Localized Change Management in Two Cases: Supply Base Cost Escalation and Obsolescence Management

by

Robert J. Harris, Jr.

B.B.A., University of Mississippi, Oxford, 2005
B.S.M.E., Georgia Institute of Technology, Atlanta, 2007

Submitted to the MIT Sloan School of Management and the Department of Aeronautics and Astronautics in partial fulfillment of the requirements for the degrees of Master of Business Administration and Master of Science in Aeronautics and Astronautics in conjunction with the Leaders for Global Operations Program at the MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2014

©2014 Robert J. Harris Jr., All rights reserved.
The author hereby grants to MIT permission to reproduce and to distribute publicly paper and electronic copies of this thesis document in whole or in part in any medium now known or hereafter created.

Signature redacted

Author

MIT Sloan School of Management and the Department of Aeronautics and Astronautics

May 9, 2014

Certified by

Deborah Nightingale, Thesis Supervisor
Professor of the Practice, Aeronautics and Astronautics and Engineering Systems Division

Signature redacted

Certified by

Leigh Hafrey, Thesis Supervisor
Senior Lecturer, MIT Sloan School of Management

Approved by

Paulo C. Lozano
Associate Professor of Aeronautics and Astronautics
Chair, Graduate Program Committee

Signature redacted

Approved by

Maura Herson
Director, MBA Program
MIT Sloan School of Management
Localized Change Management in Two Cases: Supply Base Cost Escalation and Obsolescence Management

by

Robert J. Harris, Jr.

Submitted to the MIT Sloan School of Management and the Department of Aeronautics and Astronautics on May 9, 2014, in partial fulfillment of the requirements for the degrees of Master of Business Administration and Master of Science in Aeronautics and Astronautics

Abstract

There are several models for change available to modern organizations based on decades of research. This research tends to focus on broad changes, such as enterprise transformations. This thesis presents a model developed for changes of smaller scope. These smaller changes are typically localized to a specific process or department. The Tactical Change Model is derived from existing change management literature to address these localized change efforts. The phases of the model include: Name a Goal, Investigate the Current State, Develop and “Sell” a Future State, Plan to Get From Here to There, Enact the Plan, and Spread the Knowledge. A final phase, Reflection, is used throughout the change effort. This thesis presents two cases of change at the Aerospace Systems division of United Technologies Corporation. The first case is a change in how escalation in supply costs, or headwind, is forecasted. The goal in this case is a quick, top-down method for forecasting headwind to replace a time-intensive, bottom-up method. The second case is a change in the evaluation method of obsolescence risk mitigation options. This effort is intended to improve the evaluation of these options to develop a more holistic perspective. The Tactical Change Model is used in both of these cases and evaluated using a Three Lens Analysis. The analysis generates improvements to the Tactical Change Model, including explicitly accounting for the Three Lenses throughout the model; removing the Name a Goal phase; emphasizing frequency and structure in the Reflection phase; and allowing for feedback loops.

Thesis Supervisor: Deborah Nightingale
Title: Professor of the Practice, Aeronautics and Astronautics and Engineering Systems Division

Thesis Supervisor: Leigh Hafrey
Title: Senior Lecturer, MIT Sloan School of Management
The author wishes to acknowledge the Leaders for Global Operations Program for its support of this work.
Acknowledgments

This thesis is the result of contributions made from many people. I owe much to them. Some of the most direct contributions came from my advisors. Professor Deborah Nightingale and Professor Leigh Hafrey both provided superb guidance in turning this work into an actual thesis, while also affording me the freedom to explore the project on my own terms. I appreciate that balance and recognize that it was probably what made me appreciate my thesis work the most. You both have my respect and gratitude.

I also want to thank UTC Aerospace Systems in general for allowing me to study their operations in the name of this thesis. More specifically, Rishi Grover and Justin Keppy deserve credit for providing the case studies and supporting my work in multiple ways. I am certainly indebted to Craig Maurer, Ricardo Rhone, Gabby Ramirez-Chavez, and Nancy Cheney in the Obsolescence Management Department for patiently serving as subject matter experts. I sincerely hope that this thesis is directly beneficial to them. I am also grateful to Ralph Pantano, who was able to provide the data I desperately needed and that many said did not exist. Monica Jones, Terri Heisey, and Tracy Jones deserve my thanks for going above and beyond their roles to make sure I had what I needed. I would like to thank Vickie Colvard, who took a real interest in my project and was a great cube neighbor.

My parents and my in-laws have been incredibly supportive of my goals, even when it meant moving my family across the country from them. My parents have both sacrificed throughout their lives for me, and these past two years were no exception. My wife and son have also sacrificed of themselves to follow me around the country. Jessica and Asher deserve loads of credit for these past two years. They and the soon-to-arrive Abby Cate are truly the best kind of blessings. Thank you, and I love you all.

Finally, I thank God for the all of these blessings and more that I could not hope to even remember. My career goal has been to help humanity appreciate and enjoy His creation through the aerospace field. This thesis is a milestone for me that I could not have achieved without Him. I hope to honor Him throughout the rest of my career.
# Contents

1 Introduction .......................................................... 15
   1.1 Industry Background ........................................... 16
   1.2 Company Background ........................................... 17
   1.3 Project Background ............................................ 19
   1.4 Thesis Objective .............................................. 20
   1.5 Major Findings .................................................. 20
   1.6 Outline ............................................................ 22

2 Literature Review .................................................... 23
   2.1 Change Management ........................................... 23
      2.1.1 ACE .......................................................... 23
      2.1.2 Kotter Method ............................................ 25
      2.1.3 Enterprise Transformation Roadmap ..................... 28
      2.1.4 Beckhard and Harris .................................... 31
      2.1.5 Kanter’s Skills ........................................... 33
   2.2 Three Lens Analysis ........................................... 36
   2.3 Headwind ........................................................ 37
   2.4 Obsolescence Management ................................. 40

3 The Tactical Change Model ........................................... 45
   3.1 Name a Goal ..................................................... 46
   3.2 Investigate the Current State ............................. 47
   3.3 Develop and “Sell” a Future State ....................... 48
3.4 Plan to Get From Here to There ........................................ 49
3.5 Enact the Plan ............................................................... 50
3.6 Spread the Knowledge .................................................... 51
3.7 Reflect ................................................................. 52

4 Cases ................................................................. 53
4.1 Headwind ................................................................. 53
  4.1.1 Name a Goal ............................................................ 53
  4.1.2 Investigate the Current State ....................................... 54
  4.1.3 Develop and “Sell” a Future State ................................. 55
  4.1.4 Plan to Get From Here to There ..................................... 56
  4.1.5 Enact the Plan ........................................................ 56
  4.1.6 Spread the Knowledge .............................................. 58
  4.1.7 Reflection ............................................................. 58
4.2 Obsolescence Management .................................................. 59
  4.2.1 Name a Goal ............................................................ 59
  4.2.2 Investigate the Current State ....................................... 59
  4.2.3 Develop and ”Sell” a Future State ................................. 63
  4.2.4 Plan to Get From Here to There ..................................... 67
  4.2.5 Enact the Plan ........................................................ 67
  4.2.6 Spread the Knowledge .............................................. 68
  4.2.7 Reflection ............................................................. 68

5 Analysis ................................................................. 71
5.1 Three Lens Analysis Methodology ....................................... 71
5.2 Three Lens Analysis of Headwind Case .................................. 71
  5.2.1 Strategic Design Lens Perspective on Headwind Case ............ 71
  5.2.2 Political Lens Perspective on Headwind Case .................... 72
  5.2.3 Cultural Lens Perspective on Headwind Case .................... 72
5.3 Three Lens Analysis of Obsolescence Management Case ............. 73
  5.3.1 Strategic Design Lens Perspective on Obsolescence Management Case 73
List of Figures

1-1 UTC Aerospace Systems Business Unit Structure ........................................ 18
2-1 Enterprise Transformation Roadmap as presented by Nightingale and Srinivasan.[17] 29
2-2 Change Map as Presented by Beckhard and Harris.[2] ............................... 32
2-3 Obsolescence Mitigation Strategies[26] .................................................... 41
3-1 Tactical Change Model ............................................................................. 46
3-2 Origins of the Steps of the Tactical Change Model ................................. 47
6-1 Revised Tactical Change Model ................................................................. 79
A-1 Economic indicators investigated as headwind drivers .......................... 85
A-2 Values and diagnostics for headwind equations ...................................... 87
A-3 Screenshot of General Headwind Forecast Tool Interface ....................... 88
A-4 Screenshot of General Headwind Forecast Tool Interface ....................... 89
A-5 Results of general headwind forecast ..................................................... 90
A-6 Results of negotiation headwind forecast ............................................... 91
B-1 Costs of obsolescence mitigation options versus number of parts resolved (no-
    tional only) ........................................................................................... 97
B-2 Algorithm used to trade off design refreshes and life-time buys ............. 98
B-3 Schematic of the model used to evaluate obsolescence mitigation strategies 99
Chapter 1

Introduction

Change is important in any company. In the 1980s and ‘90s, American industry began to appreciate the benefits of techniques and strategies used by their Japanese counterparts. This sparked a surge of research and implementation of lean methodologies based largely on the Toyota Production System. The American industry mimicked the processes that seemed to be providing economic advantages. Steve Spear notes the results of these efforts in his book The High-Velocity Edge:

“Though many firms had embraced various tools associated with lean manufacturing and total quality management and had gained stability and control of work sites that had been chaotic and unreliable, they still never caught up. And now I could see why. These firms had picked up the visible tools of high-velocity organizations - the value-stream maps, pull systems, production cells, statistical process control charts, and design of experiments - but they had not understood what these tools were for: managing complex work for continual improvement of that work.” [28]

To be sure, concepts like pull manufacturing, work standardization and statistical process control were quite an advancement in manufacturing technology, but the essence of lean was not to be found in artifacts such as these. They were expressions of the underlying ideology of lean. The essence of lean is change. Change allows for continuous improvement, and continuous improvement allows a company to become ever more efficient and competitive in the
marketplace. The Toyota Production System and its associated artifacts were not the source of competitive advantage in themselves. They were being used by Toyota to facilitate change in the quest for improvement, which was the source of competitive advantage. As continuous improvement and change began to come to the forefront of management technology, academic research paved the way. Several change frameworks emerged as the importance of change was realized. These frameworks are intended to standardize the change process, and just as with any standard work, they are candidates for continuous improvement. This thesis is intended to identify how change research can be used in a circumstance that deviates from the standard case that this research typically focuses on. Instead of large-scale change efforts, this thesis focuses on localized change efforts. The change model literature research is used to develop a Tactical Change Model, which is implemented in two cases and analyzed for efficacy. The results of that analysis are used to improve the model.

1.1 Industry Background

United Technologies Corporation Aerospace Systems (UTC Aerospace Systems) is a tier one supplier to aircraft companies like Boeing, Lockheed Martin, Airbus, Embraer, and Bombardier. It supplies various systems that perform important functions on these customers’ aircraft, including actuation, aerostructures, landing gear, propeller systems, wheels and brakes, engine components, sensor systems, and others.

There are few competitors, but since there are also few customers, competition for large contracts tends to be fierce. The trend in the industry for the past two decades has been consolidation, with acquisitions leading to large tier one suppliers that can offer entire systems and packages not possible for smaller, more focused companies. Further up the supply chain, lower tiered suppliers are more fragmented. They tend to be smaller companies, but with a more diverse set of customers. Competition is not necessarily fierce for sales to the aerospace industry.

The aerospace industry is a long-cycle, heavily regulated industry. Commercial aircraft are designed to last 20 years or longer, and military aircraft are typically required to last even longer. Government regulations dictate that new product development requires extensive
testing to prove airworthiness. This testing is expensive and time-consuming, leading to an important barrier to new entrants.

Similarly, outside of the relatively few suppliers of these highly regulated systems, airframers like Boeing and Airbus have little opportunity to utilize substitute products. The standard approach among suppliers in the industry is to sell the original equipment to the airframers at a minimal profit, then supply the much more profitable aftermarket - performing maintenance and replacing equipment to sustain the long life cycles of the aircraft. A supplier has an advantage in winning this aftermarket business if they supplied the original equipment on the aircraft to be serviced.

These industry dynamics lead to two effects that have important consequences. First, because the lifecycle of a typical aircraft is long and the aftermarket is important, tier one suppliers must be able to support the aftermarket with parts. However, because the lower tiered suppliers have many other customers in industries with shorter lifecycles, they tend to discontinue production of components while they are still being used on aircraft. Second, because of the long lifecycle of a typical aircraft, financial forecasts are important. Tier one suppliers must be able to predict their costs in order to convert long sales contracts with airframers into profit. The two cases examined herein represent change efforts being made to address these two effects.

1.2 Company Background

UTC Aerospace Systems provides aerospace products and aftermarket services, including electric power generation, power management and distribution systems, flight control systems, engine control systems, intelligence, surveillance, and reconnaissance systems, engine components, environmental control systems, fire protection and detection systems, propeller systems, aircraft nacelles, interiors, actuation, landing systems, and electronic systems. UTC Aerospace Systems sells these products to airframe manufacturers, the United States and foreign governments, aircraft operators, maintenance, repair and overhaul providers, and independent distributors. The largest customers for the past year were Boeing and the United States government, representing 13% and 24% of sales, respectively.[9]
UTC Aerospace Systems was formed on July 26, 2012 after UTC bought Goodrich Corporation and merged it with UTCs existing Hamilton Sundstrand division at a cost of $18.3 billion. Prior to the acquisition, Hamilton Sundstrand was quite centralized in its operations. In contrast, the Goodrich Corporation was quite decentralized, with each business unit acting almost as an independent business and the corporate headquarters operating much like a holding company. The differences between the two legacy organizations present challenges in aligning their efforts and processes, but also present opportunities to take advantages of synergies. The current structure of UTC Aerospace Systems is shown in Figure 1-1.

<table>
<thead>
<tr>
<th>Aircraft Systems</th>
<th>Power, Control &amp; Sensing Systems (PCSS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actuation Systems*</td>
<td>Electric Systems**</td>
</tr>
<tr>
<td>Aerostructures*</td>
<td>Space Systems**</td>
</tr>
<tr>
<td>Wheels &amp; Brakes*</td>
<td>Engine &amp; Control Systems (E&amp;CS)**</td>
</tr>
<tr>
<td>Interiors*</td>
<td>Fire Protection Systems**</td>
</tr>
<tr>
<td>Landing Gear*</td>
<td>Sensors &amp; Integrated Systems**</td>
</tr>
<tr>
<td>Propeller Systems**</td>
<td>Intelligence, Surveillance, and Reconnaissance Systems (ISR)*</td>
</tr>
<tr>
<td>Air Management Systems**</td>
<td>Engine Components*</td>
</tr>
</tbody>
</table>

Figure 1-1: UTC Aerospace Systems Business Unit Structure  
*Unit of Goodrich Corporation prior to acquisition  
**Unit of Hamilton Sundstrand prior to acquisition

The alignment of these two organizations has taken much planning and effort. Frameworks from lean ideology such as five whys analyses and fishbone charts were the basis of the activity. Leaders behind the change were tasked with operating the newly formed organization effectively while also building it. One senior vice president described the current state saying, "We are building a highway while we are driving on it." A few of the principles discussed in the change management literature were explicitly followed. The transformation leadership was intentional about strategically selecting projects for their operational importance and their impact on credibility and morale. Quick wins were actively planned into
the change. After one year of integration progress, the senior vice president noted, “It’s not over. We’re evolving.” This dual responsibility of operating and integrating the company has required intense effort, but at least among the senior leadership, the potential rewards of the integration warrant it. A vice president of human resources noted, “Nobody wants to fail. There’s a lot left to do.”

