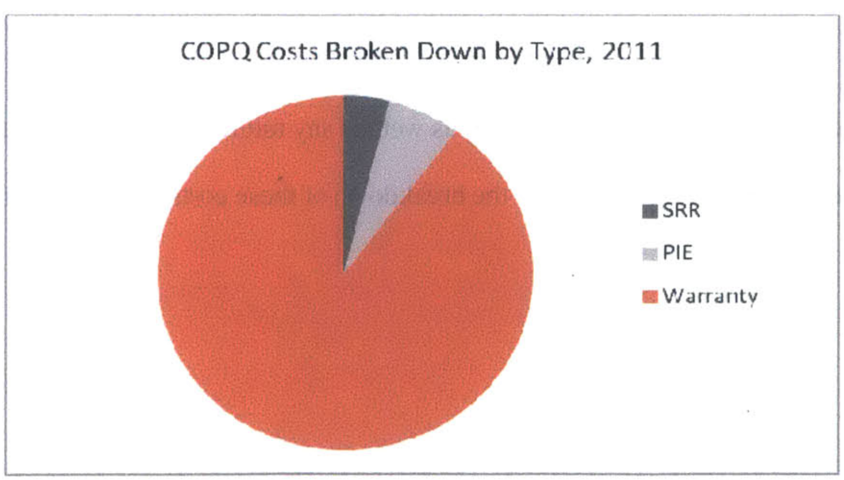

Figure 4: UTC Aerospace Systems COPQ Costs Broken Down by Type for 2011

2.3 8D Methodology

2.3.1 Background

Also known as the Eight Disciplines Problem Solving Technique, the 8D methodology was developed in the 1980s by Ford Motor Company. Its purpose is to resolve problems and is specifically designed to correct and eliminate recurring problems in situations where cause of a problem is unknown. Its name was originally derived from the eight required steps, D1 – D8, though the steps have later been modified to include a planning step, D0, making it now a nine-step process. These steps include:

D0: **Plan**: Plan for solving the problem and determine the prerequisites.

D1: **Establish a Team**: Establish an interdisciplinary team of people with product/process knowledge. Team members should include all stakeholders, subject matter experts, and representatives from the responsible problem area.

D2: **Define and Describe the Problem**: Define the issue and identify the problem based on data (not speculation) in quantifiable terms such as who, what, where, when, why, and how. Be specific and narrow down the problem to develop a formal problem statement.

D3: **Identify and Implement Containment Actions**: Define and implement containment actions to eliminate the impact of problem from any customer. This may involve sorting/purging of inventory. Describe what has been done and estimate the probability of only quality parts being shipped to the customer after the implementation date.

D4: **Determine, Identify, and Verify Root Cause**: Identify all causes that could explain the root cause of the problem. Also identify why the problem has not been noticed at the time it occurred. Use problem solving techniques such as a 5 why analysis, fishbone diagram, or event tree.

D5: **Identify Permanent Corrective Actions:** Ensure that corrective action includes ongoing controls that ensure the root cause is eliminated. Confirm effectiveness of the corrective action and preventive actions through data analysis such as statistical tests, design of experiments, or run charts.

D6: **Implement Permanent Corrective Actions**: Describe how, when, and by whom the corrective action was implemented. Identify steps or tools used to mistake proof the process, and determine the level of mistake proofing achieved.

D7: **Implement Actions to Prevent Recurrence**: List any modifications to the management systems, operation systems, practices, and procedures that must be done to prevent recurrence of this and all similar problems.

D8: **Congratulate the Team**: Hold a closing meeting to recognize the efforts of the team.

Steps D1 – D8 can be seen on the process map, below.

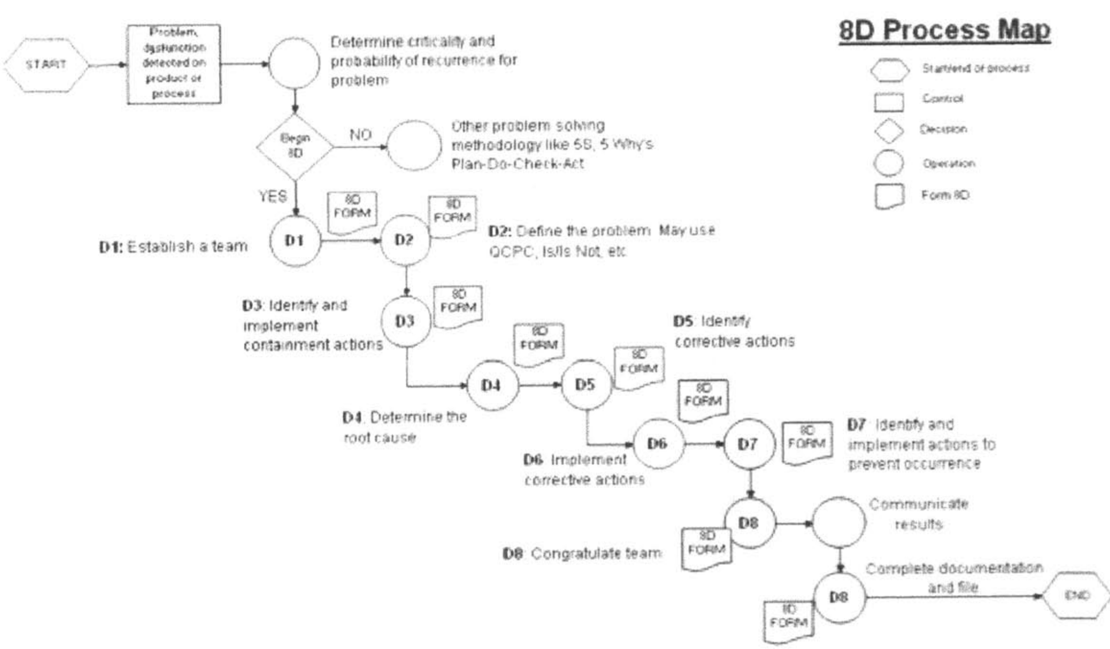

Figure 5: 8D Process Map

The tools and techniques described in the steps above are all components of the tools offered by ACE, described in Chapter 2.1. Because employees are trained in the ACE system and use many of its techniques in their day-to-day tasks, the transition to the 8D methodology was able to be made smoothly in 2011.

