Disciplined Agility for Process Control & Automation

By

Augustine Tibazarwa

Master of Science – Computer Science (2002)
Boston University

SUBMITTED TO THE SYSTEM DESIGN AND MANAGEMENT PROGRAM IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN ENGINEERING AND MANAGEMENT
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Signature of Author
Augustine Tibazarwa
System Design and Management Program
June 1, 2009

Certified by
Dr. Ricardo Valerdi
Thesis Supervisor
Lean Advancement Initiative
Engineering Systems Division

Certified by
Patrick Hale
Director
System Design & Management Program
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ABSTRACT

Process automation vendors must consider agility as a basis to gain a competitive edge in innovation. Process Automation systems can impact the operating cost of manufacturing equipment, the safe control of large quantities of energy and the safety of dangerous substances used during manufacturing. The manufacturing segment expects greater automation of larger processes, increased capability of process automation systems, and higher quality of those systems. At the same time, business requirements for process automation vendors demand shorter time to market, and greater market return for each dollar invested in product development. Therefore, process automation vendors must determine how to preserve discipline in development processes while adopting process agility necessary to meet dynamic business conditions.

Interviews with 9 leaders from 6 companies (2 manufacturers, 2 process automation vendors and 2 automation consulting firms), survey feedback from development personnel and research of literature on state-of-the-art and state-of-the-practice, yielded over 90 findings and observations on process automation business needs, development of automation offerings, and on suitability of agile practices to process automation product development.

Agile methods may require changes to manufacturer work processes, but would enable an automation vendor to unlock more of the manufacturer’s production value. Disciplined adoption of agile methods is crucial for agility to take hold throughout an automation vendor’s organization, and to meet the concerns of process automation stakeholders. Rather than dismiss the suitability of agile development to process automation, a prescriptive guidance is provided that integrates an opportunistic risk-based assessment of how much agility is appropriate. The four values and twelve principles of the Agile Manifesto are a good basis for 8 additional agile practices for process automation: transitioning to agile, investing in agile capability, managing critical system parameters, engineering system-robustness, balancing project risk, continuous system validation, assuring domain expertise and clarifying ecosystem role.

Thesis Supervisor: Dr. Ricardo Valerdi
Title: Lecturer, Engineering Systems Division
Table Of Contents

ABSTRACT ............................................................................................................................................................................. 2

1. INTRODUCTION ................................................................................................................................................................... 7
   1.1 MOTIVATION ............................................................................................................................................................................ 7
   1.2 THESIS STATEMENT & PRIMARY RESEARCH OBJECTIVES: ..................................................................................................10
   1.3 RESEARCH METHODS & APPROACHES .................................................................................................................................11
      1.3.1 Interviewing Industry Leaders, Experts and practitioners .................................................................................................12
      1.3.2 Literature Reviews ..................................................................................................................................................................13
   1.4 SUMMARY OF KEY RESULTS ..................................................................................................................................................14

2. PROCESS AUTOMATION INDUSTRY ........................................................................................................................................15
   2.1 PROCESS AUTOMATION CUSTOMERS ..................................................................................................................................16
      2.1.1 Top threats ...............................................................................................................................................................................16
      2.1.2 Domain Expertise ..................................................................................................................................................................17
      2.1.3 Perceived Competence ..............................................................................................................................................................17
      2.1.4 Customers' needs and requirements .....................................................................................................................................18
      2.1.5 Customers' unmet needs ..........................................................................................................................................................18
      2.1.6 Competitive Criteria .................................................................................................................................................................19
   2.2 PROCESS AUTOMATION VENDORS .......................................................................................................................................20

3. INNOVATION PRACTICES .........................................................................................................................................................23
   3.1 KEY DEFINITIONS ......................................................................................................................................................................23
   3.2 VALUE PROPOSITION ..................................................................................................................................................................25
      3.2.1 Value-Chain ..............................................................................................................................................................................30
      3.2.2 Value Capture: The Business Model ......................................................................................................................................30
      3.2.3 Return-On-Investment ............................................................................................................................................................31
      3.2.4 Value-Chain Properties ..........................................................................................................................................................32
   3.3 INNOVATION PROCESSES .........................................................................................................................................................34
      3.3.1 Essential Engineering Entities Model (E3M) ...............................................................................................................................36
   3.4 CASE STUDY: DEVELOPMENT PRACTICES AT EAGLE CORP ................................................................................................38
      4.1 BACKGROUND ............................................................................................................................................................................38
      4.2 PROCESS PRACTICES ...............................................................................................................................................................38
         4.2.1 Case Study Design ..............................................................................................................................................................38
         4.2.2 Results: Development practices ..........................................................................................................................................39
      4.3 KNOWLEDGE AND PROCESS ARCHITECTURE ..........................................................................................................................44
         4.3.1 Case Study Design ..............................................................................................................................................................45
         4.3.2 Results: Explicit Formal Knowledge ......................................................................................................................................46
         4.3.3 Knowledge Loops .................................................................................................................................................................47
      4.4 CASE STUDY: TIME-TO-MARKET .........................................................................................................................................66

5. AGILITY .....................................................................................................................................................................................49
   5.1 BACKGROUND ............................................................................................................................................................................49
   5.2 UNDERLYING PRINCIPLES OF AGILE ........................................................................................................................................51
   5.3 ORGANIZATION FOR AGILITY ................................................................................................................................................52
   5.4 AGILE MANIFESTO FOR PROCESS AUTOMATION ..................................................................................................................53
   5.5 AGILE METHODS FOR PROCESS AUTOMATION .....................................................................................................................57
      5.5.1 State-Of-the-Art ........................................................................................................................................................................57
      5.5.2 State-Of-the-Practice ...............................................................................................................................................................60
   5.6 LARGE-SCALE AGILITY ...............................................................................................................................................................62
      5.6.1 Agile Practice for large organizations ......................................................................................................................................62
      5.6.2 Agile Practices large systems ....................................................................................................................................................64
      5.6.3 People aspects of Agility ..........................................................................................................................................................65
   5.7 CASE STUDY: TIME-TO-MARKET .........................................................................................................................................66

3
5.7.1 Reducing Elapsed Time ................................................................. 66
5.7.2 Re-Use .................................................................................. 68
5.8 Risk Balancing .......................................................................... 69
5.9 Alignment for Agility: Metrics .................................................. 70
5.9.1 Metrics Tetra Transforms ...................................................... 71
5.9.2 Learning from Major League Baseball .................................. 76

6. Effectiveness-and-Efficiency ..................................................................... 77
6.1 Abstract ..................................................................................... 77
6.2 Introduction ................................................................................ 77
6.3 Data Analysis ............................................................................. 78
6.3.1 Business-driven demands ..................................................... 78
6.3.2 Organization Performance: Effectiveness vs. Efficiency profile ........................................... 80
6.4 Nature of Assignments ............................................................... 81
6.4.1 Effectiveness vs. Efficiency .................................................... 83
6.4.2 Effectiveness vs. Efficiency: Adopting Agile ....................... 84
6.4.3 Effective and Efficient Teams ............................................... 85
6.4.4 Analysis of Effective and Efficient Teams ............................ 88
6.4.5 Sensitivity Analysis ............................................................... 91
6.5 Summary .................................................................................... 92

7. Executive Leadership for Innovation Management .................................. 93
7.1 Managing Uncertainty ................................................................... 93
7.2 Technology Strategy ..................................................................... 95
7.2.1 Institutionalized Innovation ................................................... 95
7.2.2 Products vs. Services ............................................................ 95
7.2.3 Platform Leadership ............................................................. 98
7.3 Team Dynamics .......................................................................... 99

8. Prescriptive Guidance for Disciplined Agility ..................................... 101
  STEP #1: Sector-specific Drivers .................................................. 102
  STEP #2: Selecting Practices ....................................................... 103
  STEP #3: Total Agility Transformation ........................................ 104
  STEP #4: Pre-requisites for Agility ............................................. 105
  STEP #5: Operational Agility ...................................................... 106

9. Special Implications for Process Automation ....................................... 107

List Of Tables
TABLE 2-1: Acknowledged Competitors ........................................... 21
TABLE 3-1: Engineering Organization and Innovation ..................... 33
TABLE 5-1: Agile Practices ............................................................... 56
TABLE 5-2: Organization’s Capacity ................................................ 74
TABLE 5-3: Project Execution .......................................................... 74
TABLE 5-4: Customers’ Economic Value ........................................... 76
TABLE 5-5: Oakland Athletics Metrics ............................................. 76
TABLE 6-1: Key Parameters .............................................................. 87
TABLE 6-2: Key Parameters for Sensitivity Analysis ......................... 91
TABLE 7-1: Products vs. Services for Honeywell International Inc .... 96

List Of Figures
FIGURE 1-1: Research/Analysis Model ........................................... 11
FIGURE 2-1: Major Process Automation Players (© Honeywell International Inc) .................. 20
FIGURE 2-2: Peer Competitor Acknowledgement .......................... 22
FIGURE 3-1: Process Control Loop .................................................. 26
Throughout this document, development, product development, technology development and system development are synonymous, and are used interchangeably.
1. Introduction

1.1 Motivation

The motivation for this thesis is a recognized need for process automation vendors to change how they innovate in response to business demands. There is abundant evidence that agile methods have improved the innovation responsiveness of many technology companies. A robust guidance for automation vendors to adopt agility must be based on a good understanding of the business, technological, management and societal factors, in many cases competing factors, in an industry where, according to LaFon (2008), the goal of the product development process is to deliver “ultra quality”.


Agile or agility?

While agility and agile methods may be related, they have arguably sufficient differences to bring into question any presumed connection. The values and principles underpinning agile methods are defined in the Agile Manifesto. While agile methods are primarily software development techniques, agility is neither a technique nor limited to a specific technique. Agility is a core value for least one process automation vendor. While agile methods refer primarily to a software engineering organization, the scope of agility is usually an entire company. Merriam-Webster (1991) defines agility as “the quality or state of being agile”, and agile as “marked by ready ability to move with quick easy grace; mentally quick and resourceful.” For this research, the following definitions are assumed:

**Agile** is an adjective, and its use throughout this thesis should be understood to mean having qualities and properties that strongly reinforce the Agile manifesto.

Agile methods will refer to one of the well-known methods such as XP, Scrum or FDFS.

**Agility** is a noun, and is used to indicate the extent to which a group or organization is agile.

**Why agility?**

The choice of agility over other candidate approaches to make automation vendors more competitive, was subjective, but informed by, for example, LaFon (2008) assertion that “value is delivered when the process responds to changes in customer preferences and requirements”, hinting at the need for a process
that permits changing requirements rather than precludes them. Moreover, the perception (confirmed by findings in this research) remains that process automation offerings are lagging, although this perception is not necessarily supported by gaps expressed in business terms, between automation offerings and manufacturers’ actual needs.

Not only are more and more software companies touting the benefits of agile, but agile development leaders also continue to tackle head-on issues previously viewed as weaknesses of agile methods. Moreover, agile communities continue to mushroom and take agile methods to contexts (large enterprises, embedded software) that have historically acknowledged some (albeit qualified) benefits of plan-driven development methods.

The choice for agile was primarily based on the fact that it is currently the area generating most of the process innovations for development of commercial software to respond to today’s business needs and today’s technology.

**Hypothesis #1:** Agile methods can improve time-to-market for Process Automation offerings.

Furthermore, in order to keep the thesis focused, it was important to consider concepts that had a credible basis for implementation. For process automation, it is important to select concepts that can also be implemented to effect the proposed changes to deliver serious and sustainable benefits to an enterprise. It is important to be able to count on credible change-frameworks, such as lean, that provide a complete approach to effecting changes for a net-gain, or LaFon (2008) that describes how to architect process changes.

**Hypothesis #2:** Successful process change must simultaneously support a target effectiveness-and-efficiency profile (operational cause) and support a value-chain objective (market effect).

**Why Disciplined?**

Boehm and Turner (2004) remind that in addition to product value, there is also process value. Because agile focuses on product value, discipline becomes an important reminder for process value. The Process Automation industry is well-established, and its customers have largely well-established views and expectations of its offerings. Any changes, no matter how beneficial, must be evaluated in the context of these well-established expectations. How manufacturers view process automation vendors can be considered a monument (in lean terminology) that is beyond the immediate control of the vendors.

**Hypothesis #3:** The required capabilities to automate a manufacturing process are so numerous and diverse as to make it non-obvious and non-trivial for a vendor to choose what to focus on.
Why Development?

The Development organization within a Process Automation vendor’s enterprise remains the principle realm of innovation for the vendor’s core offerings. It was therefore only proper to consider how to make this organization more innovative and more competitive.

_Hypothesis #4: Extending a process automation product-line is driven by market push, while maintaining a product release is based on either market pull or need to reduce internal (e.g. development) cost._

_Hypothesis #5: Product development activities in process automation comprise market-related, technology-related or process-related transactions. Each transaction has a lifecycle: initiation => work => completion._

Other disciplines could have been targeted. Based on this research, one discipline in particular, control application engineering would be a good discipline to evaluate for agility. This discipline configures software developed by Development to create a specific application for a specific customer with specific needs within a specific budget. Many of the agile practices that were found to be very challenging for Development are likely to have more moderate levels of difficulty for control application engineering.

System Design and Management perspective

System Design and Management enable one to deploy _Systems Thinking_ and an array of engineering, management, business and innovation disciplines to provide a _framework_ to assess concepts underlying agile methods and proven software engineering techniques, together with the concept of agility that relates to _enterprise management_ and the concept of _discipline_ as it applies to business performance. Single-discipline approaches run the risk of being limited by existing practices. In many technology companies, the product architecture determines the organization structure. Changes based on organizational structures are therefore likely to be influenced by considerations for the current product architecture.

_Hypothesis #6: Development personnel are knowledge workers whose effectiveness and efficiency is based on discernible factors._

The process automation industry is a fiercely competitive sector with a number of characteristics (verified as part of this research) that make innovation practices particularly challenging, especially in harvesting market needs and harvesting market feedback, while still expected to maximize value-creation.
While systems thinking enables understanding the intended and uncovering the unintended effects of interacting systems (process, product, cognitive psychology), and while it is necessary to consider how disciplined agility will scale from a self-organized team, to an entire process automation enterprise, and beyond to the extended supply chain of a world-scale manufacturer, drawing conclusions from the many findings and observations, and then synthesizing new knowledge from those conclusions relied largely on heuristics. According to Valerdi (2008):

"Heuristics are 'rules of thumb', educated guesses, intuitive judgments or simply common sense. In more precise terms, heuristics stand for strategies using readily accessible, though loosely applicable, information to control problem-solving in human beings and machines."

While the Model Development and Model Usage heuristics provide a re-assuring guidance about using data that is good enough, the Model Calibration heuristics serve to instill healthy skepticism in the models proposed throughout this research, given the inability to thoroughly test the models in a real-life application.

1.2 Thesis Statement & Primary Research Objectives:

The primary research objectives were:

* Define the characteristics of development processes with ‘disciplined agility’.
* Identify the ‘efficiency vs. Effectiveness’ profile for Process Automation vendors.
* Develop metrics to connect business objectives to project efficiency and effectiveness.

While specific research activities were continually adjusted and re-defined depending on what was actually learnt at each stage, the overall research direction was guided by the 6 hypotheses. At each step, a variety of engineering and management research and analysis methods were used. While tools, techniques and concepts from each MIT SDM class were used, those from the following classes were used disproportionately more:

<table>
<thead>
<tr>
<th><strong>Engineering Content</strong></th>
<th><strong>Management Content</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>System Engineering</td>
<td>Financial Accounting</td>
</tr>
<tr>
<td>System Architecture</td>
<td>Organizing for Innovation</td>
</tr>
<tr>
<td>Software Engineering concepts</td>
<td>Technology Strategy</td>
</tr>
<tr>
<td>System Project Management</td>
<td>Managerial Accounting</td>
</tr>
<tr>
<td>Probabilistic Assessment</td>
<td>Software Business</td>
</tr>
<tr>
<td>Supply Chain Management</td>
<td>Human Side of Technology</td>
</tr>
</tbody>
</table>
1.3 Research Methods & Approaches

The research methods used consisted of interviewing automation practitioners and manufacturing industry experts, surveying process automation development personnel, reading literature on state-of-the-art and state-of-the-practice, and conducting case studies into specific concepts central to process automation.

These methods were combined into a research approach (see Figure 1-1) modeled after Pugh’s controlled convergence and concept generation iterations (Yang and Katsikopoulos, 2007).

![Figure 1-1: Research/Analysis Model]
1.3.1 Interviewing Industry Leaders, Experts and practitioners

First-hand information from leaders, experts and practitioners from the industry was essential to the research. Not only is the outcome of this research intended to help these practitioners, but their experience and insight were critical to prioritizing areas of research for further investigation. This research set out to uncover patterns that could be generalized to the entire process automation sector. It was therefore important to learn from process automation vendors and their customers (manufacturers). It was also important to learn from multiple automation vendors. The challenge lay first in selecting companies and individuals to approach, and then, in persuading them to spare time for research-related questions. Information unique to a company was not sought. Moreover, research data either unique to one company or not supported by at least 2 individuals, is not included. All quantitative data is normalized to remove specificity to a company.

### Manufacturer Leaders/Experts

<table>
<thead>
<tr>
<th>Leader / Expert</th>
<th>Process Automation Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulf Henriksson, CEO, Invensys Plc</td>
<td>Automation Vendor</td>
</tr>
<tr>
<td>Ken Hunter, Site Process Control Leader, SABIC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Randy Karg, Sr. Vice President, Sinclair Group</td>
<td>Automation Consulting</td>
</tr>
<tr>
<td>Gerrit Verniers, Process Control Technology Leader, Dow Chemical</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Christo Zemering, Site Manager, SABIC</td>
<td>Manufacturer</td>
</tr>
</tbody>
</table>

Each of the above Leader / Expert was sent a preparatory survey (Appendix C). In some cases, the survey was followed by an interview or an exchange of e-mails to explore a range of discussion points.

### Process Automation Value Chain and Development Operations Leaders/Experts

<table>
<thead>
<tr>
<th>Leader / Expert</th>
<th>Process Automation Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Peter Martin, ISA’s 50 most influential innovator</td>
<td>Industry Sector Innovation</td>
</tr>
<tr>
<td>Betty Naylor-McDevitt, Director of Marketing, (Invensys)</td>
<td>Automation vendor</td>
</tr>
<tr>
<td>Bill Nobel, Consultant, Consultant, PRTM</td>
<td>Operations Consulting</td>
</tr>
<tr>
<td>Mats Nordlund, Director of Engineering, Emerson Process Measurement</td>
<td>Automation vendor</td>
</tr>
</tbody>
</table>

Each of the above practitioners was sent a preparatory survey (Appendix D for value-chain, and Appendix E or F depending on experience with Agile), followed by an in-depth interview and discussion covering range of concepts and challenges.