1.3 Project Background

In the Annual 10K Report released by United Technologies Corporation (UTC) for 2012, several items are listed as risks, uncertainties, and other factors which may impact the forward-looking statements therein. The second listed uncertainty is the ability to integrate the acquired Goodrich operations and to realize synergies and opportunities for growth and innovation.[9] After the acquisition of Goodrich last year, the Operations groups of both divisions, Power, Controls, and Sensing Systems (PCSS) and Aircraft Systems (AS), were tasked with identifying and exploiting synergies. Members of these groups actively look for these opportunities and facilitate projects to realize the savings they represent. This work is divided into several focus areas, with employees in the Operations group assigned to specific areas. These focus areas include Product, Footprint, and Headcount. The Product group is aimed at reducing costs related to the products. The Footprint group is aimed at reducing costs associated with facilities. The headcount group is aimed at reducing costs associated with employees. The purchase and integration has provided the Operations group with an abundance of opportunities to optimize operations. One Operations manager said, “85% of our work is related to integration.”

As with any company, change is important at UTC Aerospace Systems. Several projects have been launched to recognize synergies in the new division, each implying a change effort. In addition to the changes made for the sake of synergy, the Operations group continually looks for changes that could be made to reduce costs and increase the value of the company. This thesis will focus on two projects currently underway that could facilitate cost savings or improve efficiency based on two localized changes. Those two projects are used as case studies to examine how change happens at UTC Aerospace Systems and the efficacy of the
Tactical Change Model.

1.4 Thesis Objective

The objective of this thesis is to examine localized change at UTC Aerospace Systems. Beginning with Lewin's model of unfreezing, introducing change, and freezing in 1951, there have been several change management frameworks made available to the business world.[15] However, the efficacy of a particular framework is dependent on situation-specific factors such as culture, leadership style, and organization size. This study will examine how existing change management frameworks may be adapted into a new model to fit a particular situation, localized change, represented by the two cases herein.

1.5 Major Findings

These cases indicate that existing change models are useful for making efficient and effective change, however these models may require some customization for the circumstance at hand. This is particularly true when used outside of the scope of the broad organizational transformations for which they are intended. In response, I introduce the Tactical Change Model. The Tactical Change Model represents an effort to distill a set of those existing models into a form more suited to changes of smaller scope. During the case studies, I used the Tactical Change Model as a framework to achieve the desired changes. The case studies are analyzed in this thesis to generate revisions to the Tactical Change Model. The major findings of those cases are presented here.

Three Lens Analyses, whereby strategic, cultural, and political perspectives are used to characterize an organization, is used to evaluate the change cases. These Three Lens Analyses reveal several important findings. Notably, one of those findings is that Three Lens Analyses should be incorporated into the model and considered consistently throughout the change.

One area particularly appropriate for the inclusion of a Three Lens Analysis is the current state analysis. A thorough current state analysis sets the foundation for the entire change.
No other phase of the change model has as much of an impact on the change as the current state investigation. My experience during these case studies demonstrated that a Three Lens Analysis is beneficial in a change effort.

My studies of the cases described here demonstrate the importance of incorporating persistent reflection into the change process. The models in the change literature tend to either omit reflection or, at most, imply reflection within phases dedicated primarily to other goals. This leads to many change models that have no mechanism for course correction. In contrast, my experience in the cases discussed here indicates that reflection should be performed regularly during all phases of a change. In one case, a complete revision of the final goal was induced through reflection.

Reflection was included as a separate phase in the original Tactical Change Model and used during these cases. This reflection would have been more effective, however, with improved structure. Frequency, a consistent framework, and appropriate stakeholder participation are important dimensions of this structure. As discussed above, a three lens approach, explicitly considering each lens, is one way to provide a framework for reflection. As I performed a Three Lens Analysis on these cases after their conclusion, it became clear that this technique would be useful during the reflection phase as well as the current state analysis. This would promote a holistic view of the change throughout the effort, serve as a consistent framework, and encourage participation from all appropriate stakeholders. Expanding the idea further, this three lens perspective should be used during all phases of the model. As a result, the Three Lens Analysis is incorporated into each phase of the revised Tactical Change Model.

Many change models in the change management literature specify “Name a Goal” as the first step in a change. In the cases described here, however, the goals were given. The change efforts were the result of directives, which is likely the case for most localized changes. Even without an obvious directive, tactical change efforts do not require the level of cognitive investment that broader transformational efforts require.

Two specific tools were particularly useful during the change efforts. Those tools were the expert audit and pilot test. These two actions helped persuade stakeholders about the merits of change.
A final significant finding is the fallacy of the uni-directional change model. New information and deviation from the plan may change the assumptions or premise of the change effort. The model should guide the change leader to revisit previous phases in these instances.

1.6 Outline

This thesis will begin with a review of the change model literature, including the model used generally by UTC as well as some prominent models developed within academia. The chapter continues with an introduction to an existing organizational analysis framework. This is followed by an introduction to literature around headwind and obsolescence management, which are the themes of the two cases studied here. The next chapter introduces and explains the Tactical Change Model, which is based on change models in the literature. The Tactical Change Model is then used to affect change in two cases at UTC Aerospace Systems. Next, Three Lens Analyses are used to evaluate the change cases. Based on those analyses, strengths and opportunities for refinement of the Tactical Change Model are identified in the final chapter. The thesis concludes with a revised Tactical Change Model and some effective techniques for promoting a localized change.
Chapter 2

Literature Review

A literature review is presented here for the four subject areas covered in this thesis: change management, organizational analysis, headwind, and obsolescence management. Literature regarding change management is presented as a basis for the Tactical Change Model developed in Chapter 4. Organizational analysis literature is presented to provide a way to analyze the cases. Literature regarding headwind and obsolescence management is presented in support of the changes made in those cases.

2.1 Change Management

2.1.1 ACE

All divisions within UTC, including UTC Aerospace Systems, use a proprietary operating system to drive quality into their products and processes. This operating system is called Achieving Competitive Excellence, or ACE. The ACE framework is based on a legacy of lean, and is focused on improving efficiency and reducing waste. It is "implemented on the micro level, with employees who are trained and empowered to implement the standard processes across the company."[10] ACE is the way all UTC employees do business everyday, around the world, to delight (their) customers and create value for (their) shareholders.[10] One of the main elements of ACE is a set of tools that helps the organization identify process improvement opportunities, solve problems and assists with decision-making processes.
Those tools comprise a framework through which change can be driven. ACE prescribes eight factors for success of a lean transformation:

1. Process Vision: This is the ideal state of a process, customer-oriented and waste-free. It is expressed verbally and graphically.

2. ACE Criteria: These principles provide a standardized way of describing progress from the current state to the future state and the intermediate stages.

3. Target Linkage: Targets should evaluate the progress of a transformation project by way of key process indicators. These key process indicators should be related to relevant business metrics.

4. Transformation Roadmap: This is an implementation guide for the project for all levels of tasks. Each task is budgeted, tracked, and reviewed according to a Gantt chart or similar table.

5. Toolset: These are the standard methods used to facilitate a transformation project. They are the most recognizable artifacts of ACE, and they include widely used lean tools such as 5S, value stream mapping, standard work, market feedback analysis, quality clinic process charts, root cause analysis, mistake proofing, and a gate or passport process.

6. Roles and Operations: A resource analysis is performed to identify where team members can contribute and where gaps need to be filled. A steering committee is also established to drive the transformation.

7. Competency Development: A competency development matrix is constructed to assess the skills of the organization needed to transform and support a lean organization.

8. Commitment and Communication: Organizational commitment is built from sufficient communication, and it sustains the transformation to completion.[10]
2.1.2 Kotter Method

Kotter put forth eight steps to transform an organization after observing over 100 companies for more than a decade.[14] He noted several common mistakes that led to the failure of change efforts, and created a framework that directly addressed those failure modes.

**Step 1: Establish a sense of urgency**

The first step involves identifying where and why change should be made. The motivation for the entire process comes from this step. Without motivation, change is unlikely. One can examine the relevant market and competitive environment to identify crises, potential crises, or major opportunities. Kotter notes that well over 50% of the companies he observed failed to establish an adequate sense of urgency.[14] Overcoming the fear of change, which may be accompanied by jeopardized short-term metrics and job security concerns, is vital to facilitating change. As one CEO put it, the goal is “to make the status quo seem more dangerous than launching into the unknown.”[14] A crisis or major opportunity based on market and competitive realities must be recognized and effectively communicated. In some instances, a crisis has been intentionally manufactured within the organization to instill urgency.

**Step 2: Form a powerful guiding coalition**

Senior managers with enough organizational power to gain currency for a change effort must form the core of a guiding coalition dedicated to the change. In the early stages, a small group of three to five people is sufficient, but the coalition needs to grow to dozens before significant progress can be made.[14] As the coalition grows, it must operate with different norms regarding hierarchy. Members who are not senior managers are valuable for their informal power and perspective within an organization, but their contributions will not be fully realized if the traditional boundaries and protocol stifle free exchange. A deliberate effort must be made to unify this coalition. Kotter suggests off-site retreats as a possible vehicle for this unification.[14] Finally, key line managers must be central to the coalition. Managers from outside the primary functions of the organization are likely to be seen as
unqualified to drive change by employees from inside these functions.

**Step 3: Create a vision**

A sensible, clear vision is necessary to avoid the dissolution of the transformation effort into a “list of confusing and incompatible projects that can take the organization in the wrong direction or nowhere at all.”[14] The vision serves not only to inspire employees to action, but also to guide and explain change activities. Kotter proposes the following guideline: if the vision cannot be communicated in five minutes or less and generate demonstrated understanding and interest, the vision should be refined.[14]

**Step 4: Communicate the vision**

The goal of communicating the vision is to motivate the employees to pursue it. Employees must be willing to make short-term sacrifices for the sake of the vision if significant change is to occur. If they do not believe that such change is possible, they will not be motivated to make sacrifices when necessary. To foster this belief, senior managers must communicate and support the vision through many communication channels. One organization-wide email or a handful of speeches to employee groups is not sufficient evidence of management commitment to engender widespread buy-in. Kotter gives two suggestions for the successful communication of a vision. The first is to use all existing communication channels to broadcast the vision. Company newsletter articles, quarterly meetings, management education courses, question-and-answer sessions, and routine discussions can all be used to transmit the vision in an engaging way.[14] The second suggestion is to eliminate actions by leaders that are inconsistent with the vision. Senior managers should be held accountable when they engage in behavior that contradicts the vision. Kotter warns, “Nothing undermines change more than behaviour by important individuals that is inconsistent with their words.”[14]

**Step 5: Empower others to act on the vision**

Narrow job responsibilities, misaligned incentive systems, and unsupportive managers are a few examples of obstacles that can inhibit a change effort. Delving into a change effort without addressing obstacles such as these that employees will face will not only bog down
the effort, but it can also lead to cynicism towards the integrity of the change effort and senior management. A lone executive with enough power can create sufficient obstacles. Such personnel must be treated in a way that is consistent with the vision, or the entire effort will be perceived as weak.

**Step 6: Plan for and create short-term wins**

Kotter suggests that compelling evidence of the results of the change must be observed in 12 to 14 months to sustain the effort of most people.[14] These results must be actual, unambiguous results, as opposed to subjective evaluations. These short-term wins must be actively sought. Initiatives that can demonstrate the effects of the change should be pursued early in the project. The short-term wins should not be left to chance. In addition to creating credibility for the change, these short-term wins also provide a way to sustain the urgency needed to drive change in a way that a long-term goal cannot.

**Step 7: Consolidate improvements and produce still more change**

Kotter warns against confusing short-term wins with final success. It is tempting to celebrate positive results from early projects within the change effort and lose momentum. The early victory can actually give an opportunity to those opposed to change to declare that the progress is sufficient and the effort should cease or be slowed.[14] To combat this, change leaders should leverage the credibility provided by short-term wins to take on even larger projects. One way of instilling this perspective in the organization is to measure all progress against the final goal. A metric could be devised to track this progress, reminding all employees of the progress made along with the progress yet to be made.

**Step 8: Institutionalize new approaches**

There are two primary concerns when institutionalizing changes. First, results must be correctly attributed to the new approach. There is a danger that positive results can be attributed to factors other than the change effort, minimizing the organizational momentum behind it. Second, succession in top management must be made with consideration of the change in mind. The top leaders must continue to serve as change champions. This can only
be accomplished through intentional effort. Kotter warns that his experience indicates that a new CEO can undermine years of change effort in as little as two years.[14]

### 2.1.3 Enterprise Transformation Roadmap

The Enterprise Transformation Roadmap, developed at the Lean Advancement Institute at MIT, is another framework for change. As stated in *Beyond the Lean Revolution* and as the name implies, the Enterprise Transformation Roadmap is intended for use at the enterprise level. The change process outlined begins with defining the enterprise. The definition of the enterprise sets the scope of the change effort. Nightingale and Srinivasan propose seven principles of enterprise transformation as the basis of the change framework:

1. Adopt a holistic approach to enterprise transformation
2. Secure leadership commitment to drive and institutionalize enterprise behaviors
3. Identify relevant stakeholders and determine their value propositions
4. Focus on enterprise effectiveness before efficiency
5. Address internal and external enterprise interdependencies
6. Ensure stability and flow (e.g., of information) within and across the enterprise
7. Emphasize organizational learning [17]

With these principles set in place and the enterprise defined, Nightingale and Srinivasan lay out the Enterprise Transformation Roadmap shown in Figure 2-1. This roadmap is decomposed into three cycles: the strategic cycle, the planning cycle, and the execution cycle.

The strategic cycle is focused on determining the strategic imperative and engaging leadership in the transformation. A strategic imperative is found by examining the purpose or value proposition of the enterprise. With this information, a strategic imperative can be formed which aims the enterprise toward fulfilling that purpose by achieving whatever change is necessary. An engaged leadership team is crucial to the success of a transformation.
While enterprise transformation is eventually an organization-wide process, the effort must be driven by the top leadership and its strategic vision. Nightingale and Srinivasan suggest the creation of an executive transformation council to drive the change.

Along with this demonstration of leadership support, a transformation vision must be communicated with a sense of urgency to motivate action. This vision should stimulate a new mental model of the enterprise. This new mental model should provide a holistic perspective of the enterprise and its future. Nightingale and Srinivasan recount success with setting a graduated series of milestones to reach this future version of the enterprise. With a holistic, urgent, leadership-supported vision appropriately communicated, the enterprise is prepared to begin the planning cycle of the Enterprise Transformation Roadmap.
The planning cycle is composed of four primary actions. The first, a current state evaluation, is necessary to form an enterprise-wide view of the future state. In describing the use of the current state evaluation to plan for a future state, Nightingale and Srinivasan state, “if you identify the characteristics of how each process must perform to meet the pull from a downstream process, you have created a very useful list of the characteristics of the future enterprise based on an idealistic goal of perfection.”[17] The next step is to interpret the capabilities and deficiencies identified within the current state in terms of a desired future state. This future state can be thought of as a Big Hairy Audacious Goal (BHAG), as described by James Collins and Jerry Poras in their book Built to Last, “A true BHAG is clear and compelling, serves as a unifying focal point of effort, and acts as a clear catalyst for team spirit. It has a clear finish line, so the organization can know when it has achieved the goal: people like to shoot for finish lines.”[7] After the future state is defined into a vision, the enterprise infrastructure can be aligned to support that state. Incentives are an important consideration when changing the structure and processes of the enterprise. These incentives should support the necessary changes. Finally, a plan can be created to support the execution of the transformation. Creation of a plan first involves identifying focus areas then “identifying, selecting, and sequencing projects that the transformation team believes will enable the enterprise to transform” at an increasing rate.[17]

At the beginning of the execution cycle, the plan should be communicated deliberately from the senior leadership. This demonstrates leadership support and avoids the problem of false or incomplete rumors. Then, education and training should be provided to support the effort. Specific plans and programs from the transformation plan can then be initiated. Progress along these efforts as well as the overall transformation should be tracked. As these initiatives progress, the transformation should be nurtured and enterprise thinking should be embedded. Nightingale and Srinivasan emphasize the importance of continued executive-level involvement and a holistic perspective on enterprise activity. Reflection on the transformation should be performed regularly, with lessons learned being diffused and the inevitable adjustments made to minimize obstacles. A useful example of this type of reflection is After Action Reports (AAR) performed by the United States Army. These AARs are built around four questions:
• What did we set out to do?