2.4 Hypothesis Testing

Hypothesis testing is a common statistical tool used to make decisions and to understand the likelihood and impact of making the wrong decision. A common analogy used to explain the hypothesis test is a courtroom trial where a jury must decide whether to acquit or convict a defendant. There are two situations where the jury can make the incorrect decision: (1) they can convict an innocent defendant or (2) they can acquit a guilty defendant. In statistics, the decision one is trying to make is referred to as the null hypothesis and the two types of incorrect decisions are referred to as type I and type II errors. In the case of the jury, the null hypothesis is to acquit the defendant. If the jury convicts an innocent defendant, it is considered a type I error and is also known as a false positive. On the other hand, if they acquit a guilty defendant, it is considered a type II error, or false negative. It is possible to make the correct decision in two ways: by convicting a guilty defendant or by acquitting an innocent one. The four scenarios are represented in the following chart:

		Null Hypothesis (H0)	
		TRUE	**FALSE**
Action Taken	**Do not accept H0**	**Type I error:** False Positive	Correct Outcome
	Accept H0	Correct Outcome	**Type II error:** False Negative

Figure 6: Hypothesis Testing Setup

Hypothesis testing can also be applied to use of the 8D methodology. Because the 8D tool is time and cost intensive, it would be cost ineffective to implement it unnecessarily. It is therefore possible to create similar type I and type II errors, shown below.

		H0: 8D Investigation Should Be Performed	
		TRUE	**FALSE**
Action Taken	**Do not accept H0:** Do Not Perform 8D Investigation	**Type I error:** 8D investigation performed unnecessarily	Correct Outcome
	Accept H0: Perform 8D Investigation	Correct Outcome	**Type II error:** Missed 8D investigation

Figure 7: Hypothesis Testing Used for 8D Implementation

Both type I and type II errors are costly to the organization. A type I error results when an 8D investigation is performed unnecessarily. Because its use is unnecessary, it creates extra and unnecessary work for the organization. A type II error is created when an 8D investigation is not performed in a situation where it should have been. Because the 8D methodology is focused on preventing recurring defects, a type II error is a missed opportunity to prevent the defect from occurring in the future. Both of the costs associated with these errors will be quantified in Chapter 4.

3 Issue Resolution at UTC Aerospace Systems

3.1 Issue Resolution prior to 8D implementation

Beginning in 2011, UTC Aerospace Systems (then Hamilton Sundstrand) began requiring that an 8D investigation be completed for every customer escape. A customer escape is defined as any mistake associated with a part, either during manufacturing or transportation, which leaves UTC Aerospace Systems and reaches a customer. Prior to 2011, all customer escapes were investigated using various sitespecific processes akin to the traditional Material Review Board (MRB) methodology developed mid-century by the US military. The MRB process is less rigorous than the 8D process and requires a simple root cause investigation to identify the underlying problem. Because it is not as thorough as the 8D methodology, it does not focus on containment of the problem before other parts with similar or identical defects also reach the customer. It also does not require follow-up to ensure the corrective action has been effective and the true root cause has been identified. As a result, MRB investigations took significantly less time to complete but did not focus on reduction in systemic and recurring defects.

3.2 8D Usage at UTC Aerospace Systems

3.2.1 Current State

Since 8D's introduction in 2011, all customer escapes must be investigation using the 8D methodology. When a customer escape is identified, it is recorded in a system called Clinic. The form on which is it recorded, the clinic form, is a blank electronic form where basic information on the escape is entered. Not all clinic forms require 8D investigations, although the 8D is electronically attached to the clinic form. The predominant case when a clinic form does not require an 8D investigation is for anything that is considered a customer escape. In this case, if the customer caused the defect either during installation or transportation at their facility, it is unnecessary for UTC Aerospace Systems to complete the in-depth 8D investigation to identify the source of the defect. Instead, the clinic form is used simply to record the incident and can be closed out by entering only the basic information. It is still important to record these incidents because recurring issues of customer-induced damage on a single part may indicate a design or manufacturing defect that should be addressed by UTC Aerospace Systems. For every customer-defect, the basic information is therefore tracked in the clinic form to allow UTC Aerospace Systems to identify and investigate recurring issues. However for a typical instance of customer-induced damage, the 8D investigation is not required.

If the damage is not customer-induced and an 8D investigation is required, then nine additional tabs (one for each of the steps D0-D8) must be populated as the 8D investigation is completed. The decision tree for implementing an 8D investigation is intended to follow the following path:

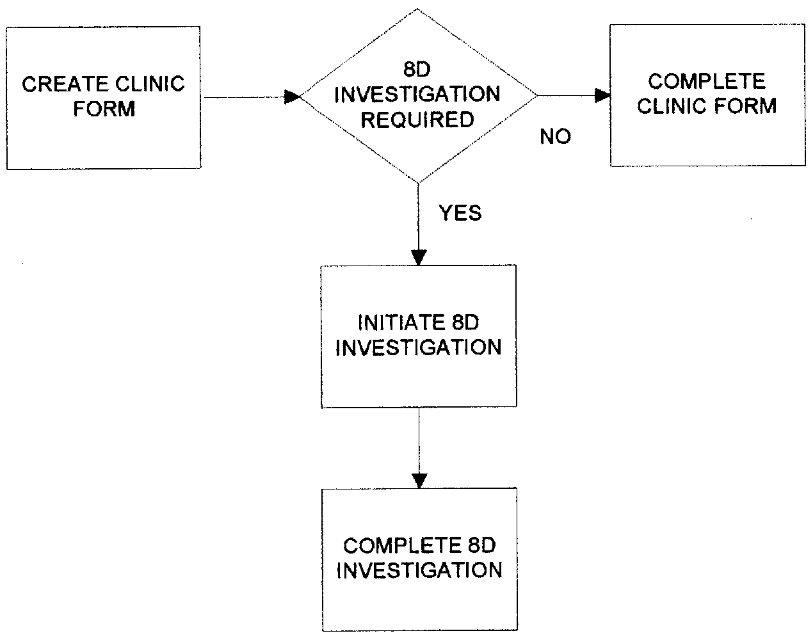

Figure 8: Clinic Form Process Flow

During the project it became clear that the terms "8D" and "clinic form" are used interchangeably and that the decision tree above was not always considered. While the terms are closely related (all 8D investigations begin with clinic forms), they are not identical (not all clinic forms require 8D investigations). In his book *Juran on Leadership for Quality*, Juran cites confusion of the meaning of key words as an example of an "obstacle to unity"[12]. He argues that these obstacles reduce the ability of an organization to manage for quality and thereby achieve high quality in their products and processes. At UTC Aerospace Systems, the confusion between the terms 8D and clinic form results in a delay in the decision whether to complete an 8D investigation. Although the manual directs employees to make the

[12] Juran, J.M. (1989). *Juran on Leadership for Quality*. The Free Press, New York. pp. 14-15.

decision immediately as in Figure 8, instead it is often delayed until later in the process. The detailed process that occurs in practice is explained further.

When a customer returns a part, it is received and processed by the clinic coordinator (a UTC Aerospace Systems employee who receives and organizes incoming material returned by customers). The coordinator initiates an 8D investigation and determines the part's home area, where it was originally produced. The part is then sent to the home area's clinic, where damaged parts are investigated. Once it reaches the clinic, employees determine whether the customer induced the damage or if the damage originated during any other portion of the lifecycle. In one case, if the damage is not conclusively customer induced, then an 8D investigation is completed and all nine steps (including containment, root cause investigation, and corrective action implementation) are performed. As discussed in Chapter 2, these steps help reduce the risk that similar defects will be caused in the future. In the other case, if it can be determined conclusively that the customer caused the damage, the 8D investigation is voided and completed without root cause and corrective action measures. Because the decision whether to implement the 8D investigation is made by the individual clinics instead of by the clinic coordinator who initially receives the part, it occurs towards the end of the process. The process flow is shown below, with the decision to complete an 8D investigation circled in red.

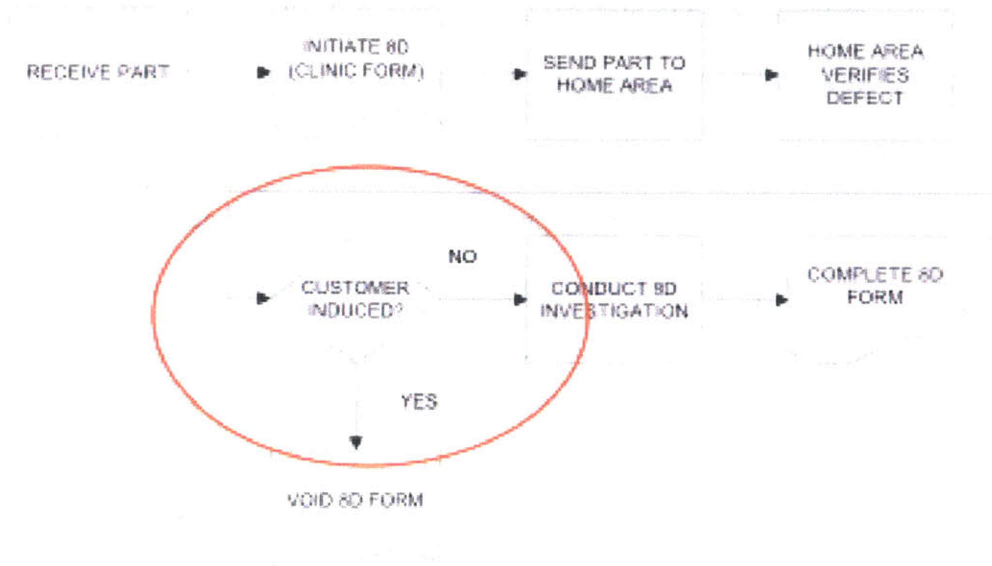

Figure 9: 8D Methodology Current State Process Flow

The effect of delaying this decision until the end of the process will be discussed as an improvement opportunity as part of Chapter 4.

3.2.2 Pros of Use

The primary benefit to implementing the 8D process is that it drives a thorough investigative process that is more effective in solving problems and preventing future defects. This is achieved in several ways:

- **More effective teamwork:**

  Step D1, use a team, requires that a multi-disciplinary team be formed to investigate the defect. Multidisciplinary teams provide viewpoints and opinions from different areas of expertise, allowing for more rapid root cause identification. They are especially more effective at solving complicated problems, particularly when issues involve multiple disciplines in their root cause. With cross-functional, interdisciplinary teams, each member does not need to know all of the technical aspects of the problem or technical disciplines in order for the team to successfully investigate and solve the problem. Additionally, step 8 requires participants to hold a closing meeting to recognize the efforts of the team, thereby promoting team bonding and improving future team performance.

- **Focus on containment:**

  The 8D methodology focuses heavily on containment actions. Immediately upon identifying the defect, step 3 requires participants to locate any parts which are either identical or may be prone to similar defects. This prevents similar additional defects from being shipped to the customer.

- **More thorough root cause analysis:**

  Step 4 requires that a thorough root cause analysis be performed including an analysis about why the defect was not identified at the time it occurred. Accurate root cause analysis is extremely important to the success of preventing future defects since applying containment actions to an incorrect root cause would be ineffective and would allow the same defect to be made again.