### Product Development

Development personnel at Eagle Corporation were sent a survey (Appendix B). Statistical analysis techniques were used to extract information from the survey responses.
1.3.2 Literature Reviews

Literature was reviewed to determine what questions to research and to pursue answers to important questions. A broad cross section of literature was reviewed, including books, trade journals, academic journals, thesis papers and conference papers on the following topics:

- Technology strategy
- Software Engineering
- Management practices
- Systems Engineering
- Process Automation
1.4 Summary of Key Results

**Hypothesis #1: Agile methods can improve time-to-market for Process Automation offerings.**

This hypothesis could not be supported, but was devalued by Observations #2.3, #5.3 and #6.2. In Chapter 2, manufacturers expressed general satisfaction with time-to-market of current offerings. The research could not find a market-related crisis in time-to-market to use as a reference to evaluate agile methods.

**Hypothesis #2: Successful process change must simultaneously support a target effectiveness-and-efficiency region (operational cause) and support a value-chain objective (market effect).**

This hypothesis is supported by findings and observations in Chapter 2, Chapter 5 and Chapter 6.

**Hypothesis #3: The capabilities to automate a manufacturing process are so numerous and diverse as to make it non-obvious and non-trivial for a vendor to choose what to focus on.**

This hypothesis is supported by findings and observations in Chapter 2, Chapter 3, Chapter 5 and Chapter 7.

**Hypothesis #4: Extending a process automation product-line is driven by market push, while maintaining a product release is based on either market pull or need to reduce internal (e.g. development) cost.**

This hypothesis is partially supported by findings and observations in Chapter 3, Chapter 5 and Chapter 7.

**Hypothesis #5: Product development activities in process automation comprise market-related, technology-related or process-related transactions. Each transaction has a lifecycle: initiation => work => completion.**

This hypothesis could not be supported and was refuted by Observations #4.4 and #4.7.

**Hypothesis #6: Development personnel are knowledge workers whose effectiveness and efficiency is based on discernible factors.**

This hypothesis is supported by findings and observations in Chapter 4 and Chapter 5.
2. Process Automation Industry

This section identifies the principal business factors driving the most important decisions for Automation vendors.

The primary objective is to test the following hypotheses:

- **Hypothesis #1:** Agile methods can improve time-to-market Process Automation products.
- **Hypothesis #2:** Successful process change must simultaneously support a target effectiveness-and-efficiency profile (*operational cause*) and support a value-chain objective (*market effect*).

The research methods used were:

- **Interviewing Manufacturer Leaders and Experts**

The Process Automation Industry is a technology intensive industry that focuses on leveraging advances in technology to improve the economic and business performance of manufacturing companies. Process Automation vendors have been at the forefront of numerous novel uses of technology that has made possible much of the material well-being of humanity today. Many of the materials taken for granted, such as plastics, drugs and cars, could not have been produced extensively without the use of process automation equipment to overcome the limitations of physical systems. Automation systems take the flexibility of software to create process interactions among physically separated components (see Leveson, 1996) that make large scale manufacturing and production viable. Process automation has changed both the technologies used by manufacturers and the operational business models of those manufacturers. According to Berra (2003), there has been

"...integration of instrument and electrical disciplines, as well as the current blending of automation and IT. End users, contractors, and suppliers have lived through mergers and consolidations. Virtually all businesses are more global, and all are trying to do a whole lot more with significantly fewer people."

The consideration for Agility is based in part to increasing literature and number of testimonials on the success of agile methods. More importantly, agile methods emphasize learning. Kelly (2008) suggests agile improves "*double-loop learning*" by having assumptions be continually questioned, and by "*exploring and developing (our own) knowledge.*" To assess double-loop learning in the context of the process automation industry, it is first important to understand the industry.

Process Automation vendors and their customers are primarily for profit business entities. A fundamental assumption in this research is therefore that the principal reason for any initiative or undertaking for
improvement is rooted in the goal of improving business performance. Consequently, a rigorous assessment of agility must be based on business imperatives that have come to bear on the process automation market.

2.1 Process Automation Customers
The research on customers was based on direct communication, through interviews, discussions, and surveys, with manufacturers and industry-segment professionals who are experts on manufacturers' business and automation needs.

All the experts indicated that vendors are generally fast enough for the industry, and often offer more features than needed. The experts did nevertheless identify a number of business challenges for Automation Vendors.

2.1.1 Top threats
Manufacturer experts identified a number of threats to Process Automation vendors. After analyzing the threats, 2 principal categories emerged: threats channeled to vendors through customers, and threats rooted in the process-automation industry. The customer-channeled threats are the same as economic factors identified by Lehmann (2005).

Customer-channeled threats

- Fluctuating commodity prices pressure manufacturers, affecting demand for automation products.
- Rapid changes in currency exchange rates affect how process automation projects are priced.
- Rapid changes in currency exchange rates make Customers reluctant to settle account payables.
- During a recession or financial crisis, customers find it harder to access credit to finance automation projects.

*Observation #2.1: Process Automation vendors are threatened by the global economic pressures affecting manufacturers directly.*

Industry-rooted threats

- Lack of demonstrated ROI for investments in process automation
- Platform commoditization with no pricing power for automation vendors
- Loss of Process Control application engineering talent
- Upgrade cycle to new HW platforms runs its course
- Standards-based platforms & open systems limit differentiation
Observation #2.2: Process Automation vendors are threatened by a complex value-chain and associated value-proposition. Manufacturers view at least some automation offerings as commodities. [Supports Hypothesis #3]

Observation #2.3: None of the manufacturers believe vendors are too slow. Moreover, vendors largely deliver what they promise. However, this belies manufacturers’ view that there is a “lack of demonstrated ROI for investments in process automation.” [Devalues Hypothesis #1]

2.1.2 Domain Expertise

Manufacturer experts were all consistent in their opinion of the domain expertise present in, or provided by Process Automation vendors.

- Vendors becoming less knowledgeable about process engineering
- Vendors becoming less knowledgeable about process control
- Vendors becoming less knowledgeable about operator needs.
- Vendors less knowledgeable about manufacturing business needs
- Vendors’ internal focus is on platforms

Observation #2.4: Manufacturers believe vendors are focusing on platforms (i.e. technology), and at the same time, vendors are making incorrect forecasts about offerings needed by manufacturers. [Supports Hypothesis #2]

2.1.3 Perceived Competence

Manufacturer experts indicated that in general vendors have “no domain expertise” in process engineering and have a “vague understanding” of Manufacturer business drivers. The experts also indicated vendors’ deficiencies in two other important for process automation:

**Process Control**

- Limited knowledge of application engineering
- Seems "old school" compared to new technology
- Functional shortcomings in applications
- Poor record forecasting manufacturers’ future needs

**Operator needs**

- Automation vendors have no clue about Operator needs
- Matching technology to reality of running a plant
2.1.4 Customers’ needs and requirements

Manufacturer experts identified a number of manufacturer shortcomings and needs that process automation vendors have been overlooking:

- Many manufacturers do not really know their precise requirements
- Manufacturers rely on vendors’ feedback to clarify requirements
- Manufacturers know what they need, but find it hard to express clear requirements

*Observation #2.5: Manufacturers concede they depend on interactions with vendors to convert needs into requirements. However, manufacturers believe automation vendors continue to lose domain expertise in key disciplines of manufacturing automation. [Supports Hypothesis #2]*

Each Manufacturer representative further indicated that his needs were representative of the industry needs, and was comfortable having other manufacturers represent his company’s needs.

2.1.5 Customers’ unmet needs

Manufacturer experts identified a number of needs not being addressed by vendors, especially persistent gaps in technology offerings and in business solutions.

**Technology Offerings**

- Process Operator Environment
- Process Unit control processing
- Enterprise Resource Planning
- Manufacturing Execution System

- System security
- Enterprise Resource Planning
- Engineering Environment
- Specifying automation strategy

*Observation #2.6: There was a strong consensus for better technology offerings for the Process Operator Environment and the Process Unit control processing. [Supports Hypothesis #3]*

**Business solutions**

- Managing supply-chain
- Managing production strategies
- Plant utilization

- Mass-and-energy balance
- Managing process units
Observation #2.7: Manufacturers showed a strong consensus for better **business solutions** for Supply Chain Management and managing production strategies. [Supports Hypothesis #3]

2.1.6 Competitive Criteria
Manufacturer experts identified the following criteria used by manufacturers when selecting a process automation vendor:

- Vendor's financial profitability
- Commissioning cost per plant capacity
- Engineering time per plant capacity
- Commissioning cost per plant type
- Engineering time per plant type
- Engineering time per I/O point
- Commissioning cost per I/O point
- Annual Operating cost per I/O point
- Annual maintenance cost per I/O point

Observation #2.8: Customers' competitive criteria are broad and include criteria in terms of I/O points, of plant type and of plant capacity. The I/O point based criteria cover all phases of automating a manufacturing facility. [Supports Hypothesis #3]

Manufacturer experts indicated that manufacturers were in general “cautious about new technology”, but were in some cases open to trying out new technology.

Observation #2.9: While manufacturers are conservative, they are at the same time looking for better technology offerings, and better business solutions.

Some experts indicated that manufacturers prefer capitalizing purchases of process automation products.

Observation #2.10: While there was no preference for how to account for manufacturers' expenditure on process automation, manufacturers expect the option of offerings that can be capitalized.
2.2 Process Automation Vendors

Vendors are typically companies with global operations that include technology R&D centers located in world-class technology clusters (U.S., Western Europe, Japan) and applications engineering and support facilities closer to large customers, typically in emerging economies. Figure 2-1 is taken from Honeywell (2008), the annual report of a major Process Automation vendor. In general, Process Automation is one of a number of distinct sectors in which the vendor competes. In Figure 2-1, Honeywell has Process Automation (along with Environmental and combustion control and Security and Life Safety) as a Products and Services Class within the Business Division of Automation and Control Solutions.

<table>
<thead>
<tr>
<th>Product/Service Classes</th>
<th>Major Products/Services</th>
<th>Major Customer/Uses</th>
<th>Key Competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental and combustion controls; sensing controls</td>
<td>Heating, ventilating and air conditioning controls and components for homes and buildings</td>
<td>Original equipment manufacturers (OEMs)</td>
<td>Bosch</td>
</tr>
<tr>
<td></td>
<td>Indoor air quality products including zoning, air cleaners, humidification, heat and energy recovery ventilators</td>
<td>Distributors</td>
<td>Cherry</td>
</tr>
<tr>
<td></td>
<td>Controls plus integrated electronic systems for burners, boilers and furnaces</td>
<td>Contractors</td>
<td>Danfoss</td>
</tr>
<tr>
<td></td>
<td>Consumer household products including humidifiers and thermostats</td>
<td>Retailers</td>
<td>Eaton</td>
</tr>
<tr>
<td></td>
<td>Electrical devices and switches</td>
<td>System integrators</td>
<td>Emerson</td>
</tr>
<tr>
<td></td>
<td>Water controls</td>
<td>Commercial customers and homeowners served by the distributor, wholesaler, contractor, retail and utility channels</td>
<td>Endress &amp; Hauser</td>
</tr>
<tr>
<td></td>
<td>Sensors, measurement, control and industrial components</td>
<td>Packaging and materials handling operations</td>
<td>Honeywell</td>
</tr>
<tr>
<td></td>
<td>Security products and systems</td>
<td>Appliance manufacturers</td>
<td>Inversys</td>
</tr>
<tr>
<td></td>
<td>Fire products and systems</td>
<td>Automotive companies</td>
<td>Johnson Controls</td>
</tr>
<tr>
<td></td>
<td>Access controls and closed circuit television</td>
<td>Aviation companies</td>
<td>Motorola</td>
</tr>
<tr>
<td></td>
<td>Home health monitoring and nurse call systems</td>
<td>Food and beverage processors</td>
<td>Schneider</td>
</tr>
<tr>
<td></td>
<td>Gas detection products and systems</td>
<td>Medical equipment</td>
<td>Siemens</td>
</tr>
<tr>
<td></td>
<td>Emergency lighting Distribution</td>
<td>Heat treat processors</td>
<td>United Technologies</td>
</tr>
<tr>
<td></td>
<td>Hand held imagers</td>
<td>Computer and business equipment manufacturers</td>
<td>Yamatake</td>
</tr>
<tr>
<td></td>
<td>Mobile and wireless computers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personal protection equipment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2-1: Major Process Automation Players (© Honeywell International Inc)
<table>
<thead>
<tr>
<th>Company</th>
<th>Acknowledged Competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeywell International</td>
<td>- ABB</td>
</tr>
<tr>
<td>(Automation &amp; Control Solutions)</td>
<td>- AspenTech</td>
</tr>
<tr>
<td>(Process Automation)</td>
<td>- Emerson</td>
</tr>
<tr>
<td></td>
<td>- Invensys</td>
</tr>
<tr>
<td></td>
<td>- Siemens</td>
</tr>
<tr>
<td></td>
<td>- Yokogawa</td>
</tr>
<tr>
<td>ABB</td>
<td>- Emerson Electric Co.,</td>
</tr>
<tr>
<td>(Process Automation Division)</td>
<td>- Honeywell International, Inc.,</td>
</tr>
<tr>
<td></td>
<td>- Invensys plc,</td>
</tr>
<tr>
<td></td>
<td>- Schneider Electric SA</td>
</tr>
<tr>
<td></td>
<td>- Siemens AG</td>
</tr>
<tr>
<td>Siemens</td>
<td>- ABB</td>
</tr>
<tr>
<td>(Industry Sector)</td>
<td>- Schneider Electric</td>
</tr>
<tr>
<td>(Industrial Automation Division)</td>
<td>- Rockwell</td>
</tr>
<tr>
<td></td>
<td>- Emerson Electric</td>
</tr>
<tr>
<td>Rockwell</td>
<td>- Siemens AG</td>
</tr>
<tr>
<td>(Control Products &amp; Solutions)</td>
<td>- ABB Ltd</td>
</tr>
<tr>
<td></td>
<td>- Schneider Electric SA</td>
</tr>
<tr>
<td></td>
<td>- Honeywell International Inc</td>
</tr>
<tr>
<td></td>
<td>- Emerson Electric Co.</td>
</tr>
<tr>
<td>Schneider</td>
<td>- Siemens AG</td>
</tr>
<tr>
<td>(Automation + Industrial Controls)</td>
<td>- Rockwell Automation</td>
</tr>
<tr>
<td>Invensys plc</td>
<td>Note: Competitors were not identified directly. The list below was the list of ‘peer companies’ used to determine “long-term incentive plan under which awards are granted to executive directors and senior executives at no (or nominal) cost.”</td>
</tr>
<tr>
<td>(Invensys Process Systems)</td>
<td>- ABB</td>
</tr>
<tr>
<td></td>
<td>- Eaton</td>
</tr>
<tr>
<td></td>
<td>- Emerson</td>
</tr>
<tr>
<td></td>
<td>- GE</td>
</tr>
<tr>
<td></td>
<td>- Honeywell</td>
</tr>
<tr>
<td></td>
<td>- Johnson Controls</td>
</tr>
<tr>
<td></td>
<td>- Rockwell</td>
</tr>
<tr>
<td></td>
<td>- Schlumberger</td>
</tr>
<tr>
<td></td>
<td>- Schneider</td>
</tr>
<tr>
<td></td>
<td>- Siemens</td>
</tr>
<tr>
<td></td>
<td>- Smiths Group</td>
</tr>
<tr>
<td></td>
<td>- Yokogawa</td>
</tr>
<tr>
<td>Emerson</td>
<td>No specific enumeration</td>
</tr>
<tr>
<td>(Industrial Automation)</td>
<td>No specific enumeration</td>
</tr>
<tr>
<td>Emerson</td>
<td>No specific enumeration</td>
</tr>
<tr>
<td>(Industrial Automation and Control)</td>
<td>No specific enumeration</td>
</tr>
</tbody>
</table>

Table 2-1: Acknowledged Competitors
The actual major competitors will vary for each vendor depending on where the boundaries for process automation are drawn. Table 2-1 was compiled from contents of Honeywell (2008), Invensys (2008), Yokogawa (2008), ABB (2008), Siemens (2008), Emerson (2008) and Schneider (2008). It shows each company’s business section that contains Process Automation, and each company’s acknowledged competitors in this market. Some companies’ annual reports did not list any competitors by name. Figure 2-2 summarizes the total number of acknowledgements by peer competitors. Table 2-1 and Figure 2-2 were used as the basis to select the top 6 Process Automation vendors that were approached as part of the research for this thesis.

![Competitor Acknowledgements](image)

**Figure 2-2: Peer Competitor Acknowledgement**
3. Innovation practices

This section aims to establish current the innovation practices used by process automation vendors.

The primary objective is to test the following hypotheses:

- **Hypothesis #3**: The capabilities to automate a manufacturing process are so numerous and diverse as to make it non-obvious and non-trivial for a vendor to chose what to focus on.

- **Hypothesis #4**: Extending a process automation product-line is driven by market push, while maintaining a product release is based on either market pull or need, to reduce internal (e.g. development) cost.

The research methods used were:

- Reviewing Literature on State-Of-the-Art
- Reviewing Literature on State-Of-the-Practice
- Interviewing Leaders/Experts on Process Automation Value-Chain

Innovation is mediation between the market and technology. Assessing agility for process automation vendors requires assessing technology-related practices and business-related practices of innovation of automation offerings.

3.1 Key Definitions

The following definitions will be used throughout this document. The definitions are based on common usage in the Process Automation industry and the manufacturing sector.

**Program**

- The marshalling and consequent mobilization of production, engineering and marketing disciplines to place a new or improved product or service or combination of products and services in the market place.
- The orchestra of activities that represents the above mobilization.
- The program is an executive component of corporate near-term business objectives.

A program represents a corporation delivering its public promise to the marketplace.

**Project**

A set of activities for production, engineering and marketing disciplines with the goal of giving form to a company’s offerings. A project might fail, but the lessons of the failed project must be learned and absorbed.
**Product**
An artifact, usually identified by a Serial Number, or a service, usually identified by a name, that can be exchanged for revenue.

**Quality Engineering**
In this phrase, Quality is used as a noun and not an adjective: this phrase therefore considers quality as an output or deliverable.