• What actually happened?

• Why did that happen?

• What are we going to do next time?

Finally, the transformation effort will lead to realization of further strategic imperatives to be achieved. Thus, the Enterprise Transformation Roadmap restarts, and the enterprise continues to improve.

2.1.4 Beckhard and Harris

Beckhard and Harris developed a simple change model to accommodate complex change.[2] The model is shown in Figure 2-2 and includes the following steps:

Step 1: Determine the need for change and the degree of choice about whether to change
Step 2: Define the desired future state
Step 3: Define the present state
Step 4: Assess the present in terms of the future
Step 5: Manage during the transition

Beckhard and Harris contend that the first step is to determine the need for change, including the sources of pressure for change, the potency of those sources, and the degree to which change is necessary. Sources of change can include governments, owners, society, or employees among others. The potency of these sources is driven by how much power each retains as well as their perspective and investment in the change. When combined, the identification of the sources of pressure and the potency of those sources begin to resemble the stakeholder analysis prescribed in other change models. This similarity reinforces the notion that a stakeholder analysis is indispensable for determining a change imperative.

Furthermore, the freedom to change or not is also important. For example, a new law requiring lower automobile emissions dictates change in an auto manufacturer. In contrast,
a new hybrid motor technology offers the same auto manufacturer a choice to change by introducing the new technology in its products, but the auto manufacturer has control over whether the change is made in this instance. The distinction is important, because it drives the allocation of effort within the company. If a change is inevitable, then all effort should be directed toward implementing the best change. If the change is discretionary, then some effort should be exerted to study whether the change should be made at all.

The next step is to define the future state. This definition should be detailed and include the organizational structure, reward system, personnel policies, authority and responsibility distributions, managerial values and practices, performance review systems, relationships with external groups, and expected organizational performance outcomes. In addition to defining the final desired state, a midpoint state should be articulated. This provides the organization a natural place to reflect on progress and adjust approaches where necessary. The midpoint state also serves as a more immediate and relatable goal than the final state during the early stages of a change.

When assessing the present state, as prescribed in step 3, one should: identify and set
priorities within different sets of problems, identify relevant stakeholder groups, and assess the readiness and capability for the proposed change. These actions provide insight into the present state beyond the structural and procedural status quo and will generate intelligence on how the change should be approached, presented, and refined. Particular attention should be paid to the “critical mass”, the minimum number of individuals or groups who must support a change for it to occur. Beckhard and Harris suggest mapping out the readiness and capability of various people or groups to facilitate a change plan.

The final two steps of the Beckhard and Harris Model involve formulating and executing a strategy to achieve the desired final state. Beckhard and Harris recommend an activity plan, a prioritized list of changes and the intervention technologies to be used to pursue those changes. Examples of intervention technologies include pilot projects, experiments, organization-wide confrontation meetings, educational initiatives, and temporary management structures. Regardless of the intervention technology employed, the transition must be viewed as a clear break from the former operations. In many instances, a transition manager will be assigned to execute the change. This transition manager may be chosen from almost anywhere in the hierarchy, but his role must be explicitly clear and supported by the organization’s leadership. A successful transition manager must have clout, respect, and effective interpersonal skills.

2.1.5 Kanter’s Skills

Kanter proposes a set of skills needed to facilitate change. They are intended to “reflect a perspective that is basic to e-culture.” E-culture is the human side of the global information era, the new way of working for all organizations which results from the growth of the internet. These skills are outlined below.

Skill 1. Sensing Needs and Opportunities: Tuning In to the Environment

Problems and weaknesses as well as opportunities should be recognized before they become well-recognized by everyone. Tuning in to the environment involves actively seeking out and being sensitive to new information. Customers and competitors should both be closely
observed. Similarly, decision challengers and people with different perspectives should be nurtured to maintain diverse sources of information. As many employees as possible should be empowered to feed information into the organization about early shifts in the organization or its environment.

Skill 2. Kaleidoscope Thinking: Stimulating Breakthrough Ideas

Kaleidoscope thinking is “look(ing) at a set of elements, the same ones everyone else sees, but then reassembl(ing) those floating bits and pieces into an enticing new possibility.”[13] Those who engage in kaleidoscope thinking assume there are many solutions for a given problem, and discover new possible solutions by changing their perspective on the problem. Reflecting on successes and mistakes, visiting drastically different environments, large-scale brainstorming sessions, and creative outlets like talent shows can all encourage kaleidoscope thinking.

Skill 3. Setting the Theme: Communicating Inspiring Visions

Kanter notes, “the one kind of power that is universal, held by every person . . . is silent veto power . . . exercise(d) by doing nothing to support or advance the change.”[13] Great ideas require support and action to yield positive results. For that reason a compelling vision, with a clear benefit to the key stakeholders, must be broadcast. The method of broadcast is important, as it can signify the gravity of the vision and the enthusiasm of the leaders. The broadcast can also affect whether employees perceive it as a threat, a condemnation, or an opportunity. Finally, the vision should motivate employees to action and provide clear actions to take. The purpose of the vision is to get as many people as possible convinced of the merits of the change and actively involved in making it come about.

Skill 4. Enlisting Backers and Supporters: Getting Buy-in and Building Coalitions

Political savvy is the essence of Kanter’s fourth skill. Driving change requires a personal network early on, and growing from a small group of backers to an ever-increasing one. Enlisting these backers comes through gathering intelligence, bargaining, and adjusting the
idea for change to gather support. During the early phase of gathering intelligence, successful change leaders typically reveal an early concept of the change. This allows for feedback on the change itself and who might be supportive, and it provides familiarity with the concept of the change among those who will later be presented with the finalized version.

**Skill 5. Developing the Dream: Nurturing the Working Team**

Often, after a change is decided upon, a working team is formed to develop and drive it. There are two components of this skill: building and nurturing the working team. In this phase the original change leader becomes a facilitator for a working team whose goal is to bring about the desired change. Building the team requires ownership of the team identity, goals, and approaches developed by the team itself. Without the intra-team bonds that arise from team identity and self-management, members of the team are likely to function without urgency or purpose. The team is nurtured successfully when all of the needed resources are provided efficiently. These resources can be in the form of food, praise, software, or any other item that helps the team reach its goal.

**Skill 6. Mastering the Difficult Middles: Persisting and Persevering**

Change efforts typically face obstacles during implementation. Kanter emphasizes the importance of persevering in the face of these obstacles. Efforts that are abandoned upon the discovery of obstacles are failures. Four common problems arise during the early implementation of a change: forecasts fall short, unexpected obstacles pop up, momentum slows, and critics get louder.[13] To overcome all of these difficulties, a change leader can focus attention on the vision for the effort, rally supporters, use clout to silence critics, and boost morale for those working directly on the change effort. Kanter describes a change leader as “like a pest, never taking no for an answer, never letting go, following up relentlessly, staying on top of people to make sure they do what they promised.”[13] Persistence and the ability to diffuse resistance during the vulnerable implementation are key factors in the success of a change effort.
Skill 7. Celebrating Accomplishments: Making Everyone a Hero

Rewards and recognition for completed milestones achieve multiple goals. First, they motivate the existing employees to continue their efforts. Second, they publicize the success and momentum of the change effort to outsiders and generate support. Third, they attract others to enlist in the change effort. Recognition is often free, and it can motivate people to attempt more change efforts.

2.2 Three Lens Analysis

Organizations are complex systems. Analyses of organizations are often performed using models or frameworks. One such framework is the Three Lens Analysis. The Three Lens Analysis was developed by John Carroll in the Organizational Studies Group at MIT Sloan and expanded upon by his colleagues at MIT Sloan.[4][31] The three lenses each provide a different perspective on the organization under analysis. John Carroll writes,

“...each represents a different way of thinking, a different lens through which you can view an organization. By trying on each lens, you gain new insights and a richer picture of an organization.”[4]

The first lens is the Strategic Design Lens. This lens focuses on the mechanics of an organization, as described by goals and their associated tasks.[4] Ancona et al. describe this perspective of an organization as a “system deliberately constructed to achieve certain strategic goals.”[31] The grouping of employees, linkages of those groups, and alignment of the efforts of those groups are all key elements of the Strategic Design Lens.[4] All of these elements are constructed to complete a specific task, which serves to further the purpose of the organization as a whole.[31]

The second lens is the Political Lens. This lens focuses on power and interests.[31] The organization is seen as a dynamic set of stakeholders, each with their own interests.[4] These stakeholders may combine into coalitions based on their shared interests. Coalitions can wield power either through imposition or negotiation. The sources of power in an organization include personal characteristics, expertise, track record, hierarchy, and informal network
position.[31] It is important to note that stakeholders can come from any level within or outside of the organization.

The third lens is the Cultural Lens. This lens focuses on the meanings assigned to objects and actions within an organization.[4] As described by Ancona et al.,

“A cultural perspective focuses on social and personal identities carried by people, the cognitive or mental maps the utilize to come to terms with the requirements and difficulties they face in their day-to-day activities, and the moral precepts and normative standards they take for granted but nonetheless bring to bear on the world and those around them.”[31]

Symbols, artifacts, and stories are important exhibitions of an organizational culture. These items help describe the attitudes, beliefs, and assumptions within the organization, which, in turn, explain actions within the organization.[4]

Carroll cautions that the three lenses are each independent, and cannot be combined into a comprehensive model of an organization.[4] While these lenses often overlap and work together, they are not intended to individually or collectively offer an exhaustive review of the organization, nor is one of the lenses expected to nullify the contributions of the other two. Instead, each of the three lenses should be used to gain a different perspective on an organization, and glean useful intelligence from that perspective.

### 2.3 Headwind

The term “headwind” is used within UTC Aerospace Systems to refer to an increase in the price of a purchased component from the previous year. Headwind is an area of focus within UTC Aerospace Systems, but every company faces the issue. As a result, a significant base of literature exists. Cost escalation affects the entire aerospace value chain. Often, headwind in the aerospace industry is related to economic indicators either by contract or by virtue of the supplier’s reaction to input costs. For example, Boeing has headwind clauses built into each of its contracts to deliver the 787 aircraft.[27] In 2006, the list price of a 787-8 was about $145 million, but by 2011, that price had increased to $193.5 million.[27] A standard approach to
headwind is to tie it to a consumer price index published by the Bureau of Labor Statistics and widely accepted as a measure of general inflation in the United States. Instead of this general index, headwind in the aerospace industry is typically tied to economic indicators reflecting changes in the prices of inputs. If the 787 list price had risen with the consumer price index, it would have reached only $163.9 million by 2011.[27] Boeing increases the aircraft price to guarantee that the revenue collected will exceed the cost of manufacturing each one sold.

In addition to the United States consumer price index, the Bureau of Labor Statistics generates other economic indicators which can be used as a basis for headwind. One set of indicators is producer price indexes. These measure the average change in prices received for domestic commodities. The producer price indices are particularly useful for determining the change in costs of inputs for a supplier. Boeing uses such indicators to determine its price increases.[27] The Bureau of Labor Statistics provides a guide for escalation based on these producer price indexes. This guide states, “because the measure price changes objectively, both in general and for particular products, free from possible manipulation by either of the contracting parties, the producer price indexes calculated by the Bureau of Labor Statistics (BLS) are widely recognized among business people, economists, statisticians, and accountants as useful in price adjustment clauses.”[19]

Other industries with long project schedules also face headwind concerns. Morris and Willson note the primary input cost factors in the construction industry: major natural disasters, labor and material costs, and code and practice changes.[1] Touran and Lopez propose a model for headwind in large multiyear construction projects based on Monte Carlo simulation.[30] Models such as these are quantitative methods which require a set of usable data. Makridakis gives three conditions under which quantitative methods work:

1. historical information is available,

2. this information can be quantified into numerical data, and

3. there is an assumption of continuity in the relationships.[16]

There are two types of quantitative forecasting methods. The first are statistical methods, which utilize time-series analysis and curve fitting methods.[12] The second are causal
methods, in which the forecasted variable is assumed to have a causal relationship with one or more independent variables.[12] Statistical methods include simple averaging and exponential smoothing as well as the Box-Jenkins approach. The Box-Jenkins approach is based on auto regressive integrated moving average (ARIMA) models. This approach provides a sophisticated analysis, but because of its complexity and the large amount of data required, it is seldom used in industry.[30] Causal methods of forecasting include neural networks and regression. Neural networks are based on models of the human brain and provide a nonlinear forecasting method when applied to time series.[30] Perhaps a more intuitive analysis is regression. Regression methods involve forecasting a dependent variable as a function of a set of independent variables. The model produced typically explains the maximum possible variation in the dependent variable using a mathematical equation in which a constant and coefficients associated with each independent variable are adjusted to minimize error between the model and the data.

Regression models are based on the assumption that some historical relationship will hold true in the future. The model proposed by Touran and Lopez is based on the assumption that the headwind in the previous years, weighted according to their recency, has a causal relationship with the headwind in the current year. Their model uses the weighted mean of these historical headwinds and Monte Carlo simulation to provide a distribution of headwind.[30]

Factors other than economic indicators also have an effect on headwind. The relationship between the manufacturer and supplier often influences headwind in the aerospace industry. Beginning in the late 1990s, American aerospace manufacturing firms began to dramatically increase outsourcing practices. In 2005, outsourcing accounted for 50 to 70 percent of the total value of aerospace products.[23] This practice improves certain important financial metrics, which are often used to evaluate executive performance. Outsourcing is sometimes part of a strategy called strategic sourcing, wherein the manufacturer and supplier are tightly integrated to make the relationship efficient and cost-effective. Strategic sourcing has two important effects. First, it causes the manufacturer to be reliant on fewer suppliers, but it also affords the manufacturer greater buying power with those suppliers than it would enjoy with a more distributed supply base. These relationships can thrive in an environment of
trust, however, a focus on short-term financial metrics can undermine that environment. For instance, consider a company that uses annual headwind as the primary metric for incentives. This focus on headwind may drive employees to disregard costs associated with switching suppliers, holding excess inventory purchased to achieve a bulk price, loss of goodwill with the supplier, and diminished product quality. In fact, this effect is already common in the aerospace industry as indicated by the following statement from an aerospace employee: “The aerospace industry that for years competed on capabilities now competes almost exclusively on year-over-year price reductions.”[23] Corum notes efforts within UTC to develop trust using a consistent Supplier Evaluation Process.[11] The Supplier Gold Program is a similar framework currently used at UTC to evaluate suppliers and provide incentives for improved operations. This sort of consistent, structured relationship is an effort to promote trust between UTC and its suppliers.

2.4 Obsolescence Management

Obsolescence management is a set of activities intended to mitigate the risk of a disruption in production due to unavailable supplies. This issue is often referred to as diminishing manufacturing sources and material sources (DMSMS).[24] DMSMS of electronic components, such as integrated circuits and discrete passive components, is particularly challenging in the aerospace industry.

In the 1980s, the end of the Cold War led to an effort in the United States Military to reduce costs. Part of those efforts was called Acquisition Reform. Acquisition Reform ended the required use of military specifications (mil-specs) for military parts and allowed the use of commercial standards and specifications.[26] One of the consequences of this change was a mismatch in lifecycles between the new commercial parts and aircraft produced for the military. Because many commercial aircraft relied on mil-specs for parts, they were also subject to the lifecycle mismatch. This is particularly true for electronic components.