- **Corrective actions are verified:**

  Steps 5 and 6 ensure that all corrective actions be tested and verified to ensure that they are effective and prevent future defects. This is similar to the point above, where identifying the incorrect root cause would be ineffective. Similarly, implementing an ineffective corrective action (even if the right root cause were identified) would not prevent future defects from being made again.

- **Actions identified to prevent recurrence:**

  The process ensures that teams identify actions to prevent recurrence and requires that steps and tools be identified to mistake proof the process. By modifying management systems, operating systems, practices, and procedures, future defects of many types can be prevented, not just similar defects.

- **Structured process drives thorough investigation and repeatability:**

  The nine steps encompass the entire process from defect identification to resolution, and the sequence of events that act as a checklist for participants to follow. This repeatability and structure of the process allows employees to become more efficient at effective problem solving.

- **Requires a timely solution:**

  UTC Aerospace Systems requires that containment actions be implemented within 30 days of defect identification, and that the issue be closed out within 90 days. Although due dates cannot always be made with 100% accuracy, UTC Aerospace Systems executives remain up to date on any overdue items and the organization even employs outside consultants to identify and track overdue items.

- **Provides feedback mechanism:**

  The methodology and documentation acts as a crucial feedback mechanism between the customer and the source of the defect. The root cause investigation ensures that the source of the defect be identified, and documentation ensures that this source (either manufacturer, distribution center, etc) is informed of the defect. Without this direct link and written documentation, it would be possible for a temporary fix to be implemented without the source of the defect being informed. Communication between the customer and the defect's source can therefore help reduce future defects by providing important feedback.

- **Improves customer satisfaction:**

  Because UTC Aerospace Systems is able to prevent future occurrences of defects, it also improves their customer satisfaction, as customers are less likely to be plagued with repeat problems on their aircraft.

- **Reduces wasteful spending:**

All of the benefits mentioned above serve to reduce waste as described in Chapter 2. Because future defects are prevented, there is less rework, inspection, testing, customer returns, etc. Along with other waste reductions already mentioned, the 8D process helps to reduce wastes in the COPQ iceberg discussed in Chapter 2. These reductions are circled in red.

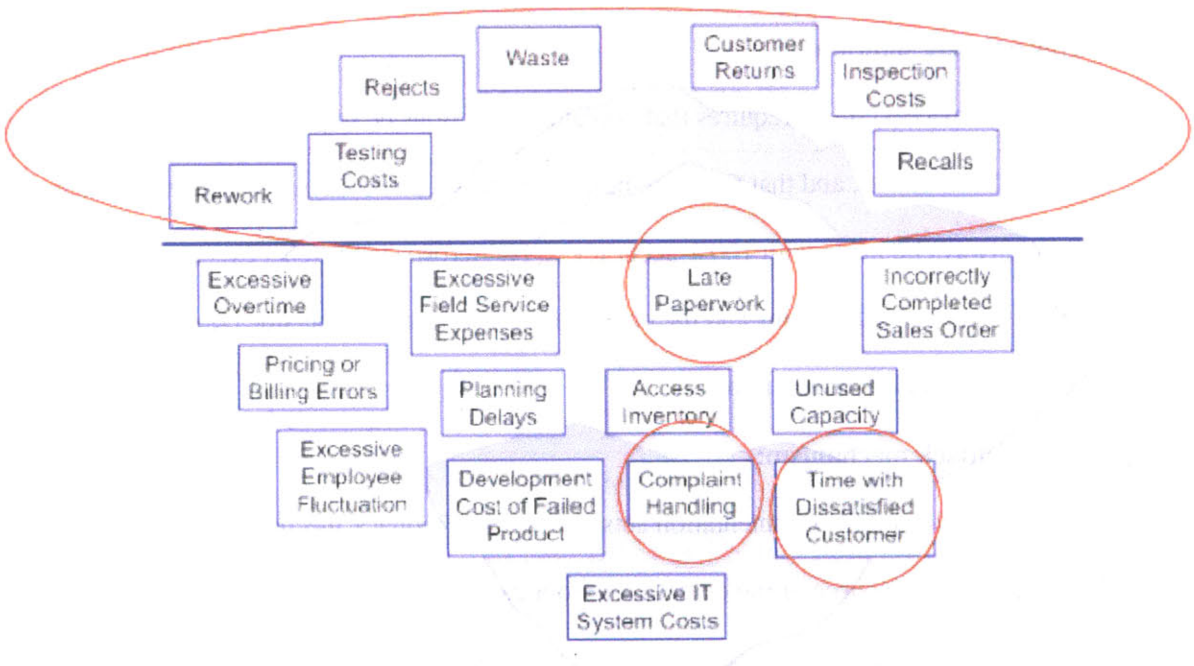

Figure 10: COPQ Cost Reductions

3.2.3 Cons of Use

While there are a significant number of benefits to employing the 8D methodology, the steps involved in creating these benefits also result in a more time consuming and costly process. Completing an 8D investigation requires extra hours for additional steps such as containment or follow up investigations. Even for defects that could be addressed with an MRB form (which does not require containment actions or follow up investigations), the 8D investigation requires that teams still conduct the rigorous process. Furthermore, if an 8D form is conducted unnecessarily, the process still requires several hours of data entry just to complete the required paperwork. This financial impact of conducting investigations unnecessarily will be further discussed as an improvement opportunity in Chapter 4. Finally, conducting rigorous 8D investigation in unnecessary situations can make employees frustrated with the process and not take it seriously in the future.

4 Improvement Opportunities

This chapter will identify opportunities to improve the 8D process. Two of these opportunities can be created by eliminating the type I and type II errors discussed in Chapter 2, both of which occur in practice at UTC Aerospace Systems. The final opportunity can be achieved by eliminating a backlog in open 8D investigations, as will be discussed in section 4.3.