**System**
Artifacts, services and products aggregated to work in unison to solve an End-User’s problem.

**Customer**
Person (or organization) that is responsible for the actual payment of a product or a service offering.

**End-User**
- Person or organization that will operate or use the product.
- Person or organization that will ultimately benefit from a service provided by product.

**Requirements**
An expressed formulation of what is wanted, or an inscription of a model of what is wanted. The process of formulating requirements involves the (conscious or unconscious) use of at least the following models:
- Personal mental model of problem from inscriber’s point of view
- Personal mental model of problem from interpreters’ point of view.
- models for visualizing the context in which the requirements shall apply
- models to express the context and the environment

**Need**
A documented formulation of a problem, expressed from End-User’s point-of-view, using models the End-User is most familiar with.

**Expectations**
General characteristics of context or environment associated with a need.
**Process**
A documented model describing:
- the major entities and artifacts
- the logical (static or temporal) inter-relationship among entities and artifacts

A process is a model, and thus documenting a model will be a subjective function of:
- the mental model of the author
- the power of the language/formulae to express the model
- the power of the language/formulae to capture the context of the model
- the power of the language/formulae to capture the environment and constraints of the model.

Similarly, reading, or interpreting a model will be a subjective function of:
- the model conjured in the mind of the reader
- the power of the language/formulae used to convey essential properties of the model
- the power of the language/formulae used to convey general properties of the model
- the power of the language/formulae used to convey unique properties and special cases of a model

**Procedure**
A documented specification of what should be done and how it should be done. A procedure is characterized by:
- steps … a logical and/or temporal and/or dependency order
- milestones
- step entry and exit criteria

A procedure may also be an explicit customization of 1 or more processes to a particular assignment.

### 3.2 Value Proposition
Process automation systems enable manufacturers to create economic value by transforming raw materials into manufactured materials orderly, safely and economically. In the past, such economic value was measured in terms of reduced headcount. Martin (2009) enumerates the value-proposition for today’s manufacturers as follows:
Observation #3.1: Value proposition of process automation to manufacturers comprises: improving production value, reducing the use of raw material, reducing energy costs, improving plant safety and improving Regulatory Compliance. [Supports Hypothesis #3]

A fundamental concept in process automation is the process control loop (see Figure 3-1). A manufacturing process is modeled logically inside a process control system (PCS), and the PCS can subsequently be used to control the manufacturing process through exchange of information with manufacturing process drivers and measurements.

![Figure 3-1: Process Control Loop](Image)

A Distributed Control System (DCS) is the dominant PCS design for controlling large physical processes. The concept is depicted in Figure 3-2.

![Figure 3-2: High Level Concept](Image)

Many manufacturing facilities involve the conveyance of dangerous (potentially life-threatening) materials, the concentration of dangerously high (potentially explosive) levels of energy in confined space, the motion of massive (potentially deadly) mechanical parts, and the production of toxic waste. These dangers have led to a complex set of stakeholders in the manufacturing industry. The principal stakeholders are summarized in Figure 3-3.
Figure 3-3: Beneficiaries and Needs

Not only must a process automation system contribute significantly to economically manage these dangers, but it may not contribute additional risks. The types of stakeholders shown in Figure 3-3 strongly suggest that a process automation system is a socio-technical system based on the definition in Rechtin (2002), implying the need to apply the design heuristic that “it’s not the facts, it’s the perceptions that count”, and offering the following maxim:

“It makes little difference what facts nuclear engineers present about the safety of nuclear power plants, their neighbor’s perception is that someday their local plant will blow.”

A viable Process Automation System must address all needs of the principal Stakeholders. Figure 3-4 is the whole product system view of a generalized architecture for a Process Automation System.
Architecting such a system should be based on the full set of heuristics for a socio-technical system proposed by Rechtin (2002). In the context of agility, most notable heuristics are:

- Success is in the eyes of the beholder and not the architect.
- Be sure there are mutually consistent answers to who benefits, who pays, who supplies and who loses.
- The choice between architectures may depend on which drawbacks stakeholders can handle, and not which one provides the most functional benefit.
- How you a system developed is more important than what is developed.
- When implementing a change, keep, some elements constant as anchors for Stakeholders
- It’s easier to change the technical elements of a [socio-technical] system than to change humans.

*Finding #3.1:* The Stakeholders for an Automation System make it a socio-technical system. The design heuristics associated with a Socio-technical system will place constraints on the technical design and greater demands on the management practices. [Supports Hypothesis #2]

*Finding #3.2:* For process automation, the choice between architectures may depend on which drawbacks stakeholders can handle, and not which one provides the most functional benefit. [Supports Hypothesis #3]
<table>
<thead>
<tr>
<th>Economic Factors</th>
<th>Assets</th>
<th>Needs</th>
<th>Automation Vendor's Business Ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory</td>
<td>Distribution and Logistics</td>
<td>Supply-Chain Optimization</td>
<td>Enterprise Resource Planning</td>
</tr>
<tr>
<td>Revenue (Production Value)</td>
<td>Finished Goods</td>
<td>Production Strategies</td>
<td>Manufacturing Execution Systems</td>
</tr>
<tr>
<td>Material Loss</td>
<td>Manufactured Products</td>
<td>Plant Utilization</td>
<td>Engineering Environment</td>
</tr>
<tr>
<td>Indirect Labor, Materials &amp; Energy</td>
<td>Manufacturing Plant</td>
<td>Process Flow</td>
<td>Operating Environment</td>
</tr>
<tr>
<td>Depreciation</td>
<td>Control Elements (valves, pumps ..etc)</td>
<td>Process Loops</td>
<td>Distributed Process Control</td>
</tr>
<tr>
<td>Capital Expense</td>
<td>Raw Materials</td>
<td>Temperature, Pressure, Flow, Mass, Volume of material</td>
<td>Field Signal Input/Output</td>
</tr>
<tr>
<td>Periodic Expense</td>
<td>Energy</td>
<td>Field Actuators</td>
<td>Field Signal Input/Output</td>
</tr>
<tr>
<td>(maintenance)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3-5: Value Chain & Ecosystem**
3.2.1 Value-Chain
According to Lehmanm (2005), value chain is a concept that “can be used to compare a company’s strengths and weaknesses against another.” Davies (2007) emphasizes the importance to a technology strategy of considering the overall ecosystem, while Cusumano (2002) advises on the need for a technology player to be clear about platform leadership vs. platform complement. To determine how agility could impact a Process Automation vendor’s business performance, it was essential to use a framework that unifies the value-creation opportunities for automation vendors with the complex range of value-capture opportunities in the manufacturing industry. An initial value-chain and ecosystem was created based on information from Martin (2006), Liptak (1985), Leveson (1999), Shinksey (1979) and Kuo (1991). This initial Value-Chain was used as a basis for an interview with Dr. Peter Martin, “one of the 50 most influential people in process automation”. The value chain in Figure 3-5 incorporates insight from Dr. Martin, manufacturer leaders and experts, and development operations leaders and experts.

3.2.2 Value Capture: The Business Model
The ability of automation vendors to capture value they have created in their offerings depends significantly on the manufacturers’ readiness. This readiness can be business preparedness or operational preparedness or infrastructural readiness, each of which may require additional investment (over and above the cost of the vendor’s offering) by the manufacturer.

An example of business preparedness, given in section 2, is that “Manufacturers are conservative, and cautious about new technology.”

An example of operational preparedness is another finding from section 2, that “Manufacturers prefer capitalizing process automation products”. Another example is described by McAfee (2008), whereby deployment of technology “provides flexibility that heightens tension between global consistency and local autonomy.” The ability of a manufacturer’s leadership to manage this tension will determine how much a vendor’s offering will be embraced or fought by the manufacturer’s employees. Manufacturer management may for example have to deploy the new technology and at the same time “leverage the talents of a high-performing manager at one location to maximize results in thousands of sites worldwide.”

Concern over infrastructural readiness is illustrated in Moschetto (2008). Information Technology (IT) is a critical enabler for Operations Management offerings, since, as asserted in McAfee (2008), the value of IT is in process-innovations. According to Moschetto (2008), the involvement of IT in process automation solutions varies. For example, 75% of IT teams have heavy to moderate involvement in Manufacturing Execution Systems (MES) purchasing decision, and 69% of MES are connected to ERP.
Observation #3.2: The ability of Automation Vendors to capture value depends on manufacturers’ business preparedness, operational preparedness, and infrastructural preparedness. [Supports Hypothesis #3]

3.2.3 Return-On-Investment
While Martin (2009) identifies the principal value-proposition for process automation, Manufacturers have been largely unable to demonstrate their ROI on investments made on process automation. Martin (2009) addresses this dilemma specifically for the pharmaceutical industry while McAfee (2006) addresses the dilemma for IT in general. Martin (2009) points out that senior management within the pharmaceutical industry see requests for capital investments that predict strong ROI yet “just can’t see the business benefits (these) investments have delivered”. McAfee (2006) points out that some corporate boards do not view IT as strategic and therefore as a competitive asset.

While Martin (2009) attributes the indemonstrable ROI of process-automation to Accounting practices, McAfee (2006) suggests the lack of an effective IT Model as the underlying cause. According to Professor McAfee, the benefits of IT consist largely of statements about individual technologies, but offer no explanation of cause and effect that could enable an organization realizes aggregate benefits.

3.2.3.1 Process Automation vs. IT
Much of the literature does not provide a clear guideline of where Process Automation and IT overlap. This makes it difficult to determine to what extent observations and findings in IT are valid for Process Automation. For a manufacturer, the physical infrastructure for process automation and Corporate IT is often the same. Moreover, the functional boundaries are blurring as more and more of the process-automation value-chain offerings can only be effectively provided as IT offerings, and certain IT offerings must be integrated with process automation systems. For manufacturers, examples of strong overlap between process automation and IT are Enterprise Resource Planning, Manufacturing Execution Systems, and Supply-Chain Management. However, the effectiveness of these services is determined by real-time connectivity to process control.

Finding #3.3: The overlap between Process Automation and IT is not clearly identified, but is generally increasing. [Supports Hypothesis #3]

3.2.3.2 Business Value: Real-Time Accounting
Not only do Manufacturers’ accounting systems fail to capture the business-value attributed to process-automation, they also incentivize Manufacturing managers to overlook the role of process automation. Manufacturing managers are measured in terms of Cost-Per-unit of Finished Goods, defined as:

\[
\text{Cost-Per-unit Finished Goods} = \frac{\text{Direct Cost + Allocated Costs}}{\text{Quantity produced}}
\]
But the manager has no control over the numerator, since allocation costs can be significant. In Bost (1993), ‘overhead rate’ varied between 434% - 577% of ‘direct labor’ over a 4-year period, while in Ferreira (1993) the ratio varied 100% - 300%. Martin (2009) views this cost-accounting practice to be “designed to support the financial reporting requirements of the organization and not its operating management”. 16 years earlier, Ferreira (1993) pointed out that “Cost Accounting managers believe it is a monumental job ... to change cost accounting standards and could take years.” Since Manufacturing Managers can only control the denominator, their strategy has been to make as much product as possible.

Finding #3.4: Manufacturers’ cost-accounting practices support financial reporting and not Operations Management.

Martin (2009) believes the business value of process automation is real, and when measured correctly, has shown a “100% return on capital investments in less than three months.” Martin (2009) proposes manufacturers make 2 major changes in order to measure the true ROI of process automation:

- change accounting measurement systems to be Real-time Cost Accounting
- Change approach to projects from RFP (Request for Proposal) to include continuous improvement.

Observation #3.3: Manufacturers are not seeing the ROI promised for process automation. [Supports Hypothesis #3]

Observation #3.4: Little has been done to change Cost-Accounting practices to better capture the actual cost of finished goods that can be used to calculate automation ROI.

Although Martin (2009) recommends that manufacturers also change their view of the operator from being a laborer to being a Performance Manager, research results from interviewing manufacturer leaders indicate that manufacturers believe process automation systems do not yet adequately provide for the Operator’s needs.

Finding #3.5: Process Automation Experts recommend a greater role for the Process Operator, in contrast with Manufacturing Leaders who believe Process Automation vendors do not adequately address Operator needs. [Supports Hypothesis #4]

3.2.4 Value-Chain Properties
Although the Value-Chain in Figure 3-5 was developed to carefully match the process automation market, it was nevertheless important to consider some key tests, namely:

- Is the depicted value-chain unique to process automation?
- Is it possible to develop a better value chain?
Research into these questions led to two useful heuristic test-cases:

**What would the value-chain look like for a market adjacent to the process-automation market?**

**What would the value-chain look like for a customer sector adjacent to today’s manufacturers?**

Both test-cases were justified on the basis of literature, such as Christensen (2003) on the disruptive nature of innovation in adjacent markets. A value-chain for the LEGO’s Mindstorm™, a robotic hobby product kit, was developed as a test-case (see Appendix). The Mindstorm value-chain was very similar to that for process automation, although the customer-type is completely different.

Figure 3-5 must therefore be accompanied by additional information to make the value-chain unique to Process Automation. Further analysis of the process automation stakeholders’ needs yielded **common properties** for each Value-Chain position. These properties are summarized in Table 3-1, and when applied to the Value Chain in Figure 3-5, make that Value Chain unique to Process Automation.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Stakeholder Need</th>
<th>Value-Chain properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. UL (for Insurance Companies)</td>
<td>Avoid exposure to preventable risk</td>
<td>Safety</td>
</tr>
<tr>
<td>2. OSHA (for Plant Worker)</td>
<td>Safe work conditions</td>
<td>Safety</td>
</tr>
<tr>
<td>3. FDA (for Consumer)</td>
<td>Safe food and drugs</td>
<td>Safety</td>
</tr>
<tr>
<td>4. NUPIC (for General Public)</td>
<td>Safe and habitable environments</td>
<td>Safety; Security</td>
</tr>
<tr>
<td>5. DCS Vendor Shareholder</td>
<td>Profitable sustainable business</td>
<td>Demonstrable Business Value</td>
</tr>
<tr>
<td>6. General Manager</td>
<td>Low cost of Ownership</td>
<td>Component Reliability</td>
</tr>
<tr>
<td>7. Process Engineer</td>
<td>Effective and efficient automation capabilities</td>
<td>IT Type</td>
</tr>
<tr>
<td>8. Facility Operator</td>
<td>Reliable system operation</td>
<td>Reliability; Visualization; Security</td>
</tr>
<tr>
<td>9. Process Automation Vendor</td>
<td>Increased market share</td>
<td>Cycle Time vs. Takt Time</td>
</tr>
<tr>
<td>10. Process Engineering Firms</td>
<td>Scalable process automation system</td>
<td>Scalability</td>
</tr>
</tbody>
</table>

Table 3-1: Engineering Organization and Innovation

*Observation #3.5: For Value-Chain levels for process automation are subject to process-automation properties. [Supports Hypothesis #3]*
3.3 Innovation Processes
Various organizations within a process automation company have shared and collaborative responsibilities for the company’s innovation. The development organization has the prime responsibility for producing the technological components that can be deployed at Customer sites to support End User business objectives. The marketing organization is generally responsible to bring offerings and customers together. The development organization and marketing organization have the joint responsibility to ensure that the offerings solve a broad enough range of End User needs and requirements.

In order to understand (intra company) practices and processes in the context of agility, it is necessary to first understand the governing forces that arise from the interactions among the principal elements for sustainable innovation in the process automation market. Figure 3-6 depicts the principal elements of innovation.

![Figure 3-6: Innovation Elements: Dynamic interaction model](image)

**Observation #3.6:** Principal agents for innovation are: Customers, Products, People Skills and Processes

Although many other factors are also important (for example, access to capital, size of the company ... etc), these 4 elements are sufficient to provide a ‘good enough’ model to establish the base elements for
the internal processes. While Customer Base and Products map closely to market and technology respectively, People Skills and Processes provide the framework in which value is created and actualized. Figure 3-6 is the dynamic model, depicting a number of on-going actions that ensure the delivery of products and focus on customers. Each of the innovation elements is a transformative entity, transforming primary inflows into primary outflows different in form. Each innovation element has an associated natural decay. Without continual renewal, instances of the element-type degrade over time. Examples of natural decay are:

**Customer Base:**
New business segment; changing business model; Mergers and Acquisitions

**Products:**
HW components obsolescence; SW failures accumulation

**Processes:**
New technology risks; New User work-flows; Standardizing User processes

**People Skills:**
Know-how for new technology; new practices need new interactions, mindsets and attitudes.
Considerations about ‘People Skills’ must also include strategic decisions about outsourcing. Murmann et al (2002) advise that “A firm must be sensitive as to whether outsourcing means greater dependence on suppliers for capability or for knowledge – each with a different set of circumstances.”
3.3.1 Essential Engineering Entities Model (E³M)

Ulrich and Eppinger (2004) define the key functions of a generic product development organization, and the tasks and responsibilities for the key functions for each phase of product development. Eight variants of the generic development process are enumerated. Using these variants, the value-chain of Figure 3-5, the value-chain properties enumerated in Table 3-1, the basic computational needs for process control implied by Kuo (1991) and Shinskey (1979), and the basic innovation process of Figure 3-6, it is possible to synthesize the Essential Engineering Entities Model (E³M) for Process Control Systems and Technology, depicted in Figure 3-8. Each entity is transformative (what comes out of each entity is different in form from what goes in), and asynchronous (it is generally impossible to synchronize the lifecycles of any 2 entities). The entities for process automation development are:

- Application Domain Body Of Knowledge
- Software (SW) Module
- Hardware (HW) Module
- Company Program
- Product Engineering Project
- System Engineering
- Software Engineering
- Hardware Engineering
- Database Engineering
- Government Health, Safety and Environment (Govt. Health, Safety & Env.)
- Customer Requirements
- Solution Supplier
- Configuration Item
- Subsystem-Engineering project
- Product Development and Engineering (Prod. Dev. & Eng.)
- Deployable Product
- Operational System
- Engineering Infrastructure
- Software (SW) System
- Hardware (HW) System
- Database
- Hardware Module
- Software Module

The most significant relationships among the entities are based on insight gained from survey responses from development personnel in a process automation vendor (see Chapter 5) on assignment dependencies. These entities are not departments, but groupings of knowledge (including formal education), vocabulary and fundamental principles. Agile methods adopted by a process automation vendor will be practiced in this methodology-independent framework.

*Observation #3.7*: Design and Development of a Process Automation system requires a set of Essential Engineering Entities. [Supports Hypothesis #4]
Figure 3-7: PCST Engineering Entities Model

This section aims to uncover the range of process needs for Automation Vendors’ personnel.