The consumer electronics industry differs from the aerospace industry in two important ways. First, the consumer and commercial electronics industry dominates the market for electric components, therefore the supply chains for these electronic components are con-
trolled by those industries. Second, the consumer and commercial electronics industries have a typical product lifecycle of around three years. The effect of these two points drives the product lifecycle of electronic components to be similar to that of consumer electronics. In contrast, the product lifecycle of an aircraft is often 20 to 40 years. In fact, the design of an aircraft may last more than ten years. In these cases, obsolescence issues could arise during the design phase. This leads to the challenge in the aerospace industry of mitigating the risk of several obsolescing components over the life of an aircraft.

There are several approaches to resolving an obsolete component risk. These strategies include stock usage, life-time buy, last-time buy, component replacement, aftermarket sources, emulation, re-engineering, salvage, and design refresh. These options and their timing after an obsolescence notification are shown in Figure 2-3. The regulatory environment in the aerospace industry and the production complexity of electronic components render aftermarket sources, emulation, salvage, and re-engineering largely infeasible. The last-time buy is a feasible strategy, but it is only a short-term solution intended to bridge the gap between the actual obsolescence and the implementation of a long-term solution. This leaves component replacement, life-time buy and design refresh as the primary long-term resolution options for obsolescence risk.

![Figure 2-3: Obsolescence Mitigation Strategies](image)

The first DMSMS mitigation technique is a component “drop-in” replacement. Drop-in replacements are identical, or nearly identical, in form, fit, and function to the obsolescing
component. This approach requires no abnormal expenditure with the possible exception of some minimal certification testing. As a result, this is the least expensive mitigation technique and the preferred option.

If there is no drop-in replacement available, a second DMSMS mitigation technique is a life-time buy. A life-time buy is a purchase of a component in quantities great enough to supply production for the life of the relevant aircraft. When a component producer notifies its customers that a component will no longer be produced, the life-time buy technique dictates a forecast of all future need of that component and purchase of enough components to fulfill that need. There are two important disadvantages of this technique. First, it relies on predictions about the aircraft lifecycle, which can last many years into the future and, therefore, are difficult to predict accurately. Second, the life-time buy leads to years of inventory of the supplied component, which must be held until the aircraft lifecycle is complete.

The final DMSMS mitigation technique is the design refresh. This approach calls for a change in the design of the end item such that the obsolescing component is removed from the bill of materials. A design refresh in the aerospace industry requires many of the same steps as a new product design, including the actual design work, supplier negotiation, design reviews, certification testing, and customer approval and integration testing. These steps, particularly the testing, represent a large initial cost for the design refresh technique.

In the case of a DMSMS component with no drop-in replacement, the obsolescence management effort is reduced to determining whether a life-time buy or a design refresh is the best option. External forces sometimes influence this decision. For instance, a customer may refuse to allow a design refresh, forcing a life-time buy. In those instances, there is no decision to be made. For this analysis, however, it is assumed that the only consideration for this decision is the cost of the options.

Rojo, Roy, and Shehab note that this area of research has emerged primarily in the past 20 years, coinciding with the timing of Acquisition Reform.[22] Furthermore, most of this research has focused on electronic components, reflecting the acuteness of the problem presented by the lifecycle mismatch between the electronic component industry and the aerospace industry. Industrial and academic research has focused on the cost of obsolescence
and the forecasting of obsolescence.[22] Singh, Sandborn, and Feldman, have investigated a method to predict an optimum design refresh plan, proposing that this approach can lower the cost of obsolescence.[26]

A life-time buy is typically perceived as a more cost-effective strategy than a design refresh. If decisions are made on a case-by-case basis, this is particularly true. The cost of a life-time buy is the sum of the purchase cost of the components and the holding costs of those components until they are used. The holding cost includes shrinkage, cost of capital, cost of labor, and costs of the storage facility. The net present value of these cost are usually in the tens of thousands of dollars. The design refresh cost is the sum of the design cost, the certification testing cost, and the cost of the new components that perform the function of the obsolescing components for the life of the product. The design and certification costs are typically on the order of $2M. The disadvantage of this case-by-case approach, however, is that it can lead to a "death by a thousand cuts" trap, whereby the sum of many low-cost resolutions is substantial.[24]

Instead of optimizing for each case, recent research indicates that a more holistic perspective on obsolescence costs can yield a more cost-effective approach. This shift requires moving from reactive obsolescence management to proactive management and, finally, to strategic management.[24] Reactive obsolescence management is limited to resolving obsolete parts only when parts are becoming obsolete immediately. Proactive management expands the approach to include systematic monitoring of obsolescence risk for a product. Strategic management broadens the approach even further to include forecasting obsolescence and planning for mitigation in advance of the actual obsolescence.

Porter presented the beginnings of a holistic approach to obsolescence mitigation with a focus on calculating the net present value of last-time buys and design refreshes as a function of a future date.[21] Discounting for the time when the costs of the mitigation approach are incurred and summing them provides an unbiased comparison of the complete lifecycle cost of both the life-time buy and the design refresh. Further research using this approach used Porter's model to optimize design refresh timing and content throughout a product lifecycle.[5] The limitation in this model is that it does not account for the coupled effects of multiple design refreshes. Instead, each design refresh is optimized individually.
Singh and Sandborn discuss an advancement along this line of research and a tool based upon it that has been developed for commercial use.[26]. This advancement, the Mitigation of Obsolescence Cost Analysis (MOCA) methodology and its corresponding software tool, uses a detailed cost analysis model for the obsolescence mitigation approaches and forecasts of component obsolescence for an entire product. An optimization algorithm is used to find the least costly mix of design refreshes and last-time buys throughout the product lifecycle, along with the timing and content of those buys and design refreshes.[26].
Chapter 3

The Tactical Change Model

The sources presented in the change management literature review each offer sufficient models for change. It is important to note that these models are primarily intended for sweeping enterprise-level changes. In fact, Nightingale and Srinivasan state, “The underlying assumption in the Enterprise Transformation Roadmap is that you are not simply tweaking your organization, but that you are setting out to do something fundamentally different: transform the enterprise.” [17] Organizations with different characteristics will need to adapt these change models for use in particular instances. In many cases, change efforts are more narrowly scoped and do not fit into the target audience of the existing change management literature. In response to this concern, I propose a new change model. This new model, the Tactical Change Model, is developed herein for localized changes.

The Tactical Change Model, outlined in Figure 3-1, is based upon the change management literature review in Chapter 3. Single lines indicate the flow of the project between phases, while the dashed lines indicate the concurrent nature of the reflection phase with all other phases. Several concepts are addressed in more than one of the literature models, which suggests consensus on the importance of those concepts. Other concepts are presented in only one model. These unique concepts may provide additional insight into a particular change situation. The bases of origin for each of the steps in the Tactical Change Model are outlined in Figure 3-2, where the steps of the Tactical Change Model are listed across the tops of each column. The remainder of this chapter describes the phases of the Tactical Change Model, while two cases used to demonstrate the use of the change model are presented in
3.1 Name a Goal

The first phase of the Tactical Change Model is “Name a Goal.” This phase is derived from first steps of the Kotter Method, the Enterprise Transformation Roadmap, and the Beckhard and Harris model. The first of Kanter’s skills also prescribes actively seeking needs and opportunities for change, thereby identifying a goal. The apparent consensus on naming a general goal motivates the inclusion of “Name a Goal” as the first phase in the Tactical Change Model.

The goal of a change should be a general idea, not a specific plan. In fact, no plans are made in this model until the fourth of six consecutive steps. The intent of this step is
to set a direction for the effort without creating unnecessary boundaries. When questioned about new product plans, a vice president at 3M noted, “We don’t constrain ourselves with plans at the beginning when ignorance is highest. Sure we plan … But that’s after we know something.”[20] The purpose of the goal is not to determine what needs to be done, but rather to motivate the rest of the change effort. Therefore, the goal should be engaging to the stakeholders. Kotter lists the failure to establish an adequate sense of urgency as the first error in unsuccessful change efforts.[14] For tactical cases, the goal need not necessarily be a Big Hairy Audacious Goal (BHAG) as described by Collins and Poras. However, just as a BHAG, the goal should be “clear and compelling, (serving) as a unifying focal point of effort, and (acting) as a clear catalyst for team spirit.”[8] The goal should be simple, clear, free of assumptions, and addressed directly at an issue to be resolved.

### 3.2 Investigate the Current State

Current state investigation is a typical step in most change models. Beckhard and Harris emphasize that it is “crucial … to develop an accurate and comprehensive picture of the
This picture can then be compared to the desired future state to determine what needs to be changed and what should not be changed. Along with the Beckhard and Harris model, the Enterprise Transformation Roadmap includes a current state investigation early in the change effort. A thorough understanding of the current state will inform the future state vision and the changes needed to achieve it. Despite the importance of this step on the content of the change, solutions are not to be formulated in this step. A complete, objective understanding of the organization and its environment should be developed. A solution developed too early can become a psychological anchor, giving undue influence to information gathered early.

Two common approaches for examining the current state are process maps and stakeholder analyses. The process map includes information about what is done by whom and in what order, giving a strategic view of the organization. It is a graphical representation of the activities that take place within the process and the interactions between those activities. Nightingale and Srinivasan warn that process maps must be constructed at an appropriate level of abstraction.[17] Fully connected maps with every activity are too complex to identify opportunities, but the process map must include enough information to appreciate the important nuances of the process.

The stakeholder analysis provides information about the people involved in the process, giving a more political view of the organization. A stakeholder analysis typically includes identification and prioritization of the stakeholders, an examination of the relationships between stakeholders, and a study on the value delivered to and from each stakeholder. The value exchanged between the organization and the stakeholders can be either quantitative or qualitative, with some measure used to compare the value exchange across stakeholders.[17] This measurement can be in the form of a rating system or a comparative chart.

3.3 Develop and “Sell” a Future State

The concept of a future state is present in every change model discussed in the change management literature review. In some models, the communication of the future state is explicitly included. The Kotter Method lists “Create a Vision” and “Communicate the Vision”
as consecutive steps. The Beckhard and Harris model and the Enterprise Transformation Roadmap include the motivations of employees as a consideration in the future state vision. This represents an accounting for the audience. Kanter’s third skill implies that the future state vision is developed while it is being communicated to employees. This allows for the incorporation of feedback into an evolving vision to support adoption of the change.

The development and “selling” of a future state are combined here to recognize the importance of their simultaneity. The marketing of the future state should be viewed as a two-way communication. While ideas for the future state are being generated and refined, they should be shaped by feedback from the stakeholders. The goal developed in the first step of the Tactical Change Model begins to transform into a more defined vision during this step based on perceived shortcomings in the current state. Kotter suggests a powerful guiding coalition be utilized to ensure that the future state is driven to completion. The guiding coalition will also help to refine the future state vision by providing information and ideas.

The word “sell” is used intentionally to evoke the idea of a marketing effort. The culture of the organization should be leveraged to build support for the change. The change should be framed as consistent with the attitudes and beliefs of the stakeholders about the organization. The benefits of the change for each stakeholder, according to the stakeholder analysis, should be emphasized, while feedback should be incorporated to improve the change and build support. This is the most critical step in getting commitment to sustain the momentum of the change.

3.4 Plan to Get From Here to There

The ACE Transformation Roadmap, not to be confused with Nightingale and Srinivasan’s Enterprise Transformation Roadmap, is a task planning effort. It involves budgeting, tracking, and reviewing the actions necessary to accomplish the desired change. The Beckhard and Harris model includes a step to assess the present in terms of the future, essentially an evaluation of what it takes to get from the current state to the future state. The Enterprise Transformation Roadmap includes a phase explicitly devoted to planning transformation
tasks. The Kotter Method includes a step aimed at short-term wins. These models imply that while the practical considerations of planning for the change are important, the organizational considerations, such as momentum, are also important.

Beckhard and Harris point out that between the current state and the future state, there is always a transition state.[2] The goal of the transition state is to deliver the organization to the future state efficiently. To accomplish this, projects must be planned, ordered, and managed thoughtfully. This step is focused on identifying and ordering the work to be completed. Beckhard and Harris describe several technologies to introduce a change, including across-the-board intervention, pilot projects, experiments, confrontation meetings, educational interventions, and temporary management structures.[2] For the tactical changes studied here, pilot projects will be used.

While planning the transition, highly visible projects with short durations are valuable. These “quick wins” serve to build credibility for the entire change, increasing the commitment of the stakeholders and mitigating the risk of the change effort appearing transient. Quick wins get the momentum of an organization moving, and they should be planned into the execution of the transition. In fact, Kotter lists the failure to systematically plan for and create short-term wins as a leading reason why change efforts fail.[14]

### 3.5 Enact the Plan

There are several considerations during the transition. Nightingale and Srinivasan point out communication, education, project tracking, monitoring progress to the final state, nurturing the change amongst the stakeholders, disseminating lessons learned, revising the execution schedule, and watching for opportunities for further change efforts.[17] Kanter emphasizes persistence and perseverance to overcome organizational resistance in his sixth skill. All of these items remain relevant in a tactical change setting.

Communication during the change should be sufficient in quality, quantity, and delivery method to ensure that the stakeholders accept the desired message, rather than a potentially negative message from an external source. Rumors from uninformed or biased sources should be guarded against.
Project tracking and final state progress monitoring are listed here separately to emphasize the need to keep both perspectives. In tactical change settings, there may be only one project. It remains beneficial, however, to track progress on both the project and the change. The difference is subtle. For example, if a new software tool is to be built and implemented to change an existing process, the technical development of the tool as well as the organizational adoption of the change are important.

Kanter notes the importance of a leader for the change execution, stating “Someone has to steer change, guiding it, monitoring the actions it entails. It is not good enough to say that change is everyone’s responsibility; then it becomes no one’s responsibility.”[13] Limiting the responsibility for the change to one person creates accountability, increasing the likelihood of success, but it also builds credibility for the change. There are some conditions for this credibility, however. Beckhard and Harris describe a successful transition manager as one who has clout to mobilize resources, respect of the existing leadership, and effective interpersonal skills.[2]

Finally, the transition should be viewed as a set of activities that build to the final state. Collins describes this as the flywheel effect.[8] As more projects or actions are completed within a change effort, momentum is added until a breakthrough is achieved and the desired final state is reached. Collins compares this to a large flywheel, which takes many pushes to reach a final desired rotational speed. Early pushes are difficult and progress is slow, but after momentum is built, subsequent pushes take less effort.

3.6 Spread the Knowledge

Disseminating innovations throughout an organization is one of the basic tenets of the lean approach. The intent is to mitigate the risk of multiple “discoveries” of the same innovation, or worse, the lack of adoption of an innovation in an area where it could provide some advantage. Knowledge first has to be captured before it can be spread.

Since the focus of the change models in the change management literature review is on enterprise-level change, there is little focus on spreading knowledge. The nature and scope of these changes imply that any learning is applied to the entire enterprise as a part of
the change. In contrast, learnings from localized change efforts are not implicitly applied throughout the organization. Intentional action must be taken to spread knowledge. The Enterprise Transformation Roadmap is an exception in the change management literature, in that organizational learning is one of its seven principles.

In describing the Enterprise Transformation Roadmap, Nightingale and Srinivasan provide one example of an effective mechanism to capture knowledge: the After Action Report (AAR) used by the United States Army.[17] These reports are based on four questions:

- What did we set out to do?
- What actually happened?
- Why did that happen?
- What are we going to do next time?

After knowledge has been distilled from experience using a mechanism like the AAR, it should be spread through appropriate means. These may mean demonstrations, conferences, seminars, or expansion of scope of a department in which the knowledge resides.