4.1 Type 1 Errors

As discussed in Chapter 2, a type I error represents a situation where an 8D investigation is warranted, but is not performed. This means the organization has allowed an issue to go unresolved, leaving the possibility for future escapes. As described in Chapter 2.2.3, when a defect is identified, UTC Aerospace Systems has the option to either repair or redesign the part. This decision is often based on whether the defect is the result of a one-time failure or a systemic issue. If UTC Aerospace Systems believes it is a one-time failure, the part is repaired or replaced, depending on the damage, and returned to the customer. If UTC Aerospace Systems believes the defect is the result of a systemic issue, then the part is redesigned and all existing parts are replaced with redesigned parts.

All of these costs fall into the Warranty bucket of UTC Aerospace Systems' COPQ structure. Being the largest contributor to overall COPQ, it is extremely important for UTC Aerospace Systems to make the correct determination if the defect is a one-time issue or a systemic problem. If a systemic problem is incorrectly identified as a one-time issue, then the part will repaired without solving the underlying problem. The part will likely fail again in the future, leading to even more repair costs. Although it is initially more expensive to redesign a part than it is to repair it (redesign costs are typically twice as much as repair costs per part), it is wasteful to incur repair costs on a part that will eventually need to be redesigned.

The following analysis shows the potential cost savings of correctly identifying systemic issues quickly on a simple valve. Many of the details and numerical values will not be disclosed for confidentiality purposes, but the percent savings in COPQ is based on real data. The analysis depends on several factors. First, the number of parts potentially affected by a systemic issue fluctuates regularly. Each month, additional aircrafts are released to customers, thereby increasing the number of affected parts. At the same time, there are also older aircraft whose warranty is expiring. Once an aircraft's warranty is expired, UTC Aerospace Systems is no longer responsible for incurring warranty costs on its parts. This analysis estimates the number of affected parts based on the number of aircraft entering into service as well as the number of aircraft coming off of warranty.

To determine the number of failures expected per month, the mean time between failure (MTBF) and annual utilization must be considered. MTBF is the mean time between unscheduled failures and is calculated as the number of fight hours a part has undergone, divided by the number of parts that have failed. The annual utilization is an estimation of the number of hours the aircraft will fly per year. Using these two numbers, the number of expected failures per month can be calculated. If a systemic issue is not identified, all failures are repaired without redesign. However once a systemic issue is identified, a UTC Aerospace Systems can start replacing these failures with redesigned parts. In addition, all parts, even those that have not failed yet, will be replaced with redesigned, upgraded parts. Because the systemic issue was corrected, failures will eventually subside.

The following results show potential Warranty COPQ cost savings as a function of the month in which the systemic issue was identified and corrected.

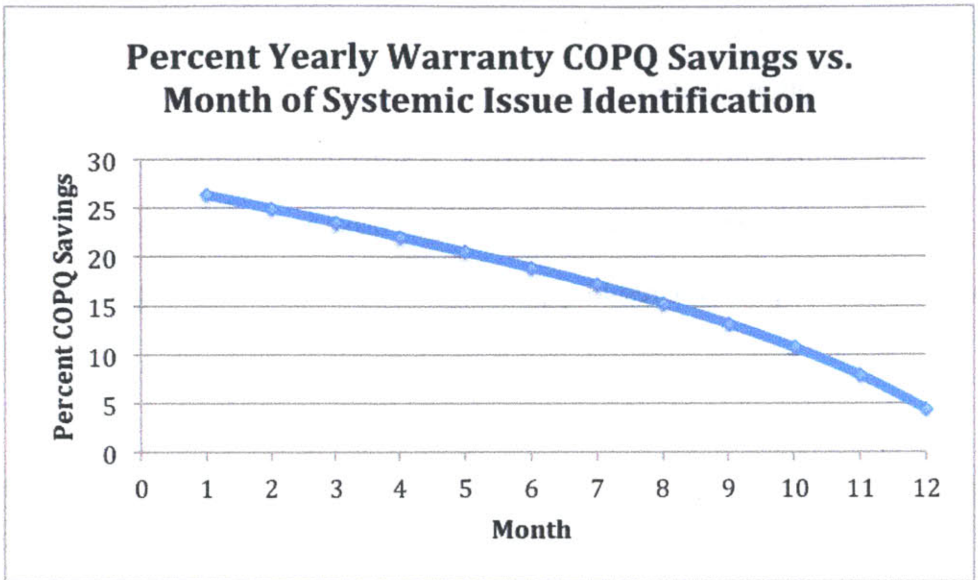

Figure 11: Percent Yearly Warranty COPQ Savings vs. Month of Issue Identification

The results show that if a systemic issue can be caught immediately, a more than 25% reduction in COPQ on that part can be achieved. Each month, the potential COPQ savings decreases.

As discussed in Chapter 3.2.2, the structured analysis and well-documented results of the 8D methodology make it possible to identify systemic issues more quickly. The above results therefore quantify the benefit using the 8D tool on all defects being returned by the customer that are potentially the result of a UTC Aerospace Systems created systemic issue. Failing to utilize 8D in all necessary situations would decrease this cost savings potential and result in type I errors.