The primary objective is to test the following hypotheses:

- **Hypothesis #5:** Product Development activities comprise market-related, technology-related or process-related transactions. Each transaction has a lifecycle: initiation => work => completion.

- **Hypothesis #6:** Development personnel are knowledge workers whose effectiveness and efficiency is based on discernible factors.

The research methods used were:

- Survey of Development personnel
- Reviewing literature on State-Of-the-Art

4.1 Background

To understand how agility would help a classic development organization, it is necessary to understand established process interactions and needs among development personnel in order to uncover any patterns.

Eagle Corporation is over 50-years old and designs, develops and sells Process Automation Systems globally. Its customer base consists of manufacturing companies, many global-scale manufacturers. Research into Eagle Corporation’s development practices was split into 2 parts.

The first part focused on understanding what influenced personnel’s practices. The data analyzed to produce this understanding was gathered through a survey given to all personnel in the Development organization. The second part focused on structural analysis of decades of Eagle Corporation’s engineering standards. The findings from the first part justified the second part.

While the first part analyzed what is perceived by personnel (the human perspective), the second part analyzed the emergent structure of explicit knowledge governing all work done by personnel.

4.2 Process practices

4.2.1 Case Study Design

Yin (2003) provides not only a structure for designing case studies, but also a guiding definition for a case study as an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident."

4.2.1.1 Study Questions

The main questions behind this study were:
1. Are current development practices for automation offerings inadequate?
2. If they are inadequate, where and why?
3. If they are adequate, do they need minor tweaks or major changes?
4. If they need major changes, would agile methods be the answer?

4.2.1.2 Study Propositions
1. The currently defined process is bureaucratic and requires too much documentation.
2. Removing some of the documentation requirements will encourage personnel to talk more.

4.2.1.3 Unit of analysis
The unit of analysis is the opinion of personnel about key elements of the development process, based on actual experience and daily practice.

The opinions are sought at the level of multi-discipline engineering groups.

4.2.1.4 Logic linking data to propositions

Proposition #1: Feedback that most groups find current process to be ineffective or inefficient.

Proposition #2: Feedback that most groups find current process requires unhelpful documentation.

4.2.1.5 Criteria for interpreting findings
An internet-based survey (Appendix B) was sent to all development personnel. The survey responses therefore came from a random sample of the development personnel. The number of questions was kept to a minimum to encourage survey participation.

Results were attributed to a group only if there were 5 or more individuals in the group.

The purpose of this study is to uncover patterns. The focus was on using the internet-based survey data analysis tools to reveal any noticeable patterns, and to focus on revealed patterns without added interpretation.

4.2.2 Results: Development practices
Each survey respondent identified himself with 1 out of a possible 13 disciplines. The distribution for the 6 largest disciplines is as follows:

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW Engineering</td>
<td>40%</td>
</tr>
<tr>
<td>Test Engineering</td>
<td>23%</td>
</tr>
<tr>
<td>HW Engineering</td>
<td>9%</td>
</tr>
<tr>
<td>System Engineering</td>
<td>7%</td>
</tr>
<tr>
<td>Product Management</td>
<td>5%</td>
</tr>
<tr>
<td>Configuration Engineering or Management</td>
<td>5%</td>
</tr>
</tbody>
</table>
RESULTS #4.1:

Figure 4-2 shows the % of personnel in each discipline who consider the defined processes to be helpful. Although software engineers are the largest group, they are among those least satisfied by today’s defined processes. The disciplines with near exuberant satisfaction with the defined processes were Functional Test Engineers, and Configuration Managers. This result is surprising since the focus of process definitions has been to help product development. Although Test Engineers may be happy with the defined processes, the Test Engineers’ exuberance may be based on the fact that enforcing defined process enables Test Engineers to wield some leverage over Software Engineers.

Observation #4.2: Test Engineers were most enthusiastic about defined processes, but the enthusiasm may be attributed to leverage over Software Engineers.

Figure 4-1: Dynamic Asset interaction model
RESULTS #4.2:

Figure 4-2 shows there is no obvious pattern between a given discipline and the work-initiating discipline. However, most work is initiated by Product Management and Requirements Management.

![Start by Product Management](image-a)

![Start by Requirements Engineering](image-b)

![Start by SW Engineering](image-c)

Figure 4-2: Initiating Assignment
RESULTS #4.3:

Figure 4-3 (a) shows the work initiators for the 4 largest disciplines. Product Management initiates work for all disciplines. Figure 4-3 (b) shows how the different disciplines are involved in initiating work for different assignment types. While SW Engineering, Test Engineering and Product Management are all noticeably involved in assignments without a clear beginning, Requirements Engineering is largest initiator of assignments with clear-beginning-and-clear-ending, while Product Management is the largest initiator of assignments with clear-beginning-but-without-clear-ending.

\[
\text{Observation #4.3: SW Engineers' work can be initiated by other SW Engineers and Test Engineers' work can be initiated by other Test Engineers. This suggests that SW Engineering and Test Engineering may have multiple-levels of work. [Supports Hypothesis #5]}
\]

\[
\text{Observation #4.4: Work perceived to have been initiated by Requirements Engineering is associated with a clear mission: a clear beginning and a clear ending. Work perceived to be initiated by Product Management appears to start well, but has no clear ending. [Refutes Hypothesis #5]}
\]

\[
\text{Observation #4.5: Defined Processes most unhelpful (45%) when personnel's assignments have a starting event or notification.}
\]

\[
\text{Observation #4.6: For assignments with a clear ending (and likely to impact schedule duration), about half the respondents considered the 'Defined Processes' to be largely inefficient.}
\]
Observation #4.7: Most assignments for development are initiated by Product Management and Requirements Engineering disciplines. However, Requirements Engineering initiates most of the assignments with a clear beginning, while Product Management initiates most of the assignments without a clear beginning. [Refutes Hypothesis #5]

Observation #4.8: Test Engineering triggers the majority of work completions.

RESULTS #4.4:
Figure 4-4 shows the distribution of what is valued most by each of the largest disciplines. Most SW and HW Engineers valued more functionality the most, while most Test Engineers valued fewer defects and better performance the most. SW Engineers did not value (internal) cost savings, and 20% of SW Engineers did not indicate any value of their work.

Observation #4.9: Different disciplines perceive different value in their work. While Software Engineers value most Number of Defect, Hardware Engineers value most Cost Savings, and Test Engineers and System Engineers value most Better Performance. [Supports Hypothesis #6]

Observation #4.10: While SW Engineers did not place the highest value on (internal) Cost Savings, many HW Engineers and Test Engineers did.
4.3 Knowledge and Process Architecture
Agile methods place a higher value on tacit knowledge than on explicit knowledge. According to Allen (1984), innovation organizations have informal structures (in addition to formal structures) one of which is the knowledge network. At the heart of this informal network are "technological gatekeepers" who keep "organizational colleagues in touch with current developments by means of his informal connections with the outside." The gatekeepers act as efficient pumps and routers of knowledge between the development organization and the world external to the organization. Hansen et al (2005) identify knowledge search cost and knowledge transfer cost as key factors determining the knowledge-sharing patterns (occurrence and effectiveness) in new-product development organizations, covering tacit knowledge and informal transfer of knowledge.

Between the Agile Manifesto and Allen, there seems to be 4 types of knowledge:

Finding #4.1: Knowledge in a technology organization can be put into 4 categories: tacit and formal, tacit and informal, explicit and formal, explicit and informal. [Supports Hypothesis #6]

Finding #4.2: Hansen et al (2005) found knowledge search to be 1% - 22% cost of total project cost, and knowledge transfer to be 1% - 57%. [Supports Hypothesis #6]

While the Agile manifesto states a preference for tacit (informal and formal) knowledge, Allen (2001) covers informal (tacit and explicit) knowledge and Hansen et al (2005) cover tacit informal knowledge, none seem to address explicit formal knowledge. Hansen et al (2005) characterize the drawback of tacit knowledge as:

"more difficult to explain its content and nuances to members of the focal team, who may in turn find it difficult to understand, thereby making the tasks of modifying and incorporating the knowledge into the product difficult."

Hansen et al then acknowledge conditions that would make explicit (=non-tacit) knowledge a better option:

"Because of these difficulties, transferring tacit knowledge is likely to be more cumbersome, take a longer time, and thus be more costly than transferring non-tacit knowledge."

Finding #4.3: While the Agile manifesto values tacit knowledge, knowledge search and transfer costs may, under certain conditions, make explicit knowledge a more cost-effective option. [Supports Hypothesis #6]
Formal knowledge is particularly important for classic development organizations and process automation vendors because of the broad range of stakeholders and their concerns (see Figure 3-3), and because of the breadth of disciplines that must be brought together (see Figure 4-9).

The survey results (Section 5.2) revealed that Development personnel at Eagle Corporation considered the company’s defined Engineering Standards to be one of the most important sources of knowledge about an assignment. This research aimed to uncover any underlying knowledge structure or emerging patterns resulting from decades of creating and updating engineering standards as repositories of knowledge.

4.3.1 Case Study Design
Over four decades, respected and expert individuals within Eagle Corporation have authored engineering standards. These standards are scrutinized by peers, and because of their obligatory burden on the company and possible auditing by external stakeholders, require review by experts representing key internal stakeholders. This (relatively) high professional standard associated with these documents made them a good candidate for research. The research consisted of reading every (more than 300) document comprising Eagle Corporation’s set of engineering standards. Any explicit reference to other documents was recorded. References to documents external to Eagle Corporation were recorded (for example IEEE standards, or IEC standards, CENELEC standards ...etc) but not included in the analysis, since the underlying objective of the research was to understand how agility would apply to an automation vendor such as Eagle Corporation.

4.3.1.1 Study Questions
The main questions behind this study were:

1. Is there a structure to Engineering Standards?
2. Will the structure help or hinder the agile learning cycle?
3. Can Engineering Standards be retained in an agile environment?

4.3.1.2 Study Propositions
1. The Engineering Standards have an underlying knowledge structure.
2. Engineering standards are captured knowledge that can buoy agile learning.

4.3.1.3 Unit of analysis
The unit of analysis is the explicit link between any 2 engineering standards documents.

4.3.1.4 Logic linking data to propositions
Proposition #1: Re-arranged structure matrix of linked standards showing major clusters of standards.
Proposition #2: Re-arranged structure matrix of linked standards showing clusters of reasonable size.
4.3.1.5 Criteria for interpreting findings

The purpose of this study was to determine if the engineering standards formed a knowledge structure. The criterion for what is structured and what is unstructured can be determined at different levels of precision, including reference to literature on cognitive psychology to determine how much information a typical person can master. For this study, the initial criterion will be what the eye perceives. If a visual inspection of the re-arranged structure matrix is not conclusive (either obvious structure or obvious lack of structure), then and only then will sophisticated criteria based on cognitive psychology be sought and used for further interpretation.

4.3.2 Results: Explicit Formal Knowledge

Figure 4-6(a) is the initial DSM (Design Structure Matrix) of the relationship among 324 Engineering Standards. Using MATLAB clustering macros developed by Ronnie Thebeau (Thebeau 2001), the DSM was re-organized to produce the best possible clustering of the documents. The re-organized DSM is shown in Figure 4-6(b). As can be seen, the re-organized DSM does not reveal any underlying structure.

*Observation #4.11: The Engineering Standards form an emergent explicit formal structure. The structure has no discernible patterns that can be used to re-organize it (into clusters) in a meaningful way. [Supports Hypothesis #6]*

The lack of a knowledge structure among the standards would make the use of these standards in agile learning-action cycles more difficult. While it would be impossible to expect everyone to be familiar with all standards, there would be no knowledge-based approach to assigning knowledge-ownership that would facilitate the time-sensitive learning + action cycles of agile development.

The MATLAB utility’s best attempt yielded 73 clusters ranging in size from 16 standards in a cluster to 2 standards in a cluster. The recommended clusters are shown in Appendix G. The distribution of cluster sizes is summarized in Figure 4-5.
4.3.3 Knowledge Loops

Using MATLAB, the structure of the engineering standards documents was analyzed for any underlying loops. These loops would be important when making changes to a standards document, or when using a standards document. The existence of loops is usually a source of surprise work if the precise number of iterations can never be known clearly during the initial (planning) stages of an assignment. Below is a summary of the standards found to be at the center of knowledge iterations. (See Appendix G for proposed clusters of the standards documents).
### Single iteration loops:

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>'136'</td>
<td>'93'</td>
<td>'159'</td>
<td>'135'</td>
<td>'101'</td>
</tr>
<tr>
<td>'134'</td>
<td>'49'</td>
<td>'138'</td>
<td>'17'</td>
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</table>

### 2 iteration loops:

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<tbody>
<tr>
<td>'136'</td>
<td>'93'</td>
<td>'159'</td>
<td>'135'</td>
<td>'101'</td>
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<tr>
<td>'134'</td>
<td>'49'</td>
<td>'138'</td>
<td>'17'</td>
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### 3 iteration loops:

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<tbody>
<tr>
<td>'136'</td>
<td>'291'</td>
<td>'137'</td>
<td>'57'</td>
<td>'68'</td>
<td>'33'</td>
</tr>
<tr>
<td>'134'</td>
<td>'159'</td>
<td>'55'</td>
<td>'64'</td>
<td>'69'</td>
<td>'262'</td>
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<tr>
<td>'93'</td>
<td>'138'</td>
<td>'289'</td>
<td>'31'</td>
<td>'115'</td>
<td>'246'</td>
</tr>
<tr>
<td>'49'</td>
<td>'135'</td>
<td>'292'</td>
<td>'119'</td>
<td>'116'</td>
<td>'247'</td>
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</tbody>
</table>

### 9 iteration loops:

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<tbody>
<tr>
<td>'136'</td>
<td>'135'</td>
<td>'57'</td>
<td>'292'</td>
<td>'68'</td>
<td>'262'</td>
<td></td>
</tr>
<tr>
<td>'134'</td>
<td>'137'</td>
<td>'64'</td>
<td>'65'</td>
<td>'69'</td>
<td>'246'</td>
<td></td>
</tr>
<tr>
<td>'93'</td>
<td>'49'</td>
<td>'17'</td>
<td>'4'</td>
<td>'115'</td>
<td>'247'</td>
<td></td>
</tr>
<tr>
<td>'159'</td>
<td>'55'</td>
<td>'101'</td>
<td>'31'</td>
<td>'116'</td>
<td>'247'</td>
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</tr>
<tr>
<td>'138'</td>
<td>'291'</td>
<td>'289'</td>
<td>'119'</td>
<td>'33'</td>
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</table>

### 19 iteration loops:

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<tbody>
<tr>
<td>'136'</td>
<td>'135'</td>
<td>'17'</td>
<td>'289'</td>
<td>'119'</td>
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<td>'134'</td>
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<td>'262'</td>
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<tr>
<td>'93'</td>
<td>'137'</td>
<td>'57'</td>
<td>'65'</td>
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</tr>
<tr>
<td>'159'</td>
<td>'55'</td>
<td>'101'</td>
<td>'4'</td>
<td>'115'</td>
<td>'247'</td>
<td></td>
</tr>
<tr>
<td>'138'</td>
<td>'64'</td>
<td>'247'</td>
<td>'31'</td>
<td>'116'</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Out of the 324 Corporate Standards, 9 were found to occur in all 6 iterations tested at random. These 9 standards are essentially *common channels* that facilitate looping through the standards documents and are as follows: '136', '134', '93', '49', '159', '138', '135', '17', '101'.

**Observation #4.12:** Despite the lack of a clear structure for re-organization, the structure of 300+ standards document revealed an unexpected pattern: 9 standards documents that show up repeatedly whenever formal iteration thru the 300+ standards is required.

The analysis essentially predicts a high likelihood of the need to consult these standards when knowledge iteration is necessary for a project team. To facilitate time-sensitive learning + action cycles of agile development, it may help to have these 9 standards be treated in a special way. For example, individuals may be designated to become human experts in those standards, in principle becoming the tacit knowledge-holders of explicit formal knowledge.
5. Agility

This section aims to establish the characteristics of, and success factors for, agile methods.

The primary objective is to test the following hypotheses:

- **Hypothesis #1:** Agile methods can improve time-to-market Process Automation products.
- **Hypothesis #6:** Development personnel are knowledge workers whose effectiveness and efficiency is based on discernible factors.

The research methods used were:

- Reviewing Literature on State-Of-the-Art
- Reviewing Literature on State-Of-the-Practice
- Interviewing Leaders / Experts on Process Automation Development Operations

5.1 Background

The case for Agility is rooted in both the business demands bearing on Process Automation Vendors, and the nature of software development. According to Kelly (2008) "Software Developers are knowledge Workers" where "...worker's individual knowledge makes little immediate difference to the end product." Today’s business environment is constantly changing as a result of both new competitors and changing customer expectations. Ideally, new knowledge acquired in technology can be used to create new opportunities, thereby providing a ‘feed forward’ effect to the changing business environment.

According to Crawley (2007), an Enterprise comprises 4 systems: Human, Economic, Natural and Knowledge, all depicted in Figure 5-1, with highly important factors to automation vendors underlined. Kelly (2008) states Agile is based on the view of Software Development as consisting of people, internal politics and emergent behavior. This view and that of Software Developers as knowledge workers suggest that agile methods focus primarily on the Human System and Knowledge System. This thesis will therefore extend the scope of agility to include the Economic System (as a source of business drivers) and Natural System (physics, Materials Science, mechanics and packaging of components). All knowledge system factors and economic system factors are underlined for a process automation vendor. The importance of the economic system is consistent with the business threats identified in chapter 2, while the importance of the knowledge system supports the centrality of innovation to automation vendors.

*Finding #5.1:* Agile practices focus primarily on the Human and Knowledge Systems. The scope of agility can be extended to the entire enterprise by including the Economic and Natural Systems of the enterprise. [Supports Hypothesis #6]
Figure 5-1: Automation vendor enterprise model --- Adapted from Crawley (2008)
5.2 Underlying Principles of Agile

Ulf Henriksson, CEO of Invensys plc, defines agility as an enterprise-wide core value necessary to “adapt, grow and swiftly change for a sustainable future.” According to Jeffingwell (2007), the aim for Agile methods is to create “reliable software more quickly and doing so while eliminating unnecessary waste and unproductive overhead.” Lean and agile form a “virtuous cycle”: lean eliminates waste, increasing the opportunity to “identify and deliver value” (enterprise-wide). This captured value will enable additional resources and motivation to eliminate more waste. At the enterprise level, Murmann et al (2002) and Kelly (2008) Agility can be viewed in the context of a Lean Enterprise, as depicted in Figure 5-2. While agility can be considered at different levels of an enterprise, agile methods can be considered at the narrower program level. At this level, agile methods can be contrasted with plan-based methods.