3.7 Reflect

The final step in the Tactical Change Model actually spans the duration of the previous steps. The AAR discussed above is an example of a reflection exercise. They are performed to intentionally investigate any deviation between the expected and actual outcomes. In a change management setting, these types of exercises should take place throughout the change effort. Knowledge should be collected as early in the change process as possible. The idea is similar to quality checks on a factory floor. Quality checks are much more cost-effective if they are interspersed throughout the production process. Defects are found early rather than at the end of the process. This way, effort and expense is not wasted on a product that is defective. Similarly, reflection throughout the change process allows for the effort to be corrected or revised if there is a deviation from the goal.
4.1 Headwind

The Operations Group is charged with improving efficiency and reducing the costs of the operations of the company. With the acquisition of Goodrich so recent, that task is largely accomplished by facilitating synergies between the two organizations, though its scope does include non-synergy savings. One area of opportunity for increased efficiency is the forecasting of cost escalation in the supply base, known internally as headwind.

4.1.1 Name a Goal

As with any other company that purchases from suppliers, UTC Aerospace Systems faces increasing costs within its supply base each year. The company tracks changes in the price of each purchased component from a standard price set at the beginning of each year. These standard prices are determined in different ways for each of the different business units, but are always based on the historical price for the component during the previous year. Any deviation from this standard price, or an increase in the standard from the previous year, is called purchase price variance (PPV). Positive PPV, representing an increase in price, is referred to as headwind. Negative PPV, representing a decrease in price, is referred to as tailwind. Effectively, headwind is the increase in price from the previous year for each purchased component.
UTC Aerospace would like to have the ability to quickly, easily, and credibly forecast the headwind they will face within the next five years. This foresight will allow planning and deployment of resources for proactive mitigation of cost increases. The goal in this case is to develop the ability to forecast headwind for the organization.

A secondary goal is to develop this forecast method in such a way as to allow employees negotiating with suppliers to have a forecast of the headwind specific to that company. With this information, a negotiator could go into a negotiation prepared with some estimate of the effect of headwind and incorporate that estimate into the negotiation strategy.

4.1.2 Investigate the Current State

UTC Aerospace Systems currently uses a bottom-up approach to forecasting headwind. Each of the business units predicts what their headwind will be for the next few years, and those forecasts are aggregated into an overall estimate for headwind. Most focus is given to the forecast for the following year. Because these forecasts are made at the business unit level, they are able to account for considerations unique to business unit and supplier. However, the distributed nature of the forecast effort has some disadvantages. First, some business units may be tempted to manipulate their headwind forecasts to affect their apparent performance against annual cost targets. Second, the variability in the approaches of the business units leaves the process vulnerable to inconsistent evaluations of uncertainty and economic influences. Third, these forecasts require employees to look at each supplier and estimate their future pricing. This is tedious, and new processes of reporting headwind have caused confusion and long delays due to rework.

Because of the disadvantages discussed above, these forecasts are seen within the organization as only directionally accurate. They are used as a reference on how headwind is generally changing. The specific forecasted values of headwind are less credible. They are not used during contract negotiations with suppliers, and they are not considered reliable beyond one year. As one finance director explained, “We need a process we can trust.”

Negotiations with suppliers tend to be performed within each of the business units according to their own practices. In some instances, the finance team within the business unit provides an expected headwind associated with a new contract. Because they are as-
sembled on a case-by-case basis, these forecasts can be tailored to the specific commodity and supplier, accounting for the relationship with the supplier, past contracts, and economic conditions. These custom-made negotiation tools can be quite accurate, but require time and effort to create and may not be available for every negotiation.

4.1.3 Develop and “Sell” a Future State

A top-down headwind forecast model addresses the gaps between the current state and the future state. The Operations group could use such a model without requiring employees at the business units to spend tedious hours creating their more granular forecasts. Simultaneously, any uncertainty arising from variability in the forecast method is also eliminated. Employees whose business unit is judged based on deviations from cost estimates are not involved in generating the forecast. Instead, a tool can be used to instantaneously turn unbiased data into a forecast using this model.

Additionally, this tool could provide headwind forecasts for an individual negotiation. This functionality would provide an alternative to custom-made negotiation tools. These forecasts could be built on the same regressions as the general headwind forecasts discussed above.

The first step to building this headwind forecast model was to investigate how headwind is reported. UTC Aerospace Systems separates its suppliers and their headwind into commodity classes. Those classes are:

- castings, forgings, and raw materials,
- composites and plastics,
- distributed products,
- electronics,
- engineered items,
- machining,
- mechanical fabrications, and
A top-down model would take in as inputs general economic indicators and provide a headwind forecast for each of the commodity types. General economic indicators with readily accessible historical values and commonly forecasted future values will aid in the creation and maintenance of the tool. These characteristics were “sold” through pitches to the primary stakeholder, the senior manager who would use the tool to forecast headwind for UTC Aerospace Systems.

4.1.4 Plan to Get From Here to There

To transition from the current state, in which all forecasts are done at the business unit level in varying ways, to the future state, in which a top-down forecast is available, a tool was necessary. This tool would compute headwind based on economic factors. The first step was to collect any available historical headwind data. Following this, appropriate economic indicators were collected. Next, multiple regressions were run to find meaningful relationships between the past headwind and economic indicators. The final step was to put these regression equations into a user-friendly tool to facilitate their use and maintenance.

After the creation of the tool, a pilot test was planned to build its credibility. A recent negotiation would be used to compare the headwind predicted by the tool to headwind actually observed in the negotiation. If successful, the results of this pilot test could be used in a continuing effort to “sell” the tool to the wider organization, particularly those responsible for negotiating with suppliers.

4.1.5 Enact the Plan

The first step in the plan to get to the future state was to collect historical headwind data. The quality and perception of this data is important for establishing the credibility of the tool. However, the upheaval surrounding the recent formation of UTC Aerospace Systems made historical data difficult to attain. Any remaining historical data was reported to be held within the business units. Despite this perception, a single employee in the Operations
Finance department had retained historical headwind data for the legacy Hamilton Sundstrand businesses. This represented half of UTC Aerospace Systems. In addition to these four previous years of data, current year headwind is tracked by the Operations department. Some effort was made to clean the data and maintain consistency despite variation in the reported data from each year as explained in Appendix A. After this collection effort, annual headwind for each commodity class for the past five years was available.

The second step was to collect relevant economic indicators and perform regressions against the five-year history of headwind for each commodity class. These economic indicators would need to be forecasted to facilitate the headwind forecasts. Future users of the tool would be no better off with a headwind forecasting tool if they had to forecast an obscure independent variable to use it. As a result, widely used economic indicators, primarily from the Bureau of Labor Statistics, were used. In addition to publicly available forecasts, UTC Aerospace Systems generates its own forecasts for these common economic indicators. After an initial pool of indictors was determined, hundreds of first-order single and multi-variate regressions were performed. The final equations used and the analysis used to determine them are exhibited in Appendix A.

For a tool that is not mandatory, ease of use is important. The tool developed to forecast headwind was designed with ease of use as a primary goal. Creating forecasts and updating the tool to include the most recent data are the two most frequent interactions users are expected to have with it. An Excel workbook was used as the basis of the tool to promote widespread distribution without the need for special software. Calculations and data are all on separate worksheets from the output worksheets within the workbook. Color codes are used to denote different types of cells, and a user guide was included in the workbook itself. Screen shots from the Excel workbook and an explanation of its operation are included in Appendix A.

After the tool was built, pilot tests were performed to verify its utility. Details of these tests can be found in Appendix A. The tool demonstrated highly accurate forecasts for two negotiation headwind forecasts, with less than 1% error. Reasonably accurate forecasts were made for general, organization-wide headwind, with approximately 20% error. These pilot tests were shared with the senior manager who was a primary stakeholder for this project.
as well as a few other stakeholders who would likely be using the forecasting tool.

4.1.6 Spread the Knowledge

The general headwind forecast provided by the tool is designed to be used by a single user and his employees, reducing or eliminating the need for multiple forecasts provided throughout the company. The negotiation headwind forecast, however, is designed for widespread dissemination. This tool is intended to provide a faster way to predict headwind related to a particular negotiation. The tool was designed in an Excel workbook, with no complicated user requirements, and a built-in user guide to promote ease of use. This ease of use and free availability are intended to facilitate widespread use of the tool. Actual dissemination of this tool is intended as a follow-up effort to this project.

4.1.7 Reflection

During the “Enact the Plan” stage of this case, a member of one of the business units revealed that his business unit had an analyst who worked to estimate the headwind of an upcoming negotiation. This was one of the objectives of the headwind forecasting tool developed in this case. In effect, the functionality was already there, and in a more rigorous form. This analyst worked with suppliers specific to one business unit, and was able to become familiar with them and their contracts. For this business unit, the negotiation intelligence that the headwind forecasting tool would provide may be unnecessary. Reflection after this revelation, which occurred late in the case, led to decreased emphasis on the part of the headwind tool intended for negotiations. Instead, more effort was directed toward the general headwind forecast function and, ultimately, the sustainability of the tool. The new focus on sustainability was significant, as the sustainability of the tool became its primary strength. The redirection of effort on this case is an example of one of the benefits of reflection.
4.2 Obsolescence Management

4.2.1 Name a Goal

During a meeting in the summer of 2013, an outside consulting company presented its findings about the UTC Aerospace Systems supply chain to members of the Operations group. Among the most important of these findings was that raw material inventory represented an outsized proportion of the total inventory. In one Puerto Rican facility, raw material constituted a majority of the inventory at the site. According to the tenets of lean, inventory represents waste, as the funds tied up by idle inventory and expensed in holding that inventory could be profitably used elsewhere. The goal in this case is to reduce waste by lowering the amount of inventory.

4.2.2 Investigate the Current State

A separate analysis of the inventory at the Puerto Rican site revealed that a large portion of this inventory is the result of large, one-time purchases known as last-time buys. According to one report 44% of the raw material inventory was the result these purchases. This data supported the suspicions that originally led to this case. Last-time buys were causing outsized inventory levels. To achieve the goal of reducing inventory waste, the first place to look was at the process that creates last-time buys.

Last-time buys are purchases of supplied components that are made just before those components go out of production. The last-time buy is made to ensure that UTC Aerospace Systems will have the components needed to build and service a product for its entire lifecycle. That lifecycle is often what drives the need for a last-time buy in the first place. Peter Sandborn describes the phenomenon as the dark side of Moore’s Law: inadequate planning causes companies to spend progressively more to deal with aging systems and their obsolescence in the face of the rapidly evolving state of the art.

Consider the new F-35 Lightning II aircraft recently added to the United States’ military asset portfolio. Conceived in the mid-1990s, the initial designs are potentially over a decade old already. The lifecycle of this aircraft is targeted at 50 years, with servicing required
for the life of the aircraft. Other military aircraft have been used for up to 90 years. These lifecycles are much longer than many of the components designed into these aircraft. Similar circumstances arise for commercial aircraft and in other industries with long life-cycle products. This presents a problem for aircraft manufacturers, particularly with electronic components.

As with all U.S. military aircraft, the F-35 aircraft will have many electronic components that are available as commercial off-the-shelf (COTS) products. As discussed in the literature review, this is the result of Acquisition Reform, and it leads to a lifecycle mismatch between aircraft and aircraft components. There are several solutions to this issue, known as diminishing manufacturing sources and material sources (DMSMS). These solutions include “drop-in” replacements, life-time buys, and design refreshes as outlined in the literature review.

The Obsolescence Management Department (OMD) at UTC Aerospace Systems is responsible for providing recommendations about obsolescencing components. These recommendations are generated by evaluating the feasibility and costs of the three options listed above. The OMD has developed a process to provide these recommendations and mitigate the risk of obsolescence.

The current process calls for the OMD to gather intelligence on obsolescencing components through product change notifications issued by manufacturers. These notifications typically warn of an imminent obsolescence and allow customers like UTC Aerospace Systems to submit their final purchase orders. The lead time between the notices and the actual shutdown of the component production line ranges from weeks to months. At this point, the OMD denotes the issue on the component record in the UTC Aerospace Systems enterprise resource planning system. This informs all employees working with this component that it is becoming obsolete. The next step for the OMD is to determine the products affected by the component obsolescence. A report generated in the enterprise resource planning system provides this information. Next, an engineer in the Component Engineering organization is petitioned to assess alternatives that may be used as drop-in replacements. A representative from the Design Engineering organization, which is responsible for the final product, reviews these alternatives for feasibility. At this point, the customers for each of the affected...
products are surveyed for their input on the drop-in replacement or design refresh options. Regulations and testing obligations may incur substantial costs for customers if changes are made to existing flight hardware designs. For this reason, customers may object to design refreshes or drop-in replacements. If the customers object, the last-time buy is the only option left and the recommendation is clear. If the customers allow drop-in replacements or design refreshes, UTC Aerospace Systems is left with a choice. Program managers for each of the products are surveyed to determine the quantities of this component needed in the future. This survey includes not only currently planned production, but also aftermarket needs and future contract production needs. Using these forecasts, component prices, drop-in replacement costs, and redesign effort costs, the OMD constructs a trade analysis between the three options: drop-in replacement, design refresh, and life-time buy. Because drop-in replacements incur much lower costs than the other options, it is usually clearly the better choice. However, if no suitable drop-in replacement is found, the OMD must weigh between the last-time buy and the design refresh. This decision is the focus of this case.

The decision about whether to perform a last-time buy or a design refresh is based on three pieces of information. The first is the program managers’ estimate of the cost of a design refresh. This estimate is typically based on labor and material cost estimates from the engineers most closely associated with the design effort, but is also subject to the program managers’ judgment. The second piece of information is the program managers’ forecasts of demand for the component. These forecasts include deterministic information from contractual agreements, but also include stochastic variability arising from unknown future scrap rates, aftermarket demand, servicing obligations, and sales related to possible program extensions. This variability is not trivial. The third piece of information is the cost of the component in both cases. For the life-time buy, the cost of the obsolescing component is not necessarily the same as it was for the component before the decision to stop its production. The costs for all of these parts as well as the costs associated with their storage in inventory are summed. Similarly, a design refresh eliminates the need for the obsolescing component, but the recurring cost of the new component introduced to perform the function of the obsolescing component must be considered. Furthermore, design refreshes can take several years to complete. A bridge buy, or a last-time buy that is not intended to
cover the entire lifecycle of the product, must be performed. As with the standard life-time buy, the inventory holding costs for these components must be considered.

This obsolescence management process has some positive features. While the OMD is composed of employees dedicated to obsolescence management, the wider team includes engineers, procurement agents, and program managers who are closely involved in the process. This mix allows for diverse, educated perspectives and information from a wide variety of sources. One important result of this cross-functional collaboration is evidenced by the history of the obsolescence mitigations. Of nearly 7,000 obsolescence events since 2005, approximately 3% have been resolved by a life-time buy, with the large majority of the remaining events mitigated through the use of existing stock or “drop-in” replacements.

The specialized knowledge and experience within the OMD is another positive feature. The OMD is composed of one manager and four engineers. The manager has been responsible for obsolescence mitigation since 2005, in what began as a temporary assignment. Two of the engineers joined soon after, and many of the wider team members have been associated with the effort since it began. This depth of experience is a valuable asset for UTC Aerospace Systems. It allows insight into trends, supplier practices, and vendor reputation. The OMD manager described the early days of obsolescence management as being in “fire-fighting mode.” Since then, a mature process has been established and the OMD is able to react to obsolescence issues with greater structure and proficiency.

The centralization of this process for several units within UTC Aerospace Systems provides another advantage. The consolidation of demand for multiple programs allows UTC Aerospace Systems to act uniformly across the company in response to a single obsolescence notification, increases its market power, and ensures that no program is surprised by an obsolescence notification.

Finally, the manager of the OMD has authority to independently make last-time buys up to a dollar limit. Beyond that, a higher level manager must approve the purchase. The exception to this is that the OMD can initiate a bridge buy purchase to support any demand that exists in the materials resource planning system. Effectively, any component that will be certainly needed within the next three to four years can be purchased by the OMD without outside approval. The independence afforded the OMD to make these last-time buys allows
important timing flexibility while long term solutions are researched.