4.2 Type II Errors

Type II errors are created when an 8D investigation is conducted unnecessarily. The extra effort to complete these investigations results in unnecessary and avoidable cost to the organization. The process flow shown in Figure 9 of Chapter 3.2.1 has already shown the current process of conducting an 8D investigation. Because the decision whether to conduct an 8D investigation is postponed towards the end of the process, it creates excess work for the organization. In situations when only a clinic form is required but an 8D investigation is unnecessarily initiated, voiding the 8D form still requires up to 10 man-hours to complete all of the paperwork, even though a full investigation is not conducted. In order to eliminate this unnecessary effort, the decision to implement the 8D methodology based upon customer-induced damage could be made by the clinic coordinator, as suggested in Chapter 3.2.1. The identification of customer induced damage is typically easy to make and can be completed by the clinic coordinator who receives the part. The resulting process flow is shown below in Figure 12:

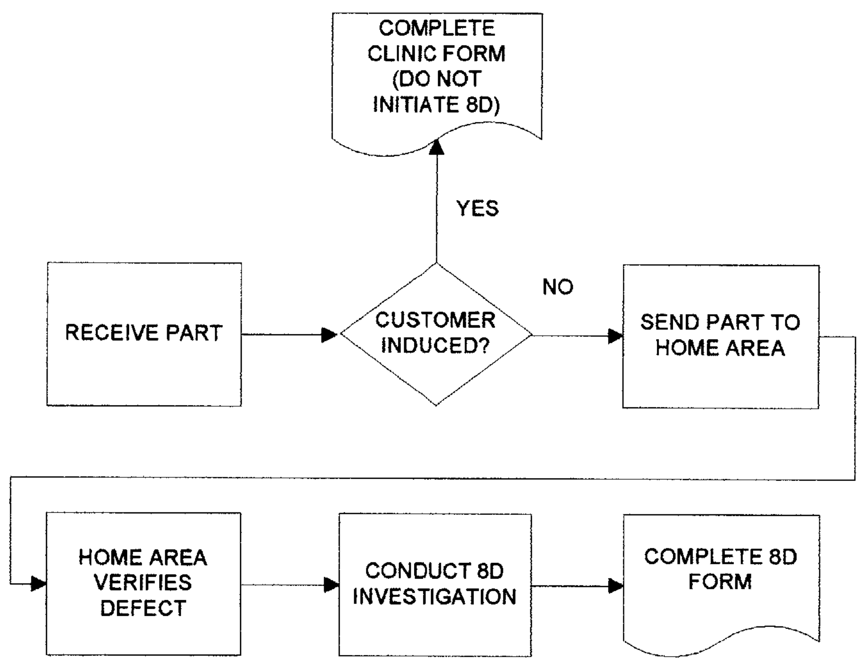

Figure 12: 8D Methodology Future State Process Flow

In 2012, 45% of all 8D forms initiated were voided. If the hours spent voiding these investigations could be avoided, a significant reduction in man-hours could be achieved. By adding a minimal amount of effort at the front of the process in order to determine immediately if the damage is customer induced, UTC Aerospace Systems could eliminate the 10 hours spend per voided investigation. Based on an average of 40 man-hours to complete a full 8D investigation, it is possible to achieve a 15% reduction in man-hours by reducing the percentage of voided investigations from 45% to 5%. More detailed results are shown below in Table 1.

	0% Caught Immediately	20% Caught Immediately	40% Caught Immediately
Percent of investigations voided immediately	0	20	40
Percent of investigations voided by clinic	45	25	5
Percent of investigations completed in full	55	55	55
Average hours spent per 100 investigations	2650	2450	2250
Percent Reduction		**7.55**	**15.09**

Table 1: Future state man hour reduction

This is currently not the process primarily due to the confusion in terminology between clinic form and 8D investigation. If this confusion is cleared up and the clinic coordinator only initiates a clinic form for parts with customer induced damage (instead of initiating an 8D investigation), this reduction can occur very simply.

4.3 Backlog

The final opportunity for improvement surrounds an open backlog of 8D investigations. At the beginning of the project, a significant backlog in open 8D investigations was discovered in the spares organization. Between January 2011 and June 2012 (the start of the project,) 81% of all spares investigations were still open. Figure 13 shows the ratio between open and closed 8D investigations by the month they were initiated.

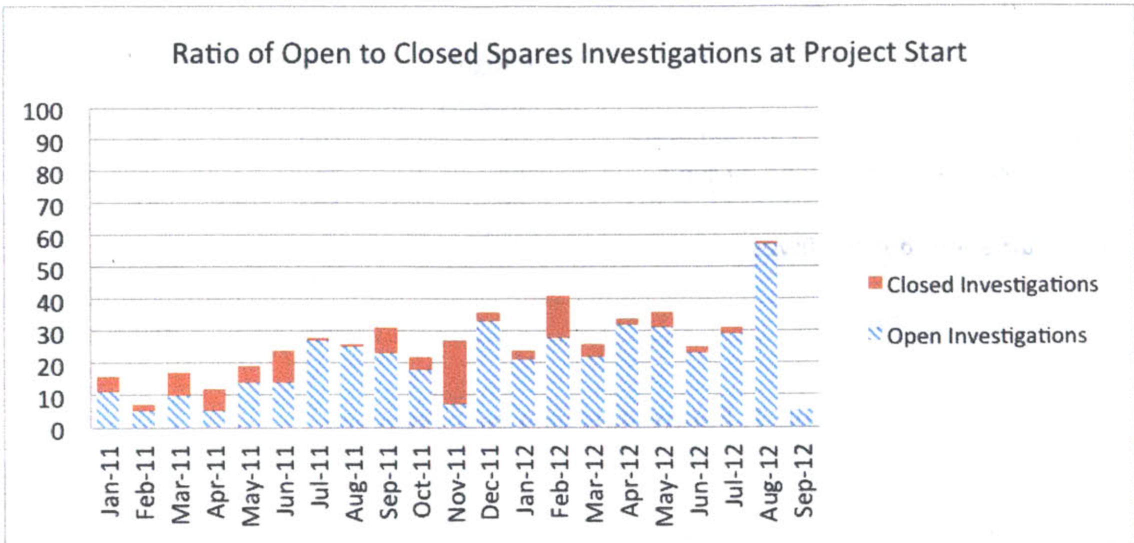

Figure 13: Ratio of Open to Closed Spares Investigation at Project Start

Having an open backlog of 8D investigations significantly impairs the feedback mechanism that is so important between the customers who report the defects and the suppliers or manufacturers who are responsible for them. The effects of an open backlog can be seen using the feedback loop shown in Figure 14.