<table>
<thead>
<tr>
<th>Organizational Level</th>
<th>Program Team</th>
<th>Program</th>
<th>Development Group</th>
<th>Profit &amp; Loss Unit</th>
<th>Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>XP</td>
<td>Scrum</td>
<td>FDD</td>
<td>RUP</td>
<td>Stage Gate</td>
<td>Waterfall</td>
</tr>
<tr>
<td>Agile</td>
<td>Lean Product Development</td>
<td>Lean Enterprise</td>
<td>Learning Enterprise</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5-2: Agile Formal Adoption Model — adapted from Kelly (2008)

There are many agile methods, each with particular emphasis and strength. Common agile methods are:

<table>
<thead>
<tr>
<th>XP (Extreme Programming)</th>
<th>Programmer-centric view of development</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD (Adaptive Software Development)</td>
<td>Project Management method based on team empowerment, and constant cycle of inspection + adaptation.</td>
</tr>
<tr>
<td>Scrum</td>
<td>Architecture-centric iterative and incremental method for Enterprise-scale development.</td>
</tr>
<tr>
<td>Crystal Clear</td>
<td>A lean software method based on domain object modeling</td>
</tr>
<tr>
<td>RUP (Rational Unified Process)</td>
<td></td>
</tr>
<tr>
<td>DSDM (Dynamic System Development Method)</td>
<td></td>
</tr>
<tr>
<td>FDD (Feature Driven Development)</td>
<td></td>
</tr>
</tbody>
</table>

A process automation project, with its typical technical complexity and range of stakeholders, will typically require a combination of agile methods, such as:

- XP (for software development)
- Scrum (for project management)
- FDD (for modeling incremental innovation + build management)
- RUP (for architectural innovation)
5.3 Organization for Agility

Based on Murmann et al (2002) and Kelly (2008), the pre-requisites for agility are:

- Organization is lean, and/or practicing lean principles
- Individuals empowered to act upon what they have learnt
- Trust and honesty among individuals
- Organization must know how to tolerate failure

According to Kelly (2008), learning and change happens at many levels: individual, team and organizational. An important level of learning not included in Kelly (2008) is the systems level where systems thinking principles focus on:

- Emergent relationships among components
- Emergent patterns
- Emergent interactions and inter-operations.

In addition, Leveson (1996) provides perspective into the corollary concept of system complexity. Leveson suggests that the challenges of building complex systems may be rooted in the intellectual manageability and human limits in managing complexity. Given that the basic human ability is not changing, it becomes necessary to augment human ability "both in terms of system designers and system users." Leveson recommends turning to cognitive psychology and social sciences for ideas to augment engineering foundations.

Kelly (2008) suggests that traditional development organizations use pre-defined processes as a defensive mechanism whereby failures can be attributed to flaws in process. For process automation vendors, stakeholders usually expect an individual in the vendor organization to be accountable for the process, so failures are not casually attributed to the process. Kelly (2008) also discourages having a common pool of developers because such an arrangement undermines a team vision. However, it is also possible that a strong culture centered on pre-defined processes obviates the need for a strong common vision and facilitates the establishment of a common-pool of developers.

Finding #5.2: Agile practices discourage a common pool of developers because of the need for a
strong team vision to bind and focus the team-members. However, it is also possible that a strong team vision is necessary in the absence of a common pool of developers guided by a pre-defined process.
Finding #5.3: The following organizational practices are not covered:

- **Transitioning to Agile**, to ensure non-disruptive co-existence of legacy processes and agile practices. [Supports Hypothesis #2]

- **Investing in Agile Capability**, a Corporate-sponsored strategic investment in capability (personnel, infrastructure and tools) to enable and sustain a higher-level of operational performance. [Supports Hypothesis #2]

5.4 Agile Manifesto for Process Automation

Agile Manifesto (2009) is very specific about what is more valuable during product development:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

**Finding #5.4:** Agile methods are founded on 5 principles of lean, 4 agile values, and 12 agile principles, all fixed.

Of the manifesto’s 12 principles, 8 have to be re-assessed for Process Automation offerings, as follows:

“Our highest priority is to satisfy the customer through early and continuous delivery of valuable software. “

Customers want a high quality solution. Continuous delivery is likely to be burdensome because of the cost of deploying changed software. However, this challenge presents an innovation opportunity to (and potential competitive edge for) an Automation vendor.

**Finding #5.5:** Focus should be on customer needs, rather than quality improvement or (internal) productivity enhancement. [Supports Hypothesis #3]

“Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage. “

This principle is highly valuable for Automation customers because they want a short time-for-last request, and have narrow but imprecise windows of opportunity to deploy new features.
“Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale. ”

Any benefits for an Automation vendor will be primarily internal to Team operations. For Process Automation Systems, regression testing, integration-testing and system-testing often take months. This principle may however spur innovation to complete regression testing in weeks.

“Business people and developers must work together daily throughout the project. “

Experts say Development personnel from Automation vendors are generally insular with little knowledge about Customers and narrow and decreasing knowledge about manufacturing. While this principle will help redress the empathy gap, Developers may struggle working directly with manufacturer representatives.

“The most efficient and effective method of conveying information to and within a development team is face-to-face conversation. “

While this reinforces Allen’s law, data does not support face-to-face to be the only efficient way. In fact data shows Engineering Standards to be very effective in pinpointing errors (essential for the high quality.)

“Working software is the primary measure of progress. “

For Process Automation offerings, only ‘high quality’ working software can be accepted as measure of success. Low quality working software is so disruptive that it is worse than no software at all.

“Simplicity--the art of maximizing the amount of work not done--is essential.”

For Process Automation offerings are typically components (modules or subsystems) of a complex system. This principle should therefore be practiced as advised by Crawley (2007) in accordance with the key System Architecting principles of “reducing complexity, resolving ambiguity and focusing creativity”. Often, requirements are articulated to provide contractual form to an (unarticulated) intent. However, access to intent may provide a better design, and access to experts in stakeholders’ needs may be essential to obtain the best architecture.

“The best architectures, requirements, and designs emerge from self-organizing teams.”

The number of stakeholders, diversity in customer types, and chain of Users for an automation system makes the gathering of requirements particularly challenging. Often, requirements are articulated to provide contractual form to an (unarticulated) intent. It is not clear how willing
customers will be willing to contractually accept anything less formal than traditional requirements. During architectural design, access to intent may provide a better design. Access to experts in stakeholders' needs is essential for the best architecture.

Finding #5.6: While 9 of the 12 agile principles need rigorous re-evaluation for Process Automation, they may also provide opportunities for innovation. These principles already have demonstrated value outside process automation, and many practices associated with the principles are well documented.
While the manifesto has fixed agile values and agile principles, different literature emphasizes different practices. Table 5-1 below summarizes practices from 3 different books. Practices that are common between books are noted with a linking identifier.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enterprise Agility:</strong></td>
<td><strong>Team Agility:</strong></td>
<td><strong>Learning Cycle:</strong></td>
</tr>
<tr>
<td>• Define / build / test component team</td>
<td>• Code reviews</td>
<td>• Test-First Development <em>(KE1)</em></td>
</tr>
<tr>
<td>• Two-level planning and tracking</td>
<td>• Release often <em>(KLE1)</em></td>
<td>• Daily Cycle <em>(a,</em>)</td>
</tr>
<tr>
<td>• Mastering the iteration <em>(LE1)</em></td>
<td>• Test Driven Development <em>(KE2)</em></td>
<td>• Test-Driven Requirements <em>(KE2)</em></td>
</tr>
<tr>
<td>• Smaller, more frequent releases <em>(KLE1)</em></td>
<td>• Pair programming <em>(KE3)</em></td>
<td>• Iteration <em>(LE1)</em></td>
</tr>
<tr>
<td>• Concurrent testing</td>
<td>• Automated testing <em>(KE1)</em></td>
<td>• Demo</td>
</tr>
<tr>
<td>• Continuous integration <em>(KL1)</em></td>
<td>• Continuous integration <em>(KL1)</em></td>
<td>• Retrospectives <em>(LE2)</em></td>
</tr>
<tr>
<td>• Regular reflection and adaptation <em>(LE2)</em></td>
<td>• Quality before features</td>
<td>• Release Often <em>(KLE1)</em></td>
</tr>
<tr>
<td></td>
<td>• Malleable design</td>
<td>• Scrum of Scrums <em>(a,</em>)</td>
</tr>
<tr>
<td></td>
<td>• Refactoring</td>
<td>• Management Tests</td>
</tr>
</tbody>
</table>

**Complex long-lived systems:**

- Intentional Architecture
- Vision + roadmap + JIT elaboration
- Agile Release Train
- Managing Highly Distributed Teams
- Impact on Customers and Operations
- Changing the organization

*(a,*) This activity is explicitly recommended by Leffingwell (2007), although not listed there as a practice.

Table 5-1: Agile Practices
5.5 Agile Methods for Process Automation

5.5.1 State-Of-the-Art
Kelly (2008) asserts that **Knowledge = Learning + Action**. Moreover, businesses today obtain a competitive advantage through access to knowledge, and by acting on that knowledge. The specific objective of learning is to improve products, the understanding of customer needs, and the processes in use. Focusing on quality improvement, productivity enhancement and cost cutting is unhelpful, although making Developers more productive is an important goal for agile methods. Kelly (2008) identifies 9 agile practices, listed in Table 5-1.

Agile discourages adding reusable code. Instead, preparation for the future is through people rather code. Kelly (2008) also recommends the following attitudes to accompany agile practices:

- Accept that requirements will change
- Organize software development activities as projects
- Focus on incremental innovation

The above practices and recommendation are further evaluated with respect to the key stakeholders in process automation systems (see Chapter 3):

**Pair programming**
Although this approach works well for individual software module, it is unclear how it would work for a System. Moreover, Leveson (1996) cites interfaces and software complexity as being the primary cause of software failures:

"The problems in building complex systems today often arise in the interfaces between the components... where the components may be hardware, software or human."

**Finding #5.7**: Agile methods do not include systems thinking considerations. In particular, the practice of pair programming does not address the systems level needs.

**Test Driven Development**
This approach works well for positive testing, for example to show that a function produces the correct output when given a known input. However, it is inadequate for negative testing, for example when testing how robust software in the presence of out-of-spec conditions. Test-cases must test for emergent behavior which is specific to an implementation and independent of requirements.

**Finding #5.8**: Test Driven Development is inadequate for negative testing since that must include test-cases to behavior that emerges from the implemented system.
Quality before features

Quality is an overloaded word. Given the stakeholders identified in Chapter 4, the various definitions of quality should be enumerated. Although considering quality before implementing features is an important practice, considering quality after features have been implemented is even more critical.

Finding #5.9: The following Large-Scale system complexity practices are not covered:

- **Managing Critical System Parameters**, to ensure architectures and designs preserve essential system (emergent) properties expected by stakeholders. (see PDSS, 2006)
- **Engineering System Robustness**, to confirm the implemented (constructed) architecture fulfills “intent associated with the externally delivered processes which are traceable to customer needs.” (See Crawley, 2007 and Frey, 2007). [Supports Hypothesis #2]

Malleable design

The emphasis on a malleable design and the avoidance of re-usable code are together a promising solution to the problem of re-usable code. Leveson (1996) argues that the practice of code re-usability has been a dominant source of catastrophic accidents. This is particularly true of software that controls machinery or energy sources, and is fundamentally rooted in how software can create interactions among physical components that would be impossible in the natural world. Since software is developed, tested and qualified in a defined context, it is risky to generalize that context to all other situations.

Finding #5.10: Emphasis on Malleable Design over re-usable code will end the misplaced expectations of re-usable software.

Valerdi et al (2009) provides a comprehensive treatment of the value of system engineering re-use, providing some important observations that should guide this recommended practice:

*Observation #3: Products, processes, and knowledge are all reusable artifacts.*

*Observation #6: Reuse is knowledge that must be deliberately captured in order to be beneficial.*

*Observation #8: The benefits of reuse do not scale linearly.*

Refactoring

Because of the high switching costs for manufacturers, a process automation vendor usually has a sizeable installed base. The software in that installed base is usually controlling dangerous
machinery or elements, often after approval by representative of the stakeholders identified in Chapter 3. Concerns over applying re-factored software to an application controlling a running plant can be compared to concerns over re-using software, covered by Leveson (2004). (Refactoring changes platform software and assumes no change to application, while re-use changes application and assumes no change to platform software).

Finding #5.11: Refactoring released software used to control a manufacturing plant, will create apprehension among manufacturers and stakeholders. [Supports Hypothesis #4]

Release Often
This practice was identified as undesirable by at least one of the Operations Management experts interviewed for this research. Most Process Control Systems are not connected to the network, and any change to a deployed automation system requires human supervision. Producing too many releases will be burdensome, and potentially costly, to manufacturers. It may also increase risk to system upsets. Elssamadisy (2009) also recognizes release often as being a problem for enterprise customers. However, no fundamental technical reasons are offered to disqualify this practice for the automation industry. Capability for painless multiple migration paths for customers may eliminate the burden to customers.

Accept that requirements will change
Requirements could change for many reasons. The author seems to assume changes in the business environment to be the root cause of the requirement change. But changes may be due to poorly understood needs. They could also be due to regulatory changes. It is not clear whether agile methods should have different practices for different root-causes for requirements changes. This is echoed strongly in a different form in LaFon (2008) which states that “Sources of change are evolving technologies, determinations and discoveries made during feasibility analyses, discovery of missing or poorly designed system specifications, or discovery of incorrectly specified components and technologies.”

Finding #5.12: Expecting requirements to change is at the heart of agility, but does introduce considerable uncertainty to a project, especially since there could be many different root-causes for a change in requirement.

Organize software development activities as projects
According to Pressmann (2001), projects are generally required to have a schedule and plans for resources. A project is therefore not appropriate for activities with considerable (technological
and organizational) uncertainty and which can therefore not be scheduled effectively. However, these types of projects can be classified as research projects, and a separate set of agile recommendations should be provided for research projects. Pressman (2001) for example, accounts for ‘prototyping’ in traditional development processes as an approach to remove technical and organizational uncertainty.

Finding #5.13: Project Management literature asserts that a highly effective strategy that includes mission statement, top management support and planning, is important for a successful project, while agile methods encourage only a good Team vision.

Focus on incremental innovation
As established in Chapter 3, manufacturers are conservative and cautious, and therefore prefer incremental innovation. However the complex value-chain established in Chapter 4 and manufacturer complaints about gaps in offerings may require breakthrough innovation, and perhaps even innovation disruptive to manufacturer processes.

Finding #5.14: Agile methods are most suitable for incremental innovation.
[Supports Hypothesis #4]

Katz (2004) characterizes projects with ‘high potential’ for implementation success as having both a highly effective strategy (planning phase) and highly effective tactics (implementation and execution). Projects with low effective strategy but highly effective tactics are more likely to have “high acceptance misuse”. Work will be done when there is no solid justification for it, or the wrong problem will be solved. Agile Methods address the need for highly effective Strategy partially through the emphasis on a Team Vision, while highly effective tactics are addressed by the learning + action cycle. While it is the actual practices that will determine the extent to which an agile implementation meets Katz (2004) standard for high potential, the principles for agile expect a high standard.

5.5.2 State-Of-the-Practice
Interviewing leaders and experts on innovation operations for Process Automation provided the following valuable insight into the state-of-practices by Vendors:

<table>
<thead>
<tr>
<th>Comparison of Automation Vendor practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation Vendors are not in the leading edge. On the whole they are slow followers of technology. This may be due to the long lifecycle (10-20 years) of automation offerings. Specifically, Vendors are behind in their processes, methods, tools and product development infrastructure</td>
</tr>
</tbody>
</table>
Observation #5.1: Automation vendors are largely behind state-of-the-art and state-of-the-practice.

Ability of Automation vendors to find proper balance of Agile practices
Automation vendors will likely need outside help. The process automation industry faces three major disadvantages when it comes to implementing process changes:

- Little cross-pollination of personnel with other industries (inter-industry cross-pollination)
- Little cross-pollination of personnel from other Automation vendors (intra-industry pollination)
- Little migration of personnel to different functions in the same company (intra-company pollination).

This degree of insularity prevents Automation vendors from implementing practicable process changes.

Observation #5.2: Automation vendors’ personnel are in general insular, with little cross-pollination with other industries. Automation vendors or even functions. Transformation to agility will therefore require external help.

Selecting Agile practices
Agile practices must be selected to fit the nature of the offering. The range of offerings is broad: a web-app that is low-risk, multiple-release tolerant and connected to the web vs. a mission-critical offering that must have a technician interface for any changes, is not on the network, and must have very high-quality from the outset. Agile practices should also address customers’ real needs. Customers are not concerned about the absolute time-to-market of an offering. They care about the ability to make late breaking requests prior to the end of the project. Agile methods should focus on providing a ‘last-time to make a change’ accommodation. Some changes may require Architectural changes, but those should be pointed out. Moreover, Product Managers usually ask for a lot of features, but are usually driven by the fear of leaving out a feature that a customer might just need.

Observation #5.3: Manufacturers are not concerned with the overall time-to-market. Their principal concern is time-to-make last request. Manufacturers would like this time to be as close to release-time as possible. [Devalues Hypothesis #1]

Agile Practices for Process Automation
Any practices in place for Process Automation offerings must:

- Preserve zero tolerance to risk
- Preserve zero tolerance to failures
- Enable good quality control practices
- Enable testing practices consistent with 6-8 weeks work cycles.
Moreover, new automation offerings are typically being introduced into a well-established manufacturing industry. Even though an offering may be new, expectations for its level of quality and permissible level of risk are well known.

*Observation #5.4:* Adoption of Agile Methods must not add new risks to the offerings, and must preserve the ability for good Quality Control.

*Observation #5.5:* Agile methods have a cycle-time of 6-8 weeks. This is longer most System-Testing cycles, so adoption of Agile may necessitate changes to System testing practices.

**Drivers for adoption of Agile**

Adoption of Agile is decoupled from other Enterprise-related initiatives. Moreover, there is little evidence that successful adoption of Agile is correlated with the industry sector. The personality of practitioners driving the adoption of Agile seems key to successful adoption.