4.2.3 Develop and "Sell" a Future State

The goal of this case is to reduce inventory. Of the options used to mitigate obsolescence, it is clear that the life-time buy is the largest source of inventory. This inventory will sit idle for years as it is used, tying up capital and incurring inventory expenses. A more holistic view of the costs of these life-time buys and the benefits of design refreshes will ensure that inventory is only increased as the result of a life-time buy if it is the best overall decision for UTC Aerospace Systems.

Despite the positive aspects of the current obsolescence process, there are some opportunities for refinement that relate to the goal of reducing inventory levels. The first is the evaluation of the life-time buy and design refresh options. When evaluating the cost of a life-time buy, some important costs are not fully considered. Costs of inventory, shrinkage, and costs of capital tied up in inventory are induced by a life-time buy. Minimization of these costs make the life-time buy a more attractive option than it really is. Perhaps more important than the understatement of the life-time buy costs, the benefits of the design refresh are often understated. The current process calls for the OMD to check all affected products for other obsolescing components when a design refresh is being considered. This is an appropriate step, as it allows the mitigation of multiple obsolescing components with one design refresh. However, this step could be taken further to realize a larger benefit of the design refresh. The cost of a design refresh is only slightly related to the number of parts resolved. If UTC Aerospace Systems resolved more obsolete parts or soon-to-be obsolete parts with a design refresh, the design refresh becomes a more attractive option. In fact, UTC Aerospace Systems already has a tool to perform these obsolescence forecasts. The Total Parts Plus software is a source of the product change notifications indicating that a component is becoming obsolete, but it also provides forecasts of when components will become obsolete up to six years in the future. These forecasts, called product health assessments, analyze the bill of materials for a given product and report the supplier name, part number, forecasted obsolescence date, as well as alternative components in some cases. Currently, these product health assessments are generated on an ad hoc basis and when directed by the
program managers to report to the customer. The forecasts are not currently used as the basis of any decision.

The second opportunity for improvement relates to the incentives inherent in the obsolescence management process. The mission of the OMD is to support production by keeping components available. This is clearly an appropriate goal, but without a balancing focus on managing cost, the riskier decision to perform a design refresh is discounted even further. A life-time buy, which provides the security of years worth of components in possession, has the apparent advantage of certainty over a design refresh, which introduces risk associated with schedule and qualification testing. Furthermore, while the OMD evaluates the costs of the obsolescence mitigation options, it is the program managers who must approve the decision. Unless the program is funded by the customer, the costs are not extracted from the program. Instead, the Operations group, which includes the OMD, bears the cost of obsolescence mitigation. Therefore, the very program managers who are responsible for the final decision have no immediate incentive to consider costs, only to consider which decision poses the least risk to the continued delivery of the product. This leads to conservative estimates of future component need and design refresh costs. This conservatism is compounded when multiple programs and multiple program managers are involved. Some instances have involved 40 program managers who were surveyed for a single obsolescence event. There is no mechanism to pool risk, so conservatism is stacked on conservatism, leading to an inflated cost of the life-time buy. In one current obsolescence case, the OMD is having difficulty getting a design refresh approved for an estimated cost of $13.2M. The alternative is a $31.5M life-time buy. This example illustrates the current organizational disinclination to perform design refreshes.

In addition to the hidden cost of conservatism discussed above, a second set of incentives increase the cost of a life-time buy if pursued. Some suppliers require a minimum quantity of purchased components, and almost all suppliers give cost breaks per unit for higher quantities purchased. Given the organizational emphasis put on headwind demonstrated in other sections of this thesis, there is a strong incentive for UTC Aerospace Systems employees to pursue these price breaks. These two factors lead to excess inventory. This inventory in excess of demand will sit idle in a warehouse for years. One employee responsible for inventory
management related a case in which 5,000 units were needed for seven years of production, but 6,000 units were purchased and shipped to the warehouse.

During a discussion about the way his department operates the manager of the OMD said, "We look at it as our own money." This is a principled perspective and one that UTC Aerospace Systems should encourage among its employees. However, this perspective is difficult to maintain if incentives are aligned such that saving money for the company is not in the best interest of the employee. As discussed, this is the case for the program managers. A more effective arrangement may be to charge program managers with responsibility for obsolescence costs and reward them for effectively managing these costs.

This sort of incentive realignment is difficult, because program managers are typically held accountable to the budget that was used to construct the proposal. In the aerospace industry, the standard business model of the original equipment manufacturers (OEMs) is such that a product is most profitable in the aftermarket and repair market. Typically, an OEM like UTC Aerospace Systems proposes a product that meets the customer’s requirements at the lowest possible cost. Profits on the sale of the product to the customer are usually small. When a final consumer, such as an airline, needs to repair or replace this product, military or FAA restrictions make it difficult to use anything other than the original qualified product. While not a perfect monopoly, this gives OEMs considerable leverage to extract profit from the final consumer. Every OEM, therefore, makes its most competitive proposal to “get on” an aircraft to be able to exploit this aftermarket later. This dynamic makes it difficult to add costs for obsolescence management into a proposal.

One countermeasure to the program manager’s lack of incentive to control obsolescence management costs is a separate budget established along with the proposal to account for obsolescence management costs. This budget would have to anticipate the cost of obsolescence management throughout the lifecycle of the product. This is not a trivial matter and any forecast is bound to be inaccurate, but even an inaccurate forecast is an improvement over a non-existent forecast. Currently, the cost of obsolescence is funded through overhead. Creating an obsolescence management budget, even if that budget is not included in a proposal, allows for the explicit attribution and control of those costs.

Furthermore, current trends in the proposal process may force OEMs like UTC Aerospace
Systems to explicitly capture an estimate of the cost of obsolescence in their proposals. Performance-based logistics (PBL) contracts are becoming more popular. Contracts such as these are commonly referred to as "power by the hour" contracts in the aircraft engine industry, where they have been more widely used in the past. The customer in a PBL purchase agrees to pay a set price for performance outcomes of a product.[6] The PBL focuses on the functionality of a product rather than the product itself. For example, if the customer needs a thrust for its aircraft, a PBL contract may call for some number of hours of acceptable operation rather than for a jet engine. This shift to PBL could force OEMs to explicitly consider obsolescence management, servicing, and repair during their initial proposals. UTC Aerospace Systems could prepare for that shift by implementing processes that forecast and control those costs. Such a process would require a holistic view of the life-cycle of a product. UTC Aerospace Systems would need to model the obsolescence of each component in a proposed product and optimize the last-time buys and design refreshes necessary to mitigate those obsolescence events.

A final point in the future state relates to incentives. In describing the value of recognition, William Manchester describes his experiences in World War II saying, "A man wouldn't sell his life to you, but he will give it to you for a piece of colored ribbon."[20] Peters and Waterman note the extensive use of non-monetary rewards in companies considered excellent and speculate that it is one property that gives those companies an advantage over their competitors.[20] It does not appear that recognition is a large part of the culture at UTC Aerospace Systems. Recognition is not used as an incentive in this case. However, some form of recognition may be a mitigation of the misaligned incentives of the OMD stakeholders. Additionally, more extrinsic incentives may drive better results from the OMD process. Both program managers and the OMD could be made responsible for all costs related to an obsolescence mitigation, with financial rewards tied to cost savings. To drive realistic estimates of design refresh costs from program managers and engineers, savings could be shared with them. This would become similar to a bid system. In this scheme, a known life-time buy cost is compared to design refresh estimates from engineers and program managers. If the design refresh is bid and performed for less than the cost of the life-time buy, a set portion of those savings is awarded to the involved engineers and program managers.
4.2.4 Plan to Get From Here to There

To achieve the desired final state, UTC Aerospace Systems would need to model the obsolescence of each component in a proposed product and optimize the last-time buys and design refreshes necessary to mitigate obsolescence events. Fortunately, the company has access to a tool that provides such an optimization of obsolescence strategy. The primary project of the change effort was developed to move from the current state to the end state. An Excel-based tool would be developed to evaluate the value of the two relevant DMSMS mitigation options, life-time buy and design refresh. This tool would then be demonstrated to the project supervisor and the end users, the OMD. A secondary project was to examine the structure of the OMD process for improvement opportunities, particularly with regard to incentives. This examination was intended to lead to a set of suggestions to align incentives throughout the process.

4.2.5 Enact the Plan

During the execution of the plan, a tool offered by the Center for Advanced Life Cycle Engineering (CALCE) at the University of Maryland was discovered. UTC is a member of the CALCE consortium. Work at CALCE led to the development of the Mitigation of Obsolescence Cost Analysis tool (MOCA). MOCA is a software-based tool that takes as inputs a bill of materials and related data and provides as outputs a relative cost estimate for different combinations of design refreshes and last-time buys. The output can thus be used to set the obsolescence management strategy for a given product during its proposal phase. Forecasts of component obsolescence is available from the Total Parts Plus tool to which UTC Aerospace Systems currently has access. Furthermore, the MOCA tool is available at no charge to UTC Aerospace Systems as a member of the CALCE consortium. Finally, the MOCA tool was a product of years of development and refinement. MOCA provides the same function as the tool proposed for this case. Furthermore, MOCA is a superior tool for UTC Aerospace Systems than what could be developed within the scope of this study. Therefore, the decision was made to revise the plan for this case.

Instead of developing a new tool, the plan was changed to study the implementation of
the MOCA tool. The in-house tool would be repurposed into a vehicle to test the proof of concept. An obsolescence expert at CALCE was invited to audit the OMD processes and make recommendations. These two efforts were intended to prepare the organization to incorporate the MOCA tool into the OMD process.

The proof of concept test was successful. Details on the mechanics of the in-house tool can be found in Appendix B. Using conservative estimates, approximately $10M could be saved during one DMSMS mitigation decision for the pilot project system. The pilot project system was an actual system being offered by UTC Aerospace System. Authentic bills of materials, part costs, obsolescence forecasts, holding costs, costs of capital, design costs, and testing costs were used. Additionally, the audit by the CALCE expert was persuasive in support of the methodology of the MOCA tool, as well as some other potential improvements.

The revision to the plan created some complication, however. New stakeholders, including the CALCE personnel and the contracting agent at UTC Aerospace Systems, were brought into the case. These new stakeholders were not analyzed carefully, leading to some loss in momentum of the change. This will be discussed in further detail in Section 5.2.7.

### 4.2.6 Spread the Knowledge

As discussed, the OMD has the responsibility to mitigate obsolescence for only a part of UTC Aerospace Systems. The responsibility for other parts of UTC Aerospace Systems is charged to employees with other primary functions, such as materials managers. Senior managers intend to increase the scope of the OMD to cover all of UTC Aerospace Systems. This will serve to spread the knowledge and innovation discovered within this case to the entire organization. As such, no active steps were taken to spread the knowledge outside of the OMD and its stakeholders. Instead, efforts were focused on improving the capabilities of the OMD to build support for its scope increase.

### 4.2.7 Reflection

During the course of this case, status updates for stakeholders were used as occasions to reflect. When the relationship between UTC Aerospace Systems and the CALCE consortium
was discovered, the goal of the effort was changed drastically. Instead of developing a finalized tool to perform obsolescence management decision support, a proof of concept test and introduction of the MOCA tool became important. The decision to change the course of the project came through a reflection exercise. The deviation between the future state and the current state changed with this new information, so reflection and revision of the plan was appropriate.

In some instances reflection comes too late to have an impact on the current project. In those cases, the reflection leads to a lesson learned for future efforts. Such an instance arose in this case. UTC Aerospace has a license to use the MOCA tool, but setup and training services are required from the CALCE consortium to ensure that the tool is used properly and implemented in a timely manner. These services required a contract between UTC Aerospace Systems and the CALCE consortium. However, the urgency or importance of this contract was not sufficiently impressed upon the appropriate stakeholders, so the contract was delayed for weeks. Furthermore, the contract that was sent out was lengthy and detailed, requiring the CALCE consortium weeks to review. The result of all of this delay was that the period for the case study ended without the MOCA tool being implemented. In fact, the contract was still under review at the end of the case study. This delay threatens the momentum of the effort. A review and evaluation of the new stakeholders may have improved the results.
Chapter 5

Analysis

5.1 Three Lens Analysis Methodology

The Three Lens Analysis described in the organizational analysis literature review is used below to assess the success of the change efforts in the cases presented. This analysis framework provides a way to review the cases in a holistic way. The Strategic Design Lens focuses on mechanics of the organization with respect to the cases. The Political Lens focuses on the interests and power within the cases. The Cultural Lens focuses on the meanings of actions and symbols present in the cases.

5.2 Three Lens Analysis of Headwind Case

5.2.1 Strategic Design Lens Perspective on Headwind Case

In the initial state, the central operations group was dependent on the business units to provide headwind forecasts. This linkage between the two groups suffered from a lack of alignment. The business units got no benefit from the exercise, but were required to spend a significant amount of time to perform it. Furthermore, the business units may have had incentive to influence the headwind forecasts to meet their own interests. A business unit is penalized if it has higher in-year headwind than forecasted. The new ability to predict headwind without input from the business units reduces the importance of the linkage formed.
between the business units and the central operations group. This mitigates the alignment issues. Additionally, the negotiation-specific functionality of the headwind tool allows the organization as designed to meet its demands. A simple, quick point of reference for negotiation allows a more efficient and effective resolution.

The Tactical Change Model used in this case led to the successful identification and resolution of the issues described above. During the investigation of the current state, the misalignment between the business units and the central operations group was identified and its effects understood. The “Develop and Sell a Future State” phase often took the form of pitches to the Operations group manager. The manager would be the final user for the headwind forecasting tool, and his input during these pitches led to multiple refinements.

5.2.2 Political Lens Perspective on Headwind Case

As with the Strategic Lens, the Political Lens reveals that the Tactical Change Model was beneficial in this case. Because the central operations group is responsible for reporting headwind forecasts and has the authority to determine how these forecasts are made, this group was the primary political power in this case. The business units did not have a significant interest in retaining their obligations, nor did they have much political recourse to do so. These circumstances were revealed during a stakeholder analysis as part of the current state investigation. The result of this revelation was that the primary stakeholder for this case became the central operations group.

5.2.3 Cultural Lens Perspective on Headwind Case

Through the Cultural Lens, an important characteristic in this case is that the culture is still evolving from the recent acquisition of Goodrich and integration into UTC Aerospace Systems. Employees from both organizations have their own beliefs, and attitudes based on their history with either Goodrich or Hamilton Sundstrand. The current state investigation revealed a manifestation of this culture in the fact that each business unit had its own process for forecasting headwind. New processes that can unify the company behind standard work and reduce the variability of those processes are valuable at UTC Aerospace Systems. A
top-down headwind tool provides just such a process, but new processes must be trusted. The culture of the central operations group emphasizes frequent, regular presentations in standard formats to report status to senior managers. Any new tool to inform those reports must be credible. To address this, pilot tests were performed and demonstrated during the “Enact the Plan” and “Spread the Knowledge” phases. These pilot tests not only proved that the tool was effective, but it proved that the tool was effective to the primary stakeholders. This was an important way to gain commitment from these stakeholders. The results built credibility for and interest in the tool.

5.3 Three Lens Analysis of Obsolescence Management Case

5.3.1 Strategic Design Lens Perspective on Obsolescence Management Case

The preliminary goal for the obsolescence management case was to reduce the cost of inventory due to obsolescence mitigation. Investigation of the current state demonstrated that life-time buys had contributed significantly to inventory levels. The current state analysis also showed that the DSMS mitigation process at UTC Aerospace Systems was well-constructed. The OMD is a group dedicated to the issue, and it was linked to various relevant departments through specifically assigned employees in those departments.