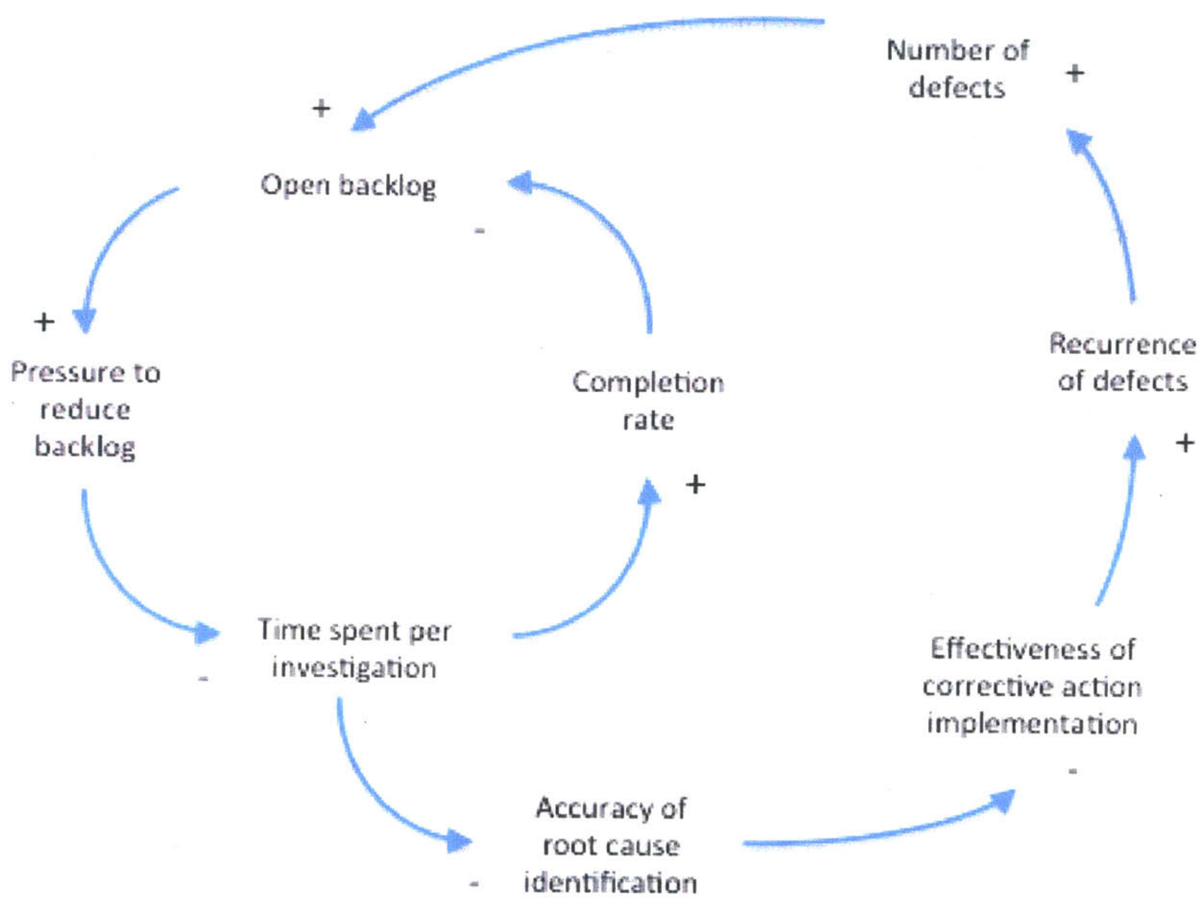

Figure 14: Open Backlog Feedback Loop

This feedback loop is both positively and negatively reinforcing. The negative feedback reduces the open backlog as pressure on employees to reduce the backlog results in less time per investigation and a higher completion rate. This effect is dampened significantly by the positive feedback that results from inaccurate investigations. Because employees are spending less time per investigation, the accuracy of the root cause investigation and the subsequent effectiveness of the corrective action measures results in recurring defects. More defects are then reported by customers, which increasing the number of defects that must be processed by the organization. This ultimately increases the open backlog of issues as employees struggle to keep up.

To prevent an open backlog, it is essential that all involved employees be informed of the defects. This requires communication, as well as a reporting tool to remind the responsible team members and inform executives of outstanding issues. The project uncovered that the IT tool did not report defects for the spares organization and employees were unaware of the backlog of open investigations. After updating the tool, the ratio of open to closed defects steadily decreased and the percentage of open investigations fell from 81% to 43%. Figure 15 shows the ratio at the end of the project and can be compared to Figure 16, which shows the ratio at the beginning of the project (and it is a repeat of Figure 13).