### 5.6 Large-Scale Agility

#### 5.6.1 Agile Practice for large organizations

Leffingwell (2007), noting that “XP is not sufficient for managing requirements of large scale system”, emphasizes the following benefits of agile development:

- More likely to be first to market
- Delivering solutions that directly address customers’ pain points
- Delivering solutions that have requisite quality and functionality
- Adapting more rapidly to business and technology changes

Leffingwell (2007) recommends 14 practices for a large scale system, identified in Table 5-1, intended to address the challenges of organizing for agility in large organizations. Some of the practices however, require further evaluation given the actual characteristics of the Process Automation sector and general requirements of a Process Automation offering.

**Intentional Architecting**

The defined practice mentions the importance of working code, but there is insufficient emphasis of the need to confirm early on that the architecture meets the intent.

**Lean requirements: Vision, roadmap, just-in-time elaboration**

62
This practice is intended to ensure performance, reliability, and scalability needs are understood by all teams. Moreover, a vision is intended to be a container for non-functional requirements. However, it is not clear if the style and brevity of a good vision statement will be sufficient to satisfy Automation Stakeholders, with real concern and justified paranoia about possible loss of life as a result of system failures.

While the roadmap provides a good tool to prioritize needs, it is not clear who defines the roadmap, and how the assumptions underlying the prioritization decisions are captured and checked. The observations in Chapter 5 suggest that Automation vendors often make wrong guesses about what Manufacturers actually need.

Observation #5.6: Agile is being implemented independent of lean initiatives.

Managing highly distributed teams
Agile may in fact make distributed development more challenging. In plan-driven development, people-people communication protocols can be defined to mitigate the effects of distance. Multi-location multi-time-zones development may make daily-meetings intrusive, while relying on ad-hoc communications routinely extends response time to a problem to >24 hours.

Observation #5.7: Daily stand up meetings may be intrusive for multi-geography multi-time-zone project. It may necessary to plan for a communication mechanism that would ensure response-time to queries not stretched to days.

Changing the organization
This practice serves to place focus on continual re-organization to identify roadblocks, bottlenecks and cultural impediments. It does not however address re-organization necessary to transition from classical plan-based development to agile. The challenges of co-existence between the two approaches for development must be carefully managed to ensure quality of offerings is not affected. Moreover, the practice does not address whether more personnel and resources will be required to implement agility. The need to fit system testing and regression testing into an 8 week time-frame will likely require additional investment.

Measuring business performance
The defined practice provides metrics that are helpful about an ongoing project. There is however no connection to the agile framework in place and the agile practices chosen.
Leffingwell (2007) recommends the Release Management Train (RMT) as the mechanism to coordinate releases from multiple teams. The RMT will have a number of properties, many of which will likely change over the duration of a project, such as:

- A vision with themes and End-to-End use cases
- Each RMT release must be customer-ready, even if it is just an internal release. A release will be preceded by 3 Team iterations + 1 Hardening iteration. Each Team must therefore have a primary plan and a fallback plan.
- RMT meets weekly, and is responsible for finding roadblocks.

Finding #5.15: The Release Management Train should be treated as a project artifact, subject to the expected best-practices of configuration management.

5.6.2 Agile Practices large systems
Elssamadisy (2009) emphasizes the following business values of Agile:

- Product Utility (value to market)
- Increase Visibility
- Increase Quality to market
- Reduce Cost to Develop
- Increase Flexibility
- Increase Product Lifetime

In this research, manufacturer experts suggested that Automation offerings are becoming increasingly commoditized. These offerings already have a long lifetime (20-30 years). Increase Product Lifetime is therefore unlikely to be a priority for Process Automation vendors. New offerings would enable vendors to ask for higher prices, while manufacturers expect existing products to go down in price over time.

Elssamadisy (2009) explores patterns (practices and guiding principles) for scaling up agile methods to large development organizations such as a major Process Automation vendor. These patterns are founded on focusing development on delivering business value and recognizing project “smells”. 3 major types of patterns are proposed:

- For rapid feedback: iteration, kickoff, stand-up, demos and retrospectives
- For fostering Team development: co-location, self-organization, cross-functional roles, and customer-part-of-team.
- For facilitating technical tasks: testing, refactoring, continuous integration, simple design, collective code ownership and pair programming

Elssamadisy (2009) makes specific recommendations for managing agile projects. The recommendations are based on the following premises:
"Software development professionals are highly trained knowledge workers. They are more qualified to make decisions regarding how best to do their jobs than their managers."

"It is demoralizing and frustrating to professionals when they can see a solution to heir problems but official processes and procedures impede that solution."

Elssamadisy (2009) recommends that management communicate goals rather than mandate tasks. Documentation should be kept to the very minimum, and stand-up meetings should be the principal forum to discuss and resolve problems. Moreover, the purpose of any document should be to evoke discussion. For very large projects, Elssamadisy (2009) recommends scrum of scrums.

Finding #5.16: While the agile values and principles are fixed, agile practices are not. Different agile thought-leaders offer different practices, although some practices are common.

Finding #5.17: While Leffingwell (2007) recommends a hardening iteration to ensure a release is ready for internal release or customer assessment, Elssamadisy (2009) views hardening as a "smell", a bad or inefficient practice.

5.6.3 People aspects of Agility

From the various literatures, it is possible to infer different types of agility: personal, team, organizational, enterprise and market. The researched literature covered team, organizational and enterprise agility. There is little mention of personal agility: how individuals make themselves more agile. Personal agility also applies to personnel in all stakeholder organizations. Leffingwell (2007) asserts "new teams and new personnel in these product-driving roles are a primary factor in the success of the agile enterprise."

While Elssamadisy (2009) states that "deliver(ing) value to the customer is the main driver for all Agile development practices" and adds that it is therefore important to "know what business value is delivered by the software development practices we use", RESULTS #4.5 shows that personnel differ in what they consider the most important value of their work, based on role. While this diversity of work value is probably beneficial in general, entrenched differences in what is most important (e.g. defect count vs. product performance) are likely to be a challenge for a cross-functional agile team that must be guided by a single vision and governed by 6-8 week iterations.

Finding #5.18: The literature has little mention of personal agility: how individuals can train themselves to be successful practitioners of agility. It is important to all individuals in a team to...
commit to a common customer (or business) value, given entrenched differences among personnel types about what is most valuable in a product. [Supports Hypothesis #6]

Elssamadisy (2009) also says “individual responsibility is the bedrock of personal agility”. Individuals must know they are responsible to recognize and respond to change. In established development organizations, it is not unusual for engineers to detect a problem but feel unauthorized, inadequate or intrusive in pointing it out.

Agile development emphasizes “communication in every aspect of SW development process.” More person-to-person communication is expected for agile projects. For distributed teams, this means more travelling for team members (not just managers), and ready-access to telephones.

**Finding #5.19:** The following dynamic large-scale business value practices are not covered:

- **Assuring Domain Expertise**, to ensure all assumptions and expectations about domain knowledge are understood, assessed and challenged, and to access the latest in state-of-the-practice. [Supports Hypothesis #6]

- **Clarifying Ecosystem Role**, to ensure team’s vision and other selected practices reinforce and support either good platform leadership or good platform contribution. [Supports Hypothesis #6]

### 5.7 Case Study: Time-to-market

The need for faster time-to-market logically leads to a requirement to doing design and development in less elapsed time. This can be achieved by reducing the elapsed time of planned activities or doing fewer activities, or a combination thereof through re-use.

#### 5.7.1 Reducing Elapsed Time

The reported labor of an actual development project of an Automation offering was analyzed. The project was a multiyear project, multi-geography (3 continents), multi-time zone project, involving 50-100 people. It was primarily a software project with limited embedded software for a hardware module.

Analysis of labor hours reported against the project showed that 81% of the effort was spent on Design & Development (= Implementation/Construction) and Testing (= Functional Testing). Figure 5-3 summarizes the cumulative amount of labor for the most time-consuming disciplines. Figure 4-4 plots the cumulative contribution of Design & Development vs. Functional Testing, while Figure 5-5 shows the % of people participating over time, as a fraction of the total number of people involved in the project.
Figure 5-3: Multi-Discipline Work Progress

Figure 5-4: Effort Contribution

Figure 5-5: People Participation
RESULTS #5.1:

- The overall testing effort is almost the same as the Implementation/Construction effort.
- The Implementation/Construction effort is a constant throughout the project. The Functional Testing effort is also a constant throughout the project. It is as though Developers and Functional Testers are already working fully in parallel throughout the project.
- Requirements Engineering and System Testing are done in steps.

RESULTS #5.2:

- Work on defects (reproducing bugs, fixing bugs and validating fixes) takes as much as 15% of the total effort. About 40% of the effort occurs in the last 30% of the project time.
- The number of people getting involved in the project is at a maximum at the beginning of the project, but falls off steadily.
- 90% of System Testing effort has been expended when the project is at 50% mark of Elapsed Time.

Observation #5.8: For a process automation vendor studied, coding and functional testing are already concurrent. Integration testing is partly concurrent with coding and functional testing, while system testing and requirements engineering are not. Any substantial benefits in concurrency can therefore only come from making system testing or requirements engineering concurrent. However, these only account for 1.6% of the total effort.

Noteworthy, by the time 90% of System Testing had been complete, the project was at its 50% mark, suggesting that the early system testing effort may have uncovered deficiencies that significantly lengthened the project duration. Creating new concurrency requires investment. Additional resources and infrastructure will be needed to manage the team-sharing and collaboration with stakeholders. And just as with Lean transformation, adopting agile methods will require permanent investment to preserve the higher level of performance.

5.7.2 Re-Use

Elapsed Time can also be reduced by identifying fewer tasks that need to be done, or by reducing the effort needed for tasks, for example through re-use. While re-using code is fraught with many problems, re-using Use Cases and design means less time need be spent on these activities. Valerdi et al (2009) describes the benefits of System Engineering re-use, and provides a cost-model, COSYSMO 2.0, that can be used to estimate the cost (savings) from re-use.
5.8 Risk Balancing
In a separate (unpublished) survey study carried out by this thesis author on general software development methods and practices, it was found that there are "2 dominant modes of assessing software methods: Waterfall vs. Iterative and Plan-Driven vs. Agile". The emergent landscape of software methods is shown below:

Considerations for Waterfall vs. Iterative are well-documented in for example Pressman (2001). The key considerations for choosing between plan-driven and agile are covered by Boehm (2004), which identifies 5 risk factors that must be independently assessed for each project. Based on the combined actual risks of the project, the project must be executed with the appropriate balance of plan-driven methods and agile methods. The "five critical factors involved in determining the relative suitability of agile or plan-driven methods in a particular project situation" are: project's size, criticality, dynamism, personnel and culture.

Finding #5.20: The following large project complexity practices are not covered:

- **Continuous System Validation**, to ensure the required project regression testing and system testing can all be completed within the 6-8 weeks sprint time.

- **Balancing Risk**, to select the appropriate balance of agility vs. plan-driven methods based on the actual risks in project size, criticality, dynamism, personnel and culture.
5.9 Alignment for Agility: Metrics

Agility is a noun indicating the extent to which a group or organization is agile. Reinartz (2008) recommends using outcome-oriented indicators over activity-based indicators. Bettencourt (2008) goes further by recommending the use of customer-oriented metrics and distinguishing between job-mapping and process-mapping. While job-mapping focuses on what the customer is trying to do (with the offering) at each step of his experience, process-mapping focuses on what the customer must actually do (or is forced to do).

Blackburn (2009) advises that “An effective system of metrics is developed when the principal aspects influencing the production process are related to how value is perceived by the customer.” Citing Lewis (2004) for inspiration, Blackburn (2009) proposes a concept of metrics that encourages Synergy & the Effects of Organizational Focus where “…the effects of the aggregate working together should be greater than the sum of the individual talents.”

In contrast, Martin (2006) proposes the Vollman Triangle as the building block for the Vollman decomposition. A manufacturer (i.e. customer) can perform the Vollman decomposition recursively in a strategy to measure the performance of an operating plan.

Agile methods are small-team practices intended to have an emergent enterprise-wide impact, suggesting a metrics framework that combines a scalable metrics set (such as Vollman triangle) with a synergistic metrics view (such as Blackburn’s organizational focus) while still preserving the focus on the customer (Bettencourt’s customer-oriented metrics).

There are therefore at least 3 types of information that need to be combined to provide indication of agility:

- The adoption of agile methods and organizational structures supporting agility
- The emergent culture, effectiveness, and efficiency of agility to map the customer’s job and deliver an offering
- The realized business value and actual customer process-mapping associated with offerings.

McGarry et al (2002) emphasize the importance to map information needs into information measures. The needs should be prioritized, although the prioritization may be dynamic. It should also be clear what kind of data is needed. The data could be historical (for indicators), planning (for estimating) or actual (for monitoring and control). The level and breadth of aggregation must also be clearly identified in process automation where scale (i.e., complexity of systems, size of systems, and emergent system of
systems) is itself to be estimated, monitored and analyzed. In the case of software, there are at least three types of aggregations that need metrics:

**Component aggregation:** subsystem component combined together to produce a larger entity with emergent quality property values.

**Functional aggregation:** software functions aggregated through permitted inter-function invocation to fulfill requirements.

**Activity aggregation:** tasks aggregated in sets of permitted task sequences to provide User work-flows.

Lewis (2004), with a bias towards a statistical treatment of data, offers additional consideration for metrics. He cautions against one-dimensional statistics that are “especially tempting when the associated measure is easy to make”, and adds “that which is most important can be found in statistics” because “Statistics enabled you to find your way past all sorts of sight-based ...prejudices”.

### 5.9.1 Metrics Tetra Transforms

This research recommends a metrics framework to measure the alignment of an organization’s agility. The framework has 2 fundamental elements: **Metrics Tetrahedron** for each context of agility, and **Transformation Rules** that link one context to another.

![Metrics Tetra](image)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>What to achieve, for example by maximizing or minimizing</td>
</tr>
<tr>
<td>Enabling</td>
<td>Free to vary as necessary</td>
</tr>
<tr>
<td>Costing</td>
<td>What to monitor and minimize</td>
</tr>
<tr>
<td>People Factor</td>
<td>Pr[Goal, Enabling, Costing]</td>
</tr>
</tbody>
</table>

**Figure 5-7: Metrics Tetra**
The Metrics Tetrahedron, shown in Figure 5-7, is a *Multivariable System Optimization Operator*, with:

<table>
<thead>
<tr>
<th>Goal Measure:</th>
<th>objective measure to maximize or minimize or optimize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabling Measure:</td>
<td>(largely) free variable</td>
</tr>
<tr>
<td>Costing Measure:</td>
<td>(largely) constrained variable</td>
</tr>
<tr>
<td>People Factor:</td>
<td>(Probabilistic) indication that personnel can cope with the specific combination of the 3 measures.</td>
</tr>
</tbody>
</table>

Each organization can customize this framework to select most important measures, and to define an objective function that best reflects the company’s business or operational objectives. This research demonstrated that careful selection of the measures and objective function, can give metrics that can be used to measure the effective gain of agility. Figure 5-8 shows 3 contexts chosen for agility: the Development Organization’s Capacity, the Execution Focus, and Economic Value. The *Organization’s Capacity* context focuses on the idealized potential of the organization’s endowments such as processes, personnel skill-sets, engineering standards and company culture. The *Execution Focus* measures how well the organization’s capacity is brought to bear on specific set of (project) objectives to create value. The *Economic Value* context measures how the created value is actually captured.

Experience in Software Engineering informs that associating measures in one context (e.g. Organization Capacity) to another (e.g. Project Execution) is not a simple 1-to-1 mapping. This thesis asserts that the mapping between contexts is transformational: all factors in one context determine all factors in the other:

*Assertion #5.1:* Measures in *Organization Capacity* context do not have a simple mapping to measures in *Project Execution* context or *Economic Value* context. Instead metrics across contexts will require multiple measures from each context.

Equation 5-1 results from the metrics and measures defined in Table 5-1, 5-2, and 5-3, together with the following generalized objective function being used all contexts:

\[ Q(T) = \frac{\text{Goal measure} \times \text{Enabling measure}}{\text{Costing measure}} \]

The significance of Equation 5-1 is that the \( Q \) metrics can be compared across contexts to assess agility. So \( Q_v \), the Economic Value metric is quantitatively related to \( Q_x \), the Execution Focus metric, and \( Q_0 \), the Organization Capacity metric.