One secondary issue that current state analysis revealed was a misalignment of incentives. Interviews during the current state investigation revealed that the goal of the OMD may not align with UTC Aerospace Systems goal for the department. The stated OMD goal was to ensure that production would not be interrupted due to obsolescence. The incentives of the OMD were constructed to support this goal. However, UTC Aerospace Systems would benefit from a more holistic perspective on cost. Life-time buys will achieve the goal of ensuring no production interruptions, but design refreshes in some instances may achieve this goal at lower long-term cost. Currently, the OMD is not directly responsible for long-term costs, and the lower short-term costs of a life-time buy are easier to get approved. The
introduction of a tool to consider long-term costs will help mitigate the bias towards lifetime buys, but an examination of the incentive structure for the OMD would also help drive the most cost-effective behavior. Similarly, program manager incentives are problematic. Program managers provide input into the DSMS process, but also have a clear incentive for the process to favor life-time buys as discussed in Section 4.2.3. This issue was identified during the stakeholder analysis performed as part of the current state investigation. As a result, suggestions for how to mitigate this incentive misalignment were made to senior management.

The Tactical Change Model was useful in identifying and resolving these issues, but the strategic design lens reveals at least one short-coming of the Tactical Change Model. The model is linear, with no feedback loops. When important new stakeholders were introduced in the “Enact the Plan” phase, no new current state investigation was initiated. This led to lack of appreciation of the incentives of the new stakeholders, both within UTC Aerospace Systems and CALCE. The result was a delay in the implementation of the planned change.

5.3.2 Political Lens Perspective on Obsolescence Management Case

During the course of this research, the OMD demonstrated their willingness to change in the pursuit of cost effectiveness. In addition to accommodating the MOCA pilot test, the OMD manager also actively investigated the use of third-party vendors for inventory management. He served as the advocate within UTC Aerospace Systems for a third-party vendor to increase awareness and instigate discussion about the feasibility of such an engagement. This effort was outside of his responsibilities, but he recognized the potential value to the company of this option. That episode illustrates the culture of the OMD, in which employees are willing to look at new ideas to lower costs. The statement from the OMD manager, “I try to treat it like my own money,” regarding use of company funds indicates the stance of the OMD.

There are two apparent reasons that the OMD would be motivated to lower costs. First is a sense of duty to the company. This will be discussed further in the Cultural Lens section. Second is an eagerness to prove their value in advance of a possible increase in their scope of responsibility. Currently, the OMD is responsible for only a portion of UTC Aerospace Systems, but discussions are underway to increase their purview to include all of
UTC Aerospace Systems. Decreased costs would improve the value of the OMD and promote the expansion of its scope.

5.3.3 Cultural Lens Perspective on Obsolescence Management Case

As discussed above, the OMD is supportive of change in pursuit of improved cost-effectiveness. Aside from the possible political reasons for this explored above, another reason why the OMD is supportive of change could be the culture. The culture of the OMD is one of integrity. The employees will try to make their operations more efficient because they feel a duty to do the best that they can.

This element of the OMD culture played an important role in the obsolescence management case. The OMD employees were willing to facilitate the investigation of the MOCA tool to increase the cost effectiveness of their department, despite the fact that implementation of this tool could require more work from them. The “sell” of the future state is much easier if the employees affected are motivated to achieve the goal. In this case, the employees were motivated to reduce costs and increase the value of their department. When the MOCA tool became a candidate to achieve that goal, it met with some skepticism but little resistance.

One way to take advantage of the OMD culture would have been to use an internal change agent. Nightingale and Srinivasan note that every transformation needs a critical mass of change agents, and internal change agents act to embed the change into the “organizational DNA.”[17] Late in the project, a member of the OMD was assigned as an internal agent. This person helped to build credibility in the project and improve its efficacy, but these benefits would have been even more effective had he been brought into that role earlier.
Chapter 6

Conclusions and Revised Tactical Change Model

These cases indicate that existing change models are useful for making efficient and effective change, however these models may require some customization for the circumstance at hand. This is particularly true when used outside of the scope of the broad organizational transformations for which they are intended. The Tactical Change Model is an effort to distill a set of those existing models into a form more suited to changes of smaller scope. The major findings of that effort are described here.

The utility of this thesis in an industrial environment depends on its ease of use. To address this need, I present a revised Tactical Change Model here for use by those who would seek to initiate a tactical change in an organization. The findings of this thesis are incorporated into the revised Tactical Change Model as shown in Figure 6-1.

There are three fundamental changes incorporated within the revised Tactical Change Model. First, the goal of the change has been converted from the output of the first phase into an input to the model, but the current state investigation should include some effort to ensure that the goal is understood. The Tactical Change Model and many of the change management literature models listed “Name a Goal” as the first phase. In the cases described here, however, the goals were given. The change efforts were the result of directives, which is likely the case for most tactical changes. Even without an obvious directive, tactical change efforts do not require the level of cognitive investment that broader transformational efforts...
require. For example, an employee who is responsible for a production line need not consider goals of making the entire organization more cost-efficient. The scope of his responsibility is narrower and will usually involve more obvious tactical goals related to that production line. Therefore, minimal effort is needed to define those goals. Instead, more effort should be directed toward the other phases to attain those goals.

Another shortcoming of the Tactical Change Model is the fallacy of the uni-directional change model. This motivates the second fundamental change to the Tactical Change Model. The discovery of the MOCA tool and the corresponding change in stakeholders in the obsolescence management case demonstrated this point. The change model should not be viewed as a set of independent phases. New information which changes the premise or assumptions of the project should trigger a consideration of revisiting a previous phase. To reflect this, I have revised the Tactical Change Model to include feedback loops indicating this possibility. The primary order of the phases is indicated by double solid lines, while the feedback loops are indicated by single solid lines. As before, the reflection phase is indicated as concurrent with all other phases using dashed lines.

The final fundamental revision to the Tactical Change Model is the incorporation of the Three Lens Analysis into the model. The analysis in the previous chapter demonstrated the importance of considering the multidimensional nature of an organization during a change. Strategy, culture, and politics all influence the efficacy of a change effort.

One particularly appropriate area for the incorporation of a Three Lens Analysis is the current state analysis phase. A thorough current state analysis sets the foundation for the entire change effort. This is demonstrated in the Three Lens Analysis performed in Chapter 6. In both cases, the current state analysis was crucial in all three lenses. No other phase of the change model has as much of an impact on the change as the current state investigation. The structure of the current state analysis is an area for improvement. In addition to the stakeholder analysis, a three lens analysis to understand the strategic, political, and cultural environment would be beneficial in any change effort.

My studies of the cases described here demonstrate the importance of incorporating persistent reflection into the change process. The models in the change literature typically do not emphasize reflection, but the obsolescence management case illustrates that reflection
Figure 6-1: Revised Tactical Change Model

provides a valuable opportunity to react to new information and adjust the change effort. This reflection would have been more effective, however, with improved structure. Increased frequency, a consistent framework, and increased stakeholder participation are opportunities for improvement. For these cases, I performed reflection approximately monthly with a small set of stakeholders. These limitations on reflection may have allowed useful information to
be either missed, because the relevant stakeholder was not included in the reflection, or delayed, because the reflection was held too infrequently. The inconsistency of the reflection framework also may have caused a gap in knowledge.

As discussed above, a three lens approach, explicitly considering each lens, is one way to provide a framework to reflection. As I performed a Three Lens Analysis on these cases after their conclusion, it became clear that this technique would be useful during the reflection phase as well as the current state analysis. This will promote a holistic view of the change throughout the effort, serve as a consistent framework, and encourage participation from all appropriate stakeholders.

As with the current state analysis and reflection, each of the other phases of the Tactical Change Model would benefit from the inclusion of a Three Lens Analysis approach. The previous chapter demonstrated that a focus on the cultural lens was lacking. Despite gathering some intelligence about the cultural environment at UTC Aerospace Systems, I found that inadequate focus was given in the case studies to leveraging this cultural knowledge to affect the desired change. It is often much more straightforward to use strategic and even political intelligence to develop the change plan. However, as Kotter notes, the failure to anchor changes in the organizational culture is an error that could undermine the entire change effort.[14]. As discussed in Section 3.3, the development and “selling” of the future state is similar to a marketing campaign. As such, a holistic approach, considering each of the three lenses, makes sense. The knowledge gained during the current state analysis and the development of the future state should then be used to explicitly address each of the three lenses during the transition planning phase. Expanding the idea further, this three lens perspective should be used during all phases of the model. As a result, the Three Lens Analysis is incorporated into each phase in the revised Tactical Change Model.

In addition to the three fundamental changes discussed, I found that three techniques proved especially useful during these cases. These do not represent changes to the Tactical Change Model, but rather important tools to consider within the framework of the Tactical Change Model.

More documentation, during each phase, would have mitigated the risk of lost or missed intelligence. The form of that documentation is dependent upon the specific circumstance,
but After Action Reports, Gantt charts, and stakeholder maps are examples of the varied types of documentation that are beneficial for a change effort.

The expert audit of the OMD process proved to be a success. Following the audit, my conversations with members of the OMD signified that they were skeptical but ultimately open to the premise of the MOCA tool, which implies a modification to their evaluation of obsolescence mitigation options. Their skepticism was due not only to the suggestion of a change from standard processes, but also the expert’s future role and benefit from the potential change. His organization, CALCE, would be hired to implement the MOCA tool, casting a perception of bias. However, this skepticism did not appear to override the value of the change in the minds of the OMD. The audit was a result of the stakeholder analysis performed earlier in the change effort. In future tactical change situations, outside expert input on a process in question is a viable tactic. The delivery of this input should be carefully managed to avoid offense or skepticism amongst the relevant stakeholders.

Another particularly successful tactic was the pilot test. I used pilot tests in both cases, and in both cases they achieved multiple goals. The primary purpose was to test the models for their ability to perform their tasks, predicting headwind and evaluating obsolescence mitigation options. However, the successful pilot tests also corresponded to a noticeable increase in stakeholder interest and enthusiasm about the projects. This increased enthusiasm was important because it was amongst the stakeholders most responsible for the implementation of the tools. The pilot tests were low-risk activities, as they had no impact on the current operations at UTC Aerospace Systems and they took little time to complete. They had an outsized reward, however, as the demonstration of their results built credibility for the project and served as a visible sign of progress.

The Tactical Change Model proved to be a useful framework during these two change cases. The revisions and tools discussed above will improve its utility. The incorporation of the Three Lens Analysis ensures that a comprehensive perspective of the organization is considered throughout the process. With these improvements, the Tactical Change Model represents a useful reformulation of existing change models into a tool appropriate for localized changes.
Appendix A

Headwind Forecasting

Headwind arises in three circumstances. First, headwind arises from expiring supplier contracts. The new contracts are typically expected to include price increases. Second, headwind arises from "spot buys." Spot buys are purchases made ad hoc without a long-term contract to specify price. Third, headwind is built into a long-term contract. Often, these contracts call for price increases according to a specified equation which is dependent on economic indicators. Contractual headwind represents a large portion of the total headwind at UTC Aerospace Systems. There is no system currently in place, however, to track the headwind specified by each of the hundreds of contracts held with suppliers. Each business unit uses their own technique to arrive at a future headwind estimate. These estimates are reported together to the senior management at UTC Aerospace Systems annually. These estimates are time-consuming, slow, vulnerable to biases, and generally viewed as directional only.

UTC Aerospace Systems desired the ability to forecast escalation in the cost of their supply base, or headwind, in a quicker, simpler, more controllable way. To that end, the aim of this case was to devise a way to forecast headwind based on commonly used economic indicators.

Past headwind data from 2009 to 2012 was collected to support regression analysis. The data gathered initially was purchase price variance. The effects of efforts to reduce headwind such as sourcing from low-cost locations is included in the purchase price variance data. In order to more accurately reflect only headwind, the effect of low-cost sourcing was estimated by UTC Aerospace Systems employees and added to the collected data. In addition, partial
headwind data for 2013 was also collected. After filtering data that appeared to be outliers at the suggestion of UTC Aerospace Systems management, a representative data set of headwind was formed. This headwind data was split into values for different commodity classes used by UTC Aerospace Systems. Those commodity classes are:

- castings, forgings, and raw materials,
- composites and plastics,
- distributed products,
- electronics,
- engineered items,
- machining,
- mechanical fabrications,
- and other.

Thirty-three economic indicators were investigated as independent variables. The indicators and their sources are shown in Figure A-1. These indicators were chosen for ease of access to their historical values and forecasts of their future values. Using indicators with these characteristics supported the construction of a quick, simple, top-down forecast method.

After collecting the past headwind data and the data for the candidate economic indicators, a battery of regressions was performed to identify useful relationships. All relationships were assumed to be first-order. Due to the limited years of data for headwind, a maximum of three independent variables could be used. Relationships that appeared nonsensical due to the direction of the relationship were disregarded. The general equation used for the regression equations is presented in Equation A.1 where $Y$ is the headwind for a given commodity class, $x$ is the value for an economic indicator, and $A$, $B$, and $C$ are the coefficients for the corresponding economic indicators. The final relationships and their statistical diagnostics
<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>n/a</td>
</tr>
<tr>
<td>US GDP</td>
<td>BEA^1</td>
</tr>
<tr>
<td>Aluminum price index</td>
<td>UTC^2</td>
</tr>
<tr>
<td>World gross product</td>
<td>OECD^3</td>
</tr>
<tr>
<td>Copper price index</td>
<td>UTC</td>
</tr>
<tr>
<td>Magnesium price index</td>
<td>UTC</td>
</tr>
<tr>
<td>Molybdenum Oxide price index</td>
<td>UTC</td>
</tr>
<tr>
<td>LME Nickel price index</td>
<td>UTC</td>
</tr>
<tr>
<td>Platinum price</td>
<td>UTC</td>
</tr>
<tr>
<td>17-4 Stainless steel price</td>
<td>UTC</td>
</tr>
<tr>
<td>304 Stainless steel price</td>
<td>UTC</td>
</tr>
<tr>
<td>Titanium 6-4 bar price</td>
<td>UTC</td>
</tr>
<tr>
<td>Titanium 6-4 scrap price</td>
<td>UTC</td>
</tr>
<tr>
<td>Tungsten price</td>
<td>UTC</td>
</tr>
<tr>
<td>Zinc price</td>
<td>UTC</td>
</tr>
<tr>
<td>US dollar/Euro conversion rate</td>
<td>Federal Reserve</td>
</tr>
<tr>
<td>S&amp;P 500 index</td>
<td>Yahoo Finance</td>
</tr>
<tr>
<td>US inflation rate</td>
<td>OECD</td>
</tr>
<tr>
<td>OECD total member country inflation</td>
<td>OECD</td>
</tr>
<tr>
<td>Labor pricing index</td>
<td>BLS^4</td>
</tr>
<tr>
<td>Major sector productivity and costs index</td>
<td>BLS</td>
</tr>
<tr>
<td>Total Producer Prices - Manufacturing costs index</td>
<td>BLS</td>
</tr>
<tr>
<td>UTC Aerospace revenue</td>
<td>UTC 10-K</td>
</tr>
<tr>
<td>UTC Aerospace operating profit</td>
<td>UTC 10-K</td>
</tr>
<tr>
<td>UTC Aerospace operating costs</td>
<td>UTC 10-K</td>
</tr>
<tr>
<td>Global airline revenue</td>
<td>IATA^5</td>
</tr>
<tr>
<td>Global airline net profit</td>
<td>IATA</td>
</tr>
<tr>
<td>Imports value</td>
<td>US Census Bureau</td>
</tr>
<tr>
<td>Exports value</td>
<td>US Census Bureau</td>
</tr>
<tr>
<td>US trade gap</td>
<td>US Census Bureau</td>
</tr>
<tr>
<td>Crude materials index</td>
<td>BLS</td>
</tr>
<tr>
<td>Intermediate materials, suppliers, and components index</td>
<td>BLS</td>
</tr>
<tr>
<td>Industrial commodities less fuels index</td>
<td>BLS</td>
</tr>
<tr>
<td>Metal and metal products index</td>
<td>BLS</td>
</tr>
<tr>
<td>Time-lagged drivers^6</td>
<td>BLS</td>
</tr>
<tr>
<td>Transformed drivers^7</td>
<td>BLS</td>
</tr>
</tbody>
</table>

^1 US Bureau of Economic Analysis  
^2 UTC internal report  
^3 Organisation for Economic Co-operation and Development  
^4 US Bureau of Labor Statistics  
^5 International Air Transport Association  
^6 Existing indicators were offset one year behind headwind  
^7 Existing indicators were transformed into a log scale

Figure A-1: Economic indicators investigated as headwind drivers
are presented in Figure A-2. Note that no best regression found included more than two economic indicators.

\[ Y = C + Ax_1 + Bx_2 + Cx_3 \]  

(A.1)

Several circumstances of this regression analysis detract from the utility of the final relationships found. First, the headwind data set is quite limited with five years of data available, yielding five data points for each commodity classes. In some cases, outlier data points reduced this data set even further. Second, the headwind data is from the legacy Hamilton Sundstrand business, which differs considerably in size and supply base composition from the headwind of UTC Aerospace Systems. Third, as shown by the diagnostics in Figure A-2, the models are less reliable than one may desire.