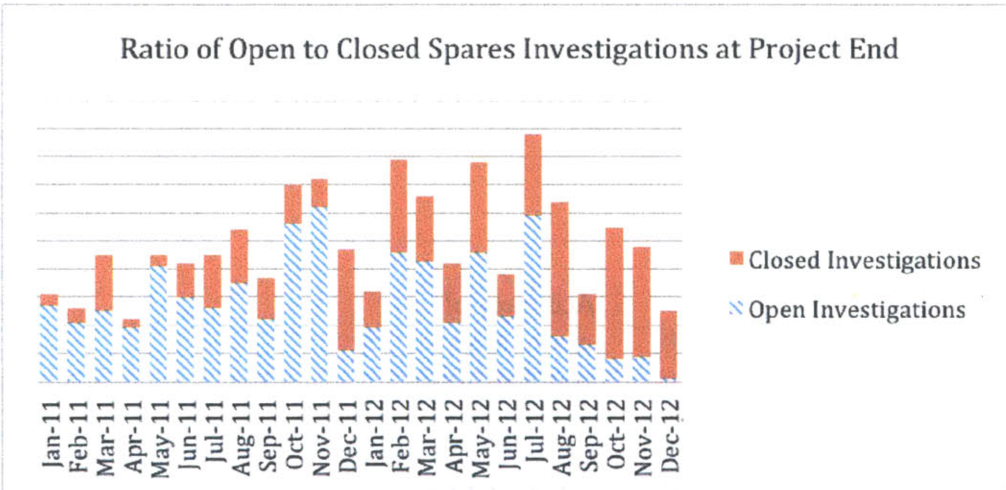

Figure 15: Ratio of Open to Closed Spares Investigation at Project End

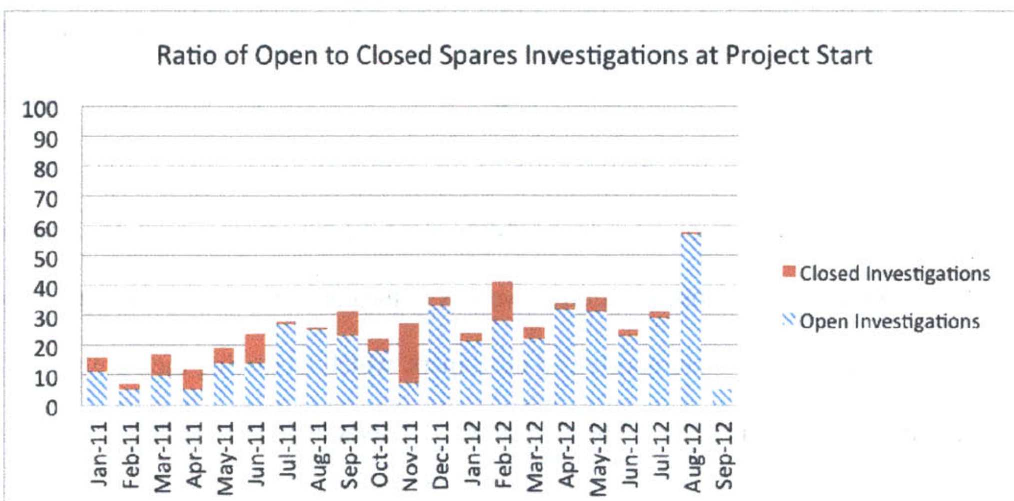

Figure 16: Ratio of Open to Closed Spares Investigation at Project Start

The scale cannot be shown for confidentiality reasons, however it has been kept consistent between the two figures to allow for comparison. Because UTC Aerospace Systems began placing a greater emphasis on spares defects, additional defects were entered into the system in between the start and end of the project, even for previous months. While this did increase the open investigation count, it placed an even larger emphasis on addressing these defects, decreasing the overall percentage of open investigations from 81% to 43%.

5 Concluding Remark

In the future, UTC Aerospace Systems can expand upon the tool used in 4.1 to more fully understand their COPQ costs. Because it considers both the repair and replacement costs, it is possible to analyze the tradeoff between repairing and replacing a part. For example, if a systemic issue has been identified and the part needs to be redesigned and replaced, UTC Aerospace Systems can use the tool to determine when to begin the redesign and the part based on the financial impact of doing so.

While implementing the 8D methodology has the potential to provide substantial benefits to UTC Aerospace Systems, its continued success is dependent on effective implementation. This paper has shown that the 8D tool can be misused in two very different ways: first by using it wastefully, and second by failing to use it in situations when its use would be effective. This paper clearly quantified the financial impact of these two situations of misuse. With continued use of the 8D methodology, it is important to ensure proper implementation to avoid wasteful spending. By continually identifying type 1 and type 2 errors, UTC Aerospace Systems can continuously improve and perfect the implementation of the 8D methodology. Doing so will not only lead to a reduction in COPQ but also lead to a more effective organization with more satisfied customers.

Works Cited

Campanella, J. (Ed.). (1999). *Principles of quality costs: Principles, Implementation and Use*. American Society for Quality, Quality Cost Committee, Milwaukee, WI.

Edgar Online. (2012). *United Technologies Corp, Form 10-K.* Retrieved 14 September 2012, from http://files.shareholder.com/downloads/UTX/2157916500x0xS1193125-12-47752/101829/filing.pdf

Evans, J.R. and William M. Lindsay. (2008) *Managing for Quality and Performance Excellence.* Thomson Higher Education, Ohio.

Feigenbaum, A.V. (1956). *Total Quality Control.* Harvard Business Review. pp. 93-101.

Juran, J.M. (1989). *Juran on Leadership for Quality.* The Free Press, New York. pp. 14-15.

Juran, J.M. et al. (1999). *Juran's Quality Handbook.* McGraw-Hill, New York. Section 8.

Juran, J.M., F.M. Gryna. (1980) *Quality Planning and Analysis.* McGraw-Hill, New York. pp. 20-25.

iSixSigma. (2011). *Cost of Quality: Not Only Failure Costs.* Retrieved 22 November 2012 from http://www.isixsigma.com/implementation/financial-analysis/cost-quality-not-only-failure-costs/

United Technologies. (2013). *About UTC.* Retrieved 14 September 2012, from http://www.utc.com/About+UTC

United Technologies. (2013). *Quality.* Retrieved 14 September 2012, from http://www.utc.com/About+UTC/Quality

UTC Aerospace Systems. (2012). *UTC Aerospace Systems delivers 100th CACTCS pack shipset for Boeing 787 Dreamliner.* Retrieved 10 October 2012 from http://utcaerospacesystems.com/latest-news/utc-aerospace-systems-delivers-100th-cactcs-pack-shipset-for-boeing-787-dreamliner/

Vining, G. (2011). *Statistical Methods for Engineers.* Brooks/Cole, Boston.