While this framework permits an organization to select its own measures, the key to a context-consistent framework is the choice of units for the measures. Each measure must be selected in accordance with McGarry et al (2002), while the set of measures in each context must yield consistent units of the metric \( Q(T) \) across all contexts.
Figure 5-8: Metrics System for Agility
### Table 5-2: Organization's Capacity

<table>
<thead>
<tr>
<th>Metric type</th>
<th>Metric name</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal measure: ((G))</td>
<td>Capacity</td>
<td>Function_points / Engineers_Testers</td>
</tr>
<tr>
<td>Enabling measure: ((E))</td>
<td>Development Process</td>
<td>minimum_time / standards</td>
</tr>
<tr>
<td>Costing measure: ((C))</td>
<td>Engineering Standards</td>
<td>minimum_cost / standards * Engineers_Testers</td>
</tr>
<tr>
<td>People Factor: (Pr[ G,E,C])</td>
<td>Effectiveness &amp; Efficiency</td>
<td>---</td>
</tr>
<tr>
<td>(Q_0 = (G\cdot E / C) \ast Pr[ G,E,C])</td>
<td></td>
<td>Function_points * idealized_time / minimum_cost</td>
</tr>
</tbody>
</table>

### Table 5-3: Project Execution

<table>
<thead>
<tr>
<th>Metric type</th>
<th>Metric name</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal measure: ((G))</td>
<td>Productivity</td>
<td>Requirements / proj_time</td>
</tr>
<tr>
<td>Enabling measure: ((E))</td>
<td>Robustness</td>
<td>proj_time / defects</td>
</tr>
<tr>
<td>Costing measure: ((C))</td>
<td>Expenditure</td>
<td>proj_cost / proj_time * defects</td>
</tr>
<tr>
<td>People Factor: (Pr[ G,E,C])</td>
<td>Vigilance</td>
<td>---</td>
</tr>
<tr>
<td>(Q_x = (G\cdot E / C) \ast Pr[ G,E,C])</td>
<td></td>
<td>Requirements * proj_time / proj_cost</td>
</tr>
</tbody>
</table>

### Table 5-4: Customers' Economic Value

<table>
<thead>
<tr>
<th>Metric type</th>
<th>Metric name</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal measure: ((G))</td>
<td>Customer's Value</td>
<td>(benefit / business_pain) \ast (features / plant_time)</td>
</tr>
<tr>
<td>= Value Proposition * Solution Deployment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabling measure: ((E))</td>
<td>Opportunity window</td>
<td>Plant_time / business_pain</td>
</tr>
<tr>
<td>Costing measure: ((C))</td>
<td>Cost Of Ownership</td>
<td>(solution_cost / pain * plant_time )</td>
</tr>
<tr>
<td>People Factor: (Pr[ G,E,C])</td>
<td>Vendor's Value</td>
<td>---</td>
</tr>
<tr>
<td>(Q_v = (G\cdot E / C) \ast Pr[ G,E,C])</td>
<td></td>
<td>(benefit / business_pain) \ast features* plant_time / solution_cost</td>
</tr>
</tbody>
</table>

Table 5-4: Customers' Economic Value
\[ Q_0 = \frac{\text{function point}s \times \text{idealized time}}{\text{idealized cost}} \]  

\[
Q_x = \frac{\text{requirements} \times \text{proj time}}{\text{proj cost}} = \left( \frac{\text{requirements}}{\text{function point}s} \right) \times \left( \frac{\text{proj time}}{\text{minimum time} \times \text{minimum cost}} \right) \frac{\text{proj cost}}{\text{minimum cost}} \times \text{minimum cost} \\
= \frac{G_0 \times E_x \times Q_0}{C_0 \times E} 
\]

\[
Q_v = \left( \frac{\text{benefit}}{\text{pain}} \right) \frac{\text{features} \times \text{plant time}}{\text{solution cost}} = \left( \frac{\text{benefit}}{\text{pain}} \right) \left( \frac{\text{features}}{\text{requirements}} \right) \left( \frac{\text{plant time} \times \text{proj time}}{\text{proj cost} \times \text{proj cost}} \right) \\
= \left( \frac{G_V \times E_x \times Q_0}{C_X \times V} \right) \times \frac{G_0 \times E_x \times Q_0}{C_0 \times X} \times \frac{G_0 \times E_x \times Q_0}{C_0 \times X} \\
= \left( \frac{\text{benefit}}{\text{pain}} \right) \frac{G_{X \times Y} \times E_{X \times Y} \times G_0 \times E_0 \times Q_0}{C_{0 \times Y} \times C_{X \times Y}} 
\]

Equation 5-1

**Finding #5.21:** A metrics framework can be used to measure and relate agility in its 3 key contexts: Organizational Endowments, Execution Focus and Economic Value. [Supports Hypothesis #2]

A metrics framework is proposed, consisting of 3 sets of metrics and measures for 3 separate contexts, and using measures in Table 5-2, T-3 and 5-4. Each context has a metric, Q, which has the same formulaic form in all contexts. Because the units for Q are the same in all contexts, then the values for Q can be used to compare relative context gain. Each Q can be written as a product of context-ratios.
5.9.2 Learning from Major League Baseball

In Lewis (2001), the turnaround of the Oakland Athletics is attributed to the club’s use of Bill James’ SABR (Society for American Baseball Research) metrics. The metrics are based on a different perspective of what to value during a baseball game. Viewing the game as a production line to maximize runs, James found on-base percentage to be the best indicator of production potential, requiring managers to have different expectations of team players: all batters must act like lead off men with the goal being to get on base, all batters need to have the power to hit home-runs since pitchers would then pitch more cautiously and walk batters more, and the ability to hit is more mental than physical.

Agile methods emphasize different values from classic plan-driven methods (see Agile Manifesto, 2001). For example, classic plan-driven projects for automation offerings are usually multi-year projects concerned with time-to-market. However, adopting agile methods would change focus from time-to-market to timely completion of 6-8 week iterations. Adopting agile methods is therefore an opportunity to find metrics that reflect better the agile value. Table 5-5 provides a non-exhaustive mapping of key factors for the Oakland Athletics turnaround to agile development concepts.

<table>
<thead>
<tr>
<th>Oakland As focus factors</th>
<th>Possible Agile concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bases</td>
<td>Number of concurrent Agile teams</td>
</tr>
<tr>
<td>2. Pitcher</td>
<td>User, customer, stakeholder or competitor</td>
</tr>
<tr>
<td>3. Percentage-On-base</td>
<td>% agile teams in synch for iteration.</td>
</tr>
<tr>
<td>4. Out</td>
<td>Agile team falling outside the 6-8 weeks iteration period.</td>
</tr>
<tr>
<td>5. Game is not time-limited, but determined by number of outs.</td>
<td>Release often; Notion of “how long is the project” has reduced significance.</td>
</tr>
<tr>
<td>6. All batters must act like lead off men, the goal is to get on base</td>
<td>Test Driven Development; Every team-member must behave like a Tester, with goal to implement a feature to pass all tests.</td>
</tr>
<tr>
<td>7. All batters need to have power to hit home-runs, since pitchers would then pitch more cautiously and walk batters more.</td>
<td>Cross-functional Teams; All team-members should speak the Users’ language, since Users would trust more and therefore dictate fewer requirements and focus more on needs.</td>
</tr>
<tr>
<td>8. The process of hitting is more mental than physical.</td>
<td>Constant learning; Delivering within 6-8 weeks is more attitudinal and cultural than raw power to code.</td>
</tr>
<tr>
<td>9. With players on base, opponents can’t score</td>
<td>Competitive edge; So long as Agile Teams are producing features every 6-8 weeks, competitors can’t get ahead.</td>
</tr>
</tbody>
</table>

Table 5-5: Oakland Athletics metrics
6. Effectiveness-and-Efficiency

This section aims to quantify the impact of Effectiveness and Efficiency.

The primary objective is to test the following hypotheses:

- **Hypothesis #2:** Successful process change must simultaneously support a target effectiveness-and-efficiency region (*operational cause*) and support a value-chain objective (*market effect*).

The research methods used were:

- **Reviewing Literature on State-Of-the-Art**
- **Analyzing survey results using Probabilistic Analysis techniques**

6.1 Abstract

Agile® methods promise to bring greater agility to software development organizations. However, classical development organizations have struggled to transition to agile organizations. Moreover, there is limited insight into an organization's established characteristics that may impact, and possibly limit, the organization's success in the adoption of agile methods. Research into organization's established **Effectiveness vs. Efficiency** profile provided new insight into what experienced personnel consider most important to be effective and efficient in a niche technology market space. The established characteristics of a classic development organization are then compared to the prerequisites for agile to identify the key considerations to transform an organization traditionally characterized by pre-defined procedures into one with disciplined agility. The research finds that classic development organization have a characteristic **Effectiveness vs. Efficiency** profile that can affect the likelihood of successful adoption of agile methods, and that is consequently important in selecting the best strategy for transformation to agility.

6.2 Introduction

Agile methods have shown success at many new software development companies. However, classic development organizations have struggled to become comparably agile. Traditional organization transformation falls into (at least) 3 perspectives:

- **Management**, (with emphasis on top-down management skills to effect a culture that induces or fosters the desired organizational attributes
- **Lean Enterprise**, with emphasis on Customer Focus to identify value streams that add value for the customer.
- **Innovation**, with emphasis on enriching knowledge networks that link disparate technology ideas and spark solutions to address market needs.
The research in this paper focuses on the assertion that classic development organizations have an *Effectiveness vs. Efficiency* profile that characterizes the organization, and on the hypothesis that profile should inform strategies selected to adopt agile methods.

### 6.3 Data analysis

The data analyzed in this section is the same data obtained from the case study in Chapter 4. This section is an extension of that study, but focuses on analyzing and interpreting the data to get insight into the effectiveness and efficiency of current processes. While the analysis in Chapter 4 was focused on understanding the state of current development practices (pre-agile), the analysis in this section focuses on the possible impact to those practices during a transition to agile development.

#### 6.3.1 Business-driven demands

Intense competition in the Process Automation industry has made market share and brand power essential objectives for Eagle Corporation. Eagle’s corporate leadership in turn exerts 2 principal demands on the development organization: shorter time-to-market and high-quality products. Figure 1 summarizes the development organization’s response to what influences:

- How quickly that person completes his assignment.
- How well he discovers and removes defects from his deliverables.
Figure 6-1: Influencing Time and Quality
The key observations are:

*Observation #6.1:* Defined Processes have greatest influence when identifying the total scope of an assignment, and as a source of knowledge. However, Defined Processes are not as influential when trying to complete an assignment as quickly as possible, or to discover errors in a deliverable.

*Observation #6.2:* The greatest influence for speed is the Organization’s Capability and Organizational Experience. [Devalues Hypothesis #1]

*Observation #6.3:* Defined processes and Defined Standards were considered the most influential source of knowledge.

Observation #6.1 suggests that the (currently) defined processes do not provide a process framework that can convincingly influence the speed of execution. However, Observation #6.3 suggests the (currently) defined processes and standards are important established sources of knowledge.

*Assertion #6.1:* Improving the speed of execution can not be convincingly achieved using the currently defined process framework, and would require a more convincing process framework, such as agile framework. However, the expressed value of defined processes and defined standards as repositories of knowledge suggests the need to consider co-existence of agile methods with defined standards, either during a transition to agile, or on a permanent basis.

6.3.2 Organization Performance: Effectiveness vs. Efficiency profile

Effectiveness and Efficiency are basic and common concepts in many frameworks for organizational transformation. It was therefore important to characterize Eagle Corporation’s Effectiveness and Efficiency. These 2 concepts were presented to personnel in contexts directly relevant to daily work.

**Effectiveness** is an indicator of whether a defined process can be followed to successfully produce the desired deliverable. The following choices were offered as degrees of the effectiveness of defined processes.

- No defined Process
- Defined Process is significantly different from actual work
- Defined process is helpful

**Efficiency** is an indicator of the minimal use of key enterprise resources (e.g., personnel, money, or time) when producing a desired deliverable. The following choices were offered as degrees of Efficiency:
6.4 Nature of Assignments

Responses from the development personnel were analyzed to identify any patterns related to the effectiveness or efficiency of defined process. One such pattern was that of the nature of assignments, which had been enumerated as follows:

- Has a clear beginning and clear end
- Has no clear beginning but a clear end
- Has a clear beginning but no clear end
- Has no beginning and no end

Figure 6-2 shows the Effectiveness of defined processes for the 4 enumerations of assignments. Figure 6-3 shows the Efficiency of defined processes for the 4 enumerations of assignments.

Figure 6-2: Process Effectiveness for Assignment type
Assignment has no beginning but has clear ending: About 40% of personnel consider the defined processes to be significantly different from actual work that must be done, and therefore largely unhelpful. Moreover, 60% believe the defined processes are inefficient with too many gaps.

Assignment has a marked beginning but no clear ending: An absolute majority considers the defined processes helpful. However, and notably, 30% believe the defined processes are unhelpful. Furthermore, 40% believe the defined processes are inefficient, of which 25% believe the processes have too many overlapping steps and duplicate tasks.

Assignment has a marked beginning but no clear ending: Only 50% of personnel consider the defined processes helpful. 25% do not believe there are any defined processes. While 50% believe the defined process is lean (very efficient), another 50% believe the processes are inefficient with too many gaps.

Assignment has a marked beginning and a clear ending: Close to an absolute majority considers the defined process helpful, but 25% do not believe there are any defined processes. A slight majority, about 55% believe their defined processes are efficient. 25% out of the remaining 45% believe their processes have too many gaps.

The key observations are:
Observation #6.4: 25% of assignments with a clear-beginning, have no defined process.

Observation #6.5: A greater percentage of assignments with a clear-beginning have defined processes that are helpful.

Observation #6.6: For assignments with no-clear-ending, 40%-50% of personnel believe the defined processes to be inefficient.

Observation #6.7: For assignments with a clear-ending, the efficiency of the defined processes depends on the effectiveness of the process, and is worst when there are no defined process.

6.4.1 Effectiveness vs. Efficiency

The data was further analyzed to determine the characteristic Effectiveness vs. Efficiency profile for Eagle Corporation. Figure 4 is a 3D plot of the Cumulative Distribution Function (CDF) Pr [X ≥ x, Y ≥ y] where X is Effectiveness and Y is Efficiency. Figure 5 is the contour plot of the CDF. The plots show that:

- About 30% of personnel find the defined processes ineffective (undefined or different from real work) and inefficient (random or with too many gaps or with too much overlap).
- 30%-40% of personnel have no effective defined process.
- About 50% of personnel believe they have effective-and-efficient processes.

![CDF: Effectiveness vs. Efficiency](image)

Figure 6-4: Process Effectiveness for Assignment type
Observation #6.8: The Effectiveness vs. Efficiency contour lines in Figure 5 change from being concave closer to the origin, to becoming more convex further away. At low effectiveness and efficiency, it is generally easier to improve effectiveness. However, higher efficiency becomes possible once the processes become sufficiently effective. [Supports Hypothesis #2]

Observation #6.9: Process Effectiveness and Efficiency are not necessarily competing. They can also be mutually reinforcing: the higher the effectiveness the greater the efficiency.

![CDF: Effectiveness vs. Efficiency](image)

Figure 6-5: CDF: Effectiveness vs. Efficiency

6.4.2 Effectiveness vs. Efficiency: Adopting Agile
An important area of research was the influence of the Effectiveness-and-Efficiency of defined processes on adopting Agility. To quantify this influence, the research analyzed an individual’s effectiveness and efficiency on the overall effectiveness-and-efficiency of a team. The emergent team effectiveness-and-efficiency was analyzed quantitatively, pre- and post-agile. A number of simple scenarios were constructed to describe the possible key events during the adoption of Agility. Key events (see Figure 6-6) were those considered to potentially impact the effectiveness and efficiency of the team. Scenarios
were simulated using a combination of C# programming and MS-EXCEL®. Probabilistic Risk Assessment was then used to evaluate the relative significance of each key event.

The analysis considers adopting agility during a period of co-existence of classic defined processes, where those processes are effective and efficient, and of agile methods where defined processes are ineffective or inefficient. Operationally, such a co-existence can be heralded in by permitting those dissatisfied with classic processes to use agile methods.

![Event tree diagram](image)

**Figure 6-6: Classic ↔ Agility Co-existence Event tree**

6.4.3 Effective and Efficient Teams

The actual Effectiveness and Efficiency of a Team are unknown (not directly measurable). One factor that a manager can control is the number of people in a team. However, not every team member will be efficient and effective. The manager must therefore choose enough team members to make up for
ineffective and inefficient team members. So if the scope of work in a project requires 5 effective and efficient people, then the manager must select enough people to be confident that there are enough to provide the required capacity of 5 effective and efficient.

To understand the co-existence of defined processes and agile methods, this research analyzed number of ‘M’ team members that a manager must have in a team to have a desired confidence level that there are at least ‘t’ effective and efficient team members. The key considerations for such a team are as follows:

**M**: Team Composition

The selection a project Team with ‘m’ members is a random event, since the actual composition of the team is random. Because the team composition is a random event, the overall Effectiveness-and-Efficiency of the team will be a random event. (Hogg, 1994).

**Z**: Effective and Efficient team members using defined process

Of the M team members, Z are effective and efficient in defined processes. This is a random event since the actual team composition is random.

**V**: Number of Agile adopters who commit errors

During co-existence of Defined Processes and agile methods, the remaining M-Z team members dissatisfied with defined processes are permitted (and encouraged to adopt agile methods). But a number of these team members, will make process mistakes or simply be ineffective or inefficient while using agile methods.

**S**: Effective and Efficient Agile adopters affected by erroneous Agile users.

During co-existence of defined processes and agile methods, the remaining M-Z team members dissatisfied with defined processes are permitted (perhaps even encouraged) to adopt agile methods. But a number of these team members will make process mistakes, or simply be ineffective or inefficient while using agile methods.

\[
\text{Pr} [\text{Erroneous Agile user affects another Team member }] = b \quad \text{Eqn. (1)}
\]

\[
\Rightarrow \text{Pr} [\text{No one affected by 'v' Erroneous Agile Users }] = (1 - b)^v \quad \text{Eqn. (2)}
\]

\[
\Rightarrow \text{Pr} [\text{A Team member affected by 'v' Erroneous Agile Users }] = 1 - (1 - b)^v \quad \text{Eqn. (3)}
\]

**S**: ‘Z’ Individuals now impacted by ineffective and inefficient Agile adopters.
Organizational adoption of agile methods means that even those using defined processes must now accept work, deliverables, and decisions that use no predefined process. Mistakes made by those using agile methods can now impact those using defined processes.

**T:** Effective and Efficient Team Members.
This is the total of effective-and-efficient team members using defined processes or agile methods.

The key parameters are summarized in Table 6-1.