The models were put into a forecasting tool to facilitate their ease of use within UTC Aerospace Systems. This tool was built in an Excel environment to support its accessibility. It was designed to forecast in two modes. First, general headwind for each commodity class across all of UTC Aerospace Systems can be calculated based only on future forecasts of spending as shown in Figure A-3. Second, the headwind expected in a particular negotiation can be calculated based on the commodity class, the original price when the last contract went into effect, the current price, and the duration of the previous contract as shown in Figure A-4. If the negotiation is for a spot buy, the only input required is the current price of the product. The interface for the tool was kept simple, with the models, independent variables, and calculations all housed on separate sheets from the forecasting sheets. A detailed instruction sheet was also included to explain how the tool can be used, updated with new data, and modified with new models.

Despite the drawbacks discussed above, pilot tests of the forecasting tool were positive. Three pilot tests were performed using two negotiations and one general headwind forecast. The two negotiation tests were based on actual negotiations that had recently concluded, providing a basis for evaluation of the accuracies of the forecasts. The general headwind forecast was compared to the headwind forecast provided by the existing bottom-up process. This comparison is shown in Figure A-5 below. Similarly, the results of the two negotiation
<table>
<thead>
<tr>
<th>Commodity Class Y</th>
<th>Constant C</th>
<th>Coefficient 1 ( x_1 )</th>
<th>Economic Indicator 1 A</th>
<th>Coefficient 2 ( x_2 )</th>
<th>Economic Indicator 2 B</th>
<th>Coefficient 3 ( x_3 )</th>
<th>Economic Indicator 3 C</th>
<th>( R^2 )</th>
<th>Adjusted ( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castings, Forgings, Raw Materials</td>
<td>-15542629.00</td>
<td>84707.28</td>
<td>Metal and Metal Products</td>
<td>0</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
<td>0.9056</td>
<td>0.8113</td>
</tr>
<tr>
<td>Composites/Plastics</td>
<td>-11305862</td>
<td>7767030.6</td>
<td>USD($)/Euro(€) Conversion Rate</td>
<td>1260.2333</td>
<td>S&amp;P 500</td>
<td>0</td>
<td>N/A</td>
<td>0.9287</td>
<td>0.786</td>
</tr>
<tr>
<td>Distributed Products</td>
<td>-64661211</td>
<td>4664.602</td>
<td>US GDP</td>
<td>-3060771</td>
<td>Major Sector Productivity</td>
<td>0</td>
<td>N/A</td>
<td>0.7308</td>
<td>0.1923</td>
</tr>
<tr>
<td>Electronics</td>
<td>-5160240</td>
<td>6387.6612</td>
<td>S&amp;P 500</td>
<td>-1344155</td>
<td>Major Sector Productivity</td>
<td>0</td>
<td>N/A</td>
<td>0.9466</td>
<td>0.8399</td>
</tr>
<tr>
<td>Engineered Items</td>
<td>-22375696</td>
<td>1613.1678</td>
<td>US GDP</td>
<td>-25246.64</td>
<td>BLS Labor Pricing</td>
<td>0</td>
<td>N/A</td>
<td>0.9746</td>
<td>0.9237</td>
</tr>
<tr>
<td>Machining</td>
<td>20801442.00</td>
<td>161514372</td>
<td>US Inflation</td>
<td>-8.341013</td>
<td>Imports</td>
<td>0</td>
<td>N/A</td>
<td>0.9916</td>
<td>0.9749</td>
</tr>
<tr>
<td>Mechanical Fabrications</td>
<td>-11305862</td>
<td>7767030.6</td>
<td>USD($)/Euro(€) Conversion Rate</td>
<td>1260.2333</td>
<td>S&amp;P 500</td>
<td>0</td>
<td>N/A</td>
<td>0.9287</td>
<td>0.786</td>
</tr>
</tbody>
</table>

Figure A.2: Values and diagnostics for headwind equations.
Figure A-3: Screenshot of General Headwind Forecast Tool Interface
pilot tests are shown in Figure A-6.

While the results of these pilot tests indicate that the tool is currently useful, the key to its utility is its sustainability. The simple forecasting interface requires a few simple steps to produce a forecast. This ease of use should encourage adoption of the tool. Furthermore, the tool was built to have improving accuracy with little work on the part of the user. Every year, new historical headwind data can be incorporated and the regressions performed to get more accurate relationships. These regressions can be input into the forecast tool without inputting new equations. Only the new coefficients and any new independent variable names are required. Since the headwind data that the current models were built on are flawed as discussed above, every year of new, better-suited headwind data will improve the accuracy of the tool. In this way, the tool satisfies the original goal of the case. Instead of providing a set of models that work for one year and then become obsolete, this effort has produced a sustainable tool that evolves to provide increasingly accurate forecasts every year.
<table>
<thead>
<tr>
<th>General Headwind</th>
<th>Bottom-up Headwind Forecast</th>
<th>Top-down Headwind Forecast</th>
<th>Delta</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castings, Forgings, Raw Materials</td>
<td>$5,104,100</td>
<td>$2,804,285</td>
<td>$(2,299,815)</td>
<td>45%</td>
</tr>
<tr>
<td>Composites and Plastics</td>
<td>$14,941,500</td>
<td>$13,350,540</td>
<td>$(1,590,960)</td>
<td>11%</td>
</tr>
<tr>
<td>Distributed Products</td>
<td>$2,960,500</td>
<td>$910,720</td>
<td>$(2,049,780)</td>
<td>69%</td>
</tr>
<tr>
<td>Electronics</td>
<td>$816,200</td>
<td>$604,027</td>
<td>$(212,173)</td>
<td>26%</td>
</tr>
<tr>
<td>Engineered Items</td>
<td>$6,014,900</td>
<td>$5,309,486</td>
<td>$(705,414)</td>
<td>12%</td>
</tr>
<tr>
<td>Machining</td>
<td>$5,730,200</td>
<td>$6,788,893</td>
<td>1,058,693</td>
<td>-18%</td>
</tr>
<tr>
<td>Mechanical Fabrications</td>
<td>$255,400</td>
<td>$437,018</td>
<td>$181,618</td>
<td>-71%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$35,822,800</strong></td>
<td><strong>$30,204,970</strong></td>
<td><strong>$(5,617,831)</strong></td>
<td><strong>16%</strong></td>
</tr>
</tbody>
</table>
### Figure A-6: Results of negotiation headwind forecast

<table>
<thead>
<tr>
<th>Supplier 1 (Composites)</th>
<th>Supplier 2 (Electrical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Price</td>
<td>Expected Price</td>
</tr>
<tr>
<td>$2,83</td>
<td>$5,38</td>
</tr>
<tr>
<td>$2,84</td>
<td>$5,39</td>
</tr>
<tr>
<td>$1,86</td>
<td>$1,87</td>
</tr>
<tr>
<td>$1,87</td>
<td>$1,89</td>
</tr>
<tr>
<td>$1,37</td>
<td>$1,37</td>
</tr>
<tr>
<td>$1,37</td>
<td>$1,37</td>
</tr>
<tr>
<td>$4,00</td>
<td>$4,01</td>
</tr>
<tr>
<td>$7,497,872</td>
<td>$7,456,308</td>
</tr>
</tbody>
</table>

% Error
- 0.3%
- 0.01%
- 0.01%
- 0.4%
- 0.2%
- 0.01%
- 0.01%
- 0.01%
- 0.6%
Appendix B

Obsolescence Management

As discussed in Section 2.4, there are two options for obsolescence management of interest in this case: the life-time buy and the design refresh. The factors governing the cost a life-time buy are shown in Equation B.1:

\[ C = \sum_{a=1}^{m} p_a + \sum_{a=1}^{m} NPV h_a \]  

(B.1)

where \( C \) is the cost of mitigating obsolescence using a life-time buy discounted to present day, \( m \) is the number of components resolved, \( p \) is the price of each component, and \( NPV h \) is the net present value of all costs associated with holding a component in inventory until it is used in production. The factors governing the cost of a design refresh are shown in Equation B.2:

\[ C = \sum_{b=1}^{q} d_b + \sum_{b=1}^{q} t_b + \sum_{b=1}^{m} NPV n_b \]  

(B.2)

where \( C \) is the cost of mitigating obsolescence using a design refresh discounted to the present day, \( q \) is the number of products with obsolescing components resolved, \( d \) is the cost of the design effort for each product, \( t \) is the testing cost for each product, \( m \) is the number of components used to replace the functionality of obsolescing components, and \( NPV n \) is the net present value of all future purchases of those new components.

If the scope of the mitigation is limited to a few components that are obsolescing at a given time, the life-time buy is nearly always a less costly approach. However, if the scope...
of the obsolescence mitigation is larger, with many components resolved, the cost of the life-
time buy increases nearly linearly. The cost of the design refresh is nearly flat with respect
to the number of components resolved. This is because for every component resolved, the
life-time buy strategy requires that the component be purchased immediately and held for
the lifecycle of the product. Both portions of the cost in Equation B.1 are affected. In
contrast, the design refresh strategy only requires that the functionality of each component
resolved is accounted for in the bill of materials after the redesign. The bill of materials
can be purchased as needed for production instead of at the time of the mitigation. The
design and certification test costs are minimally dependent on the number of components
resolved. Therefore, the attractiveness of the design refresh option, as measured by lifecycle
cost relative to that of the life-time buy option, increases with the number of components
resolved. This effect is illustrated in Figure B-1.

At any given time, there are a set number of components in a product that are obsolescing.
As discussed above, the attractiveness of the design refresh option, and the cost-effectiveness
of obsolescence mitigation, increases with the number of components addressed by the miti-
gation. To increase the number of components addressed beyond those obsolescing at a given
time, obsolescence for all components can be forecasted. For example, instead of only ad-
dressing the components that are obsolete immediately, one may also address all components
that are expected to become obsolete over the next three years.

Given the obsolescence forecasts for an entire bill of materials for a given product or
system and the factors in Equations B.1 and B.2, one could determine optimal times for
design refreshes and life-time buys to mitigate component obsolescence for the entire lifecycle
of that product or system. This analysis could be performed to determine an optimal mix of
design refreshes and life-time buys over the lifecycle of a product or system. As discussed in
Section 4.2.5, the Center for Advanced Life Cycle Engineering (CALCE) at the University of
Maryland has developed a tool called Mitigation of Obsolescence Cost Analysis (MOCA) to
perform such analysis. This analysis is based on forecasts of obsolescence for the components
on that bill of materials. Those forecasts are available through standard industry products
such as Total Parts Plus and PartMiner. UTC Aerospace Systems has a license for MOCA,
and is in contract negotiations for CALCE personnel to test and implement MOCA at UTC
Aerospace Systems.

In advance of the implementation of MOCA, an analysis was performed to test whether a obsolescence mitigation strategy using design refreshes could be more attractive than an exclusively life-time buy strategy for an actual UTC Aerospace system. A preliminary Excel-based tool was built to support this analysis. This preliminary tool takes as inputs the product identification numbers for a system, the yearly demand for that system, the bill of materials for each product, the redesign cost for each product, the cost and life expectancy for each component, holding costs, and cost of capital. The output is a series of net present values for a set of obsolescence mitigation strategies that range from exclusively life-time buys to exclusively design refreshes. The tool is has two main features, an optimization algorithm and a simulation model.

The testing algorithm is designed to input varying decisions into the simulation model. In this instance, the algorithm was designed to be simple to support the early pilot test. The algorithm simply assumes for the first simulation that all obsolescence risks are mitigated by design refreshes. With each ensuing simulation, the components of one additional product are resolved by life-time buys. The algorithm proceeds in this way until the last simulation, in which all products are resolved by last-time buys. Figure B-2 demonstrates this algorithm.

For each simulation, a net present value of the obsolescence mitigations strategy is calculated. These net present values can then be compared to identify the most cost-effective strategy of those simulated. It should be noted that this algorithm does not test all combinations of life-time buys and design refreshes. Only a small fraction of the total number of possible combinations is simulated. As such, the algorithm cannot be relied upon to find an optimal obsolescence mitigation strategy. Rather, the tool may be used to indicate that design refreshes can lower the cost of obsolescence mitigation for a system from an exclusively life-time buy strategy.

The simulation model calculates the net present value of the obsolescence mitigation strategy set by the testing algorithm. For each life-time buy, the components of Equation B.1 are summed. For any design refresh, the components of Equation B.2 are summed. For a product assigned by the algorithm to design refresh, any component within three years of forecasted obsolescence are considered an obsolescence risk to be resolved. This serves to
increase the cost-effectiveness of the design refresh. A schematic of the model operation is shown in Figure B-3.

The pilot test was performed on a new system at UTC Aerospace Systems. The system included twelve products, with bills of materials ranging from one component to 195 components. Because this system is early in its lifecycle, no obsolescence is forecasted for the next five years. To enable a meaningful analysis, the analysis was set three years into the future, so that a set of components would be within the three-year window for obsolescence risk. After finding the cost for all the obsolescence mitigation strategies considered through the testing algorithm, a strategy of design refresh for seven of the products was found to provide a $10.5M saving over an exclusively life-time buy strategy.

As discussed, the tool designed to support this analysis will not provide a demonstrably optimal obsolescence mitigation strategy, nor is it designed for the ease of use necessary for deployment at UTC Aerospace Systems. The MOCA tool is intended to fulfill those requirements. However, this preliminary tool was designed to find if there are opportunities to use design refreshes to lower the cost of obsolescence mitigation throughout the lifecycle of one system. The savings forecasted indicate that design refreshes, with their scope expanded to include forecasted obsolescence, can provide a cost savings.
Figure B-1: Costs of obsolescence mitigation options versus number of parts resolved (notional only)
<table>
<thead>
<tr>
<th>Product</th>
<th>Simulation 1</th>
<th>Simulation 2</th>
<th>Simulation 3</th>
<th>Simulation 4</th>
<th>Simulation 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>B</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>C</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>D</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>E</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>F</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>G</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>H</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>I</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>J</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>K</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>L</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>Simulation 6</th>
<th>Simulation 7</th>
<th>Simulation 8</th>
<th>Simulation 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>B</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>C</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>D</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
</tr>
<tr>
<td>E</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>F</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>G</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>H</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>I</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>J</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>K</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>L</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>Simulation 10</th>
<th>Simulation 11</th>
<th>Simulation 12</th>
<th>Simulation 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>B</td>
<td>Design Refresh</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>C</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>D</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>E</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>F</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>G</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>H</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>I</td>
<td>Life-time Buy</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>J</td>
<td>Life-time Buy</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
<tr>
<td>K</td>
<td>Life-time Buy</td>
<td>Design Refresh</td>
<td>Life-time Buy</td>
<td>Life-time Buy</td>
</tr>
</tbody>
</table>

Figure B-2: Algorithm used to trade off design refreshes and life-time buys
Figure B-3: Schematic of the model used to evaluate obsolescence mitigation strategies
Bibliography


102