<table>
<thead>
<tr>
<th>Parameter(s)</th>
<th>Constraints</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M, m$</td>
<td></td>
<td>$M$: Random Event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M$: Discrete Random Variable; Number of individuals in a Team</td>
</tr>
<tr>
<td>$Z, z$</td>
<td>$0 \leq z$</td>
<td>$Z$: Random Event</td>
</tr>
<tr>
<td></td>
<td>$z \in Z^+$</td>
<td>$z$: Discrete Random Variable; Members who are Effective and Efficient in defined processes</td>
</tr>
<tr>
<td>$W, w$</td>
<td>$w = m - z$</td>
<td>$W$: Members who can adopt Agile methods</td>
</tr>
<tr>
<td>$V, v$</td>
<td>$0 &lt; v &lt; w$</td>
<td>$V$: Random Event</td>
</tr>
<tr>
<td></td>
<td>$z \in Z^+$</td>
<td>$v$: Discrete Random Variable; Members who adopt Agile but are ineffective or inefficient</td>
</tr>
<tr>
<td>$U, u$</td>
<td>$u = w - v$</td>
<td>$U$: Members who adopt Agile effectively and efficiently</td>
</tr>
<tr>
<td></td>
<td>$z \in Z^+$</td>
<td></td>
</tr>
<tr>
<td>$S, s$</td>
<td>$0 &lt; s &lt; z$</td>
<td>$S$: Random Event</td>
</tr>
<tr>
<td></td>
<td>$z \in Z^+$</td>
<td>$s$: Discrete Random Variable; Members effective-and-efficient in defined processes affected by inefficient or ineffective Agile adopters</td>
</tr>
<tr>
<td>$S_A, s_A$</td>
<td>$0 &lt; s_A &lt; u$</td>
<td>$S_A$: Random Event</td>
</tr>
<tr>
<td></td>
<td>$z \in Z^+$</td>
<td>$s_A$: Discrete Random Variable; Members effective-and-efficient in Agile methods but affected by inefficient or ineffective Agile adopters</td>
</tr>
<tr>
<td>$P$</td>
<td>$0 \leq p \leq 1$</td>
<td>$Pr[\text{Team Member Effective and Efficient in Defined Processes}]$</td>
</tr>
<tr>
<td>$R$</td>
<td>$0 \leq r \leq 1$</td>
<td>$Pr[\text{Team Member ineffective or inefficient while using Agile}]$</td>
</tr>
<tr>
<td>$B$</td>
<td>$0 \leq b \leq 1$</td>
<td>$Pr[\text{Erroneous Agile user affects another team member}]$</td>
</tr>
</tbody>
</table>

Table 6-1: Key Parameters
6.4.4 Analysis of Effective and Efficient Teams

Figure 7 and Figure 8 show plots of \( \text{Pr}[T \geq 5] \) for Eagle Corp. This is the likelihood that the team has 5 or more effective-and-efficient team members, and can be written as in Eqn. (4) under the constraint of Eqn. (5). With reference to the parameter definitions of Table 6-1, Eqn. (4) and Eqn. (5) lead to Eqn. (6). \( \text{Pr}[T > n] \) can then be re-written more generally as in Eqn. (7).

\[
\begin{align*}
\text{Pr}[T \geq n] &= \sum_{i=n}^{M} \text{Pr}[T = i] \quad \text{Eqn. (4)} \\
\text{Pr}[T = i] &= \text{Pr}[Z = z, S_A = s_A, S = s, V = v] \cdot t = z - s + (m - z - s_A) - v \quad \text{Eqn. (5)} \\
\text{Pr}[T = i] &= \sum_{t \leq s} \sum_{0 \leq v \leq m} \sum_{0 \leq s_A} \sum_{0 \leq s} \sum_{0 \leq v} \text{Pr}[Z = z] \cdot \text{Pr}[V = v] \cdot \text{Pr}[S = s] \cdot \text{Pr}[Z = z] \cdot \text{Pr}[S_A = s_A] \\&= \sum_{t \leq s} \sum_{0 \leq v \leq m} \sum_{0 \leq s_A} \sum_{0 \leq s} \sum_{0 \leq v} \text{Pr}[Z = z] \cdot \text{Pr}[V = v] \cdot \text{Pr}[S = s] \cdot \text{Pr}[S_A = s_A] \
\text{Pr}[T > n] &= \sum_{m} \sum_{s} \sum_{v} \sum_{s_A} \sum_{s} \sum_{0 \leq v} \text{Pr}[Z = z] \cdot \text{Pr}[V = v] \cdot \text{Pr}[S = s] \cdot \text{Pr}[S_A = s_A] \
\text{Eqn. (7)}
\end{align*}
\]

Given that each of \( Z, V, S \) and \( S_A \) is a binomial distribution (see Figure 6-6), then they can be written as in Eqn. (8).

\[
\begin{align*}
Z &\sim \text{Binomial}(m, z, p) \\
V &\sim \text{Binomial}(m - z, v, r) \\
S &\sim \text{Binomial}(z, s, 1 - (1 - b)^r) \\
S_A &\sim \text{Binomial}(m - z - v, s_A, 1 - (1 - b)^r) \quad \text{Eqn. (8)}
\end{align*}
\]

\[
\begin{align*}
\text{Pr}[Z \leq k] &= I_{-p}(m - k, k + 1) \\
\text{Pr}[V \leq k] &= I_{-r}(m - z - k, k + 1) \\
\text{Pr}[S \leq k] &= I_{-(1 - b)}(z - k, k + 1) \\
\text{Pr}[S_A \leq k] &= I_{-(1 - b)}(z - k, k + 1) \quad \text{Eqn. (9)}
\end{align*}
\]

\( \text{Pr}[T \geq n] \) is the "probability that the Team has at least the minimum required \( n \) individuals who are effective and efficient". A practical and helpful interpretation of \( \text{Pr}[T \geq n] \) is the "confidence level in the team's capability to deliver successfully and on time". Cost is omitted because additional staff must be included to ensure enough effective-and-efficient individuals are present.

In Figure 6-7 and Figure 6-8, the line labeled 'Defined Process' shows the case where only classically defined processes are used.
Figure 6-7 depicts $\Pr[T \geq 5]$ when Agile methods are adopted without considerable care to ensuring their effectiveness. A value of $r=0.8$ assumes 80% of Agile Users will be ineffective or inefficient. The effectiveness and efficiency of currently defined processes in Eagle Corporation is 53% (from results of section 6.4.1), thus $r=0.8$ depicts the scenario where Agile methods are adopted without requiring those methods to be more efficient and more effective than classic defined processes. Figure 6-7 shows that high values of $r$ must be accompanied with near-zero values for $b$. Adopting agile methods that are less effective and efficient than existing processes will improve a team’s capacity only if inefficiencies from the agile users can be contained and not leaked to those using defined processes. Even an 80% containment ($b=0.2$) will likely make the overall team effectiveness and efficiency worse post-agile.

![Introducing Agile: Contained Errors](image)

Figure 6-7: Introducing Agile: Contained Errors

Figure 6-8 depicts the confidence level in the team’s capacity assuming 50% likelihood than an ineffective or inefficient agile team-member will affect another effective-and-efficient team member. The plots provide 2 important types of insight:

Observation #6.10: When classic teams have low probability of having the desired level of effectiveness and efficiency, introducing Agile will almost always significantly improve that probability. However, the Manager is limited in how big the team may be. Beyond a certain team size, making the team any bigger will only make the team’s effectiveness and efficiency lower. [Supports Hypothesis #2]
The manager in effect loses the ability to improve the team’s effectiveness by adding more people to the team.

Observation #6.11: Even when the Agile methods are highly effective and efficient \( (r=0.8) \), a poor containment of Agile errors \( (b=0.50) \) means the benefits of Agile will be constricted in a co-existence situation, making it almost impossible to ever attain high probabilities of effectiveness-and-efficiency while still limited in the size of the team.

![Introducing Agile: Uncontained Errors](image)

Figure 6-8: Introducing Agility: Uncontained Agile Errors
6.4.5 Sensitivity Analysis
Since successful sustainable adoption of agile methods may depend on the right strategy for co-existence (transitory or permanent) between agile methods and plan-driven methods, it is worthwhile to consider the sensitivity of the plots in Figure 6-7 and 6-8 to the effectiveness-and-efficiency of currently defined processes, quantified in section 6.3 via a survey. A simple sensitivity analysis is possible using Bayes' Theorem (Rice, 2007). Table 6-2 defines the key parameters for the analysis, distinguishing between a survey (or other diagnostic techniques) that inquires about the effectiveness-and-efficiency of processes, and individuals who actualize the effectiveness-and-efficiency.

<table>
<thead>
<tr>
<th>Parameter(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P(E)$</td>
<td>Probability an individual using process is <em>in practice</em> effective-and-efficient.</td>
</tr>
<tr>
<td>$P(N)$</td>
<td>$1 - P(E)$</td>
</tr>
<tr>
<td>$P(S^+)$</td>
<td>Probability someone surveyed from the development organization <em>considers</em> process to be effective-and-efficient.</td>
</tr>
<tr>
<td>$P(S^-)$</td>
<td>Probability someone surveyed from the development organization <em>considers</em> process to be ineffective or inefficient.</td>
</tr>
</tbody>
</table>

**Table 6-2: Key Parameters for sensitivity analysis**

Using Bayes' Theorem, $P(E \mid S_\cdot)$ can be written as shown in Eqn. (10), and denotes the likelihood that a team-member is really effective-and-efficient having indicated so in a survey response. $P(S_\cdot \mid E)$ is the accuracy of the survey in persuading team-members to answer correctly when the process is effective-and-efficient.

$$P(E \mid S_\cdot) = \frac{P(S_\cdot \mid E) \cdot P(E)}{P(S_\cdot \mid E) \cdot P(E) + P(S_\cdot \mid N) \cdot P(N)}$$

Eqn. (10)

The survey accuracy was varied from 0 – 100%, assuming an initial $P(E) = 53\%$ based on the results of section 6.4.1. For survey accuracy values of greater than 50%, $P(E \mid S_\cdot)$ is nearly equal to the survey accuracy, indicating that the accuracy for the co-existence strategy is as good as the accuracy of the surveying method used to determine effectiveness-and-efficiency.
6.5 Summary

In Eagle Corporation, about 1/2 of personnel are using effective and efficient defined processes while about 1/4 are not using a defined process. The organization’s effectiveness-and-efficiency profile can be measured (using statistical sampling methods), and can then be used to determine the probabilistic confidence level in a team having the required effectiveness-and-efficiency to complete tasks of known scope and in a known duration.

A key decision in transforming Eagle Corporation’s effectiveness and efficiency is whether to adopt agile methods in co-existence with established defined processes. Analyzing the probabilistic confidence level, reveals that adoption of agility may show an overall improvement, but may also introduce new constraints. Organizations that generally have teams with low-levels of probabilistic confidence in effectiveness-and-efficiency will benefit from higher probabilistic confidence levels. However, if the current teams already have high (> 70%) probabilistic confidence levels, then introducing agility will constrain the max. size of those teams, and may even lower the probabilistic confidence levels, unless agile inefficiencies and ineffectiveness can be contained. Adopting agility must therefore be accompanied by deliberate discipline to contain agile errors.
7. Executive Leadership for Innovation Management

While Chapter 5 focused on what is required to make agile methods work for process automation, the analysis in Chapter 6 showed possible risks to a process automation company that chooses to adopt agile methods, if the adoption of agile methods is not properly managed. The role of Executive Leadership was mentioned briefly in Chapter 5. However, further understanding of the pivotal role of Executive Leadership is considered in 3 key areas not adequately covered by the literature focusing on agility, namely managing uncertainty, technology strategy, and managing team dynamics.

7.1 Managing Uncertainty

This section aims to describe uncertainty not addressed by agile methods.

The research methods used were:

- Reviewing Literature on State-Of-the-Art

At the heart of successful innovation is the taming of uncertainty. According to Rice et al (2008), "real breakthrough innovations ... are fraught with high degree of uncertainty". For process automation vendors, there are 4 principal sources (or channels) of uncertainties: technology, market, organizational and personnel. Rice et al assert that most management assume high ratio of knowns to unknowns and therefore rely on prescribed paths for product development and for decision making. In additional, such managers are averse to experimenting with the market, presumably out of fear of introducing new uncertainties.

![Diagram of managing uncertainty]

**Figure 7-1: Managing uncertainty --- adapted from Rice (2008)**

Rice et al argue not only is management's assumption wrong, but managers should also adopt a learning plan that recognizes that in reality project teams actually proceed on a path filled with assumptions. Figure 8-1 depicts the proposed Learning Plan and how it relates to uncertainty.
Finding #7.1: Uncertainty is not a function of the development process, but of the type of innovation being pursued.

Finding #7.2: Although a well-defined process, the Stage gate Approach, does not reduce technology or market uncertainty. Therefore, if the technology uncertainty is high, a Stage gate approach will not help.

The Stage Gate Approach is common among Process Automation Vendors. According to Rice et al (2008), by insisting on a Stage Gate approach, Automation vendors are assuming that their projects have low uncertainty. More importantly, should an automation vendor wish to engage in breakthrough innovations, it will have to use processes and practices that include Learning Plan and Discovery Driven Planning.

Finding #7.3: The centrality of learning as a fundamental strategy to managing uncertainty agrees with the essence of learning agility. A general adoption of agility could therefore help vendors looking for breakthrough innovations. However, literature on the suitability of agility for breakthrough innovations remains ambivalent, with Kelly (2008) recommending limiting agile methods to incremental innovation.
7.2 Technology Strategy

This section aims to establish technology strategy factors unique to Process Automation technology.

The primary objective is to test the following hypotheses:

- **Hypothesis #3:** The capabilities to automate a manufacturing process are so numerous and diverse as to make it non-obvious and non-trivial for a vendor to choose what to focus on.

- **Hypothesis #4:** Extending a process automation product-line is driven by market push, while maintaining a product release is based on either market pull or need to reduce internal (e.g. development) cost.

The research methods used were:

- Reviewing Literature on State-Of-the-Art
- Reviewing Literature on State-Of-the-Practice

7.2.1 Institutionalized Innovation

Iyer et al (2008) advises that “Technology and strategy are inseparable”. Anthony et al (2008) goes further asserting that the key to long-term success for technology-based companies, such as Process Automation vendors, is getting multiple market successes, which require that Senior Management define “strategic goals and boundaries” and create balanced portfolio of growth opportunities. Innovation for Multiple successes should not be an open-ended venture, but be based on “strategic dimensions affecting Innovation”. Management must know what is desirable vs. discussable vs. unthinkable. Innovators who know what company wants to do (goals) and will not do (boundaries) can focus their creative efforts. “Boundaries can be liberating”, while a blank slate adds more uncertainty for Managers. This concept of bounding innovation reinforces the notion of discipline in innovation. Anthony et al (2008) further recommends the strategy for innovation not determine resource allocation. Rather, how resources can be allocated should determine the strategy, and a Process Automation vendor should base its innovation strategy on the resources and skill sets it has and will be able to keep. According to Anthony et al (2008), the best approach is to “invest a little to learn a lot”, while the “best time to start investing in new business is when least needed.”

7.2.2 Products vs. Services

Reinartz (2008) focuses on the products vs. services mix for manufacturers (which includes Process Automation vendors), stating that manufacturers believe adding value in the form of services will provide a competitive advantage after products start to become commodities (as is the case with automation offerings). Reinartz (2008) asserts that manufacturing companies will “most likely struggle to turn a profit from their service businesses” because:
• Each customer’s requirements become increasingly customized making it difficult for vendor to leverage learning and knowledge.
• Vendor’s salespeople have increasingly lower-level contacts in the customer’s hierarchy.

Analysis of the financials for one automation vendor, Honeywell International Inc., refutes this assertion, showing this vendor has been successful with its services offerings. Table 7-1 summarizes the key financial data obtained from Honeywell (2008).

**Observation #7.1:** Honeywell services are profitable, contrary to Reinartz (2008). However, Honeywell’s financials confirm Reinartz (2008) assertion that services have higher structural costs. Honeywell has been more successful keeping Costs and Revenue in line for products than for services. [Supports Hypothesis #4]

<table>
<thead>
<tr>
<th>Honeywell</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales Product</td>
<td>$29,212</td>
<td>$27,805</td>
<td>$25,165</td>
</tr>
<tr>
<td>Sales Services</td>
<td>$7,344</td>
<td>$6,784</td>
<td>$6,202</td>
</tr>
<tr>
<td>Cost Products</td>
<td>$23,043</td>
<td>$21,629</td>
<td>$19,649</td>
</tr>
<tr>
<td>Cost Sales</td>
<td>$4,951</td>
<td>$4,671</td>
<td>$4,447</td>
</tr>
<tr>
<td>Gross Revenue Product</td>
<td>$6,169</td>
<td>$6,176</td>
<td>$5,516</td>
</tr>
<tr>
<td>Gross Revenue Services</td>
<td>$2,393</td>
<td>$2,113</td>
<td>$1,755</td>
</tr>
<tr>
<td>Gross Margin Products</td>
<td>21%</td>
<td>22%</td>
<td>22%</td>
</tr>
<tr>
<td>Gross Margin Services</td>
<td>33%</td>
<td>31%</td>
<td>28%</td>
</tr>
<tr>
<td>P vs. S: Sales</td>
<td>3.98</td>
<td>4.10</td>
<td>4.06</td>
</tr>
<tr>
<td>P vs. S: Cost</td>
<td>4.65</td>
<td>4.63</td>
<td>4.42</td>
</tr>
<tr>
<td>P vs. S: Profits</td>
<td>2.58</td>
<td>2.92</td>
<td>3.14</td>
</tr>
<tr>
<td>P vs. S: Gross Margin</td>
<td>0.65</td>
<td>0.71</td>
<td>0.77</td>
</tr>
</tbody>
</table>

**Table 7-1:** Products vs. Services for Honeywell International Inc.

**Figure 7-2:** Products vs. Services ratios for Honeywell
Figure 7-2 plots the different products vs. services ratios to show the actual trends. The plots show that the Services business is more profitable than products business. However, as the Gross Margin for Products has remained largely constant, that of Services has fallen by 5 percentage points. Although Honeywell has managed its products cost in line with its products revenues, its cost of services has been more difficult to keep in line with services revenues.

**Observation #7.2:** For process Automation vendors, product offerings are a larger source of revenue and require costs to be managed in line with revenues.

**Finding #7.4:** Automation vendors need to have a strategy that is clear about products vs. services. Services need an economies-of-scale strategy while products need an economies-of-sale strategy. Products however, may include hardware product components, which traditionally require an economies-of-scale strategy [Supports Hypothesis #3].

This finding seems to confirm the suggestion by Reinartz (2008) that products require “Industrial back-office ... accustomed to controllable processes”, but that services require “front-office customization that makes delivery-costs very high.” Reinartz (2008) advises manufacturing companies that become mature to:

“...make sure their processes focus on customer needs and customer processes, based on detailed descriptions of core customer concerns and operating processes, and including metrics that are outcome-oriented rather than activity-based.”

**Finding #7.5:** Product organizations are likely to be geographically separated from services personnel. This makes agile sprint collaborations that include service representation more difficult.

Cusumano (2004) emphasizes the need for a clear strategy on products vs. services mix, arguing that a product-centric strategy should be underpinned by traditional economies of sale while a services-based strategy should take advantage of economies of scale that “can come from structuring knowledge such as how to do requirements, manage projects, customize applications, conduct user acceptance testing...”

Reinartz (2008) identifies 3 major drivers for growth in B2B: business models requiring outsourcing, increased need for asset optimization, and higher Return-On-Asset expected. All of these drivers were mentioned by the Manufacturer Experts as promising business opportunities for Process Automation vendors. Factors cited by both Reinartz (2008) and the manufacturer experts as favoring B2B services include commoditization of product offerings and saturation of the (customer) installed base.
Finding #7.6: Process Automation vendors need technology strategies based business models requiring outsourcing, increased need for asset optimization and higher Return-On-Asset.

7.2.3 Platform Leadership
Another important strategic decision described by Cusumano (2002) is choosing between platform leader and platform complementor. The need for platform leadership for at least some positions in the process automation value chain was expressed by some of the manufacturing industry leaders (although a fear of platform leader’s clout was also expressed). The presence of numerous standards has led to fragmentation. Cusumano (2002) describes the 4 levers of platform leadership 3 of which have a profound impact on agile practices for a process automation vendor:

**Product Technology**
The Process Automation vendor must define a process automation architecture (hardware or software or system) that will become the base architecture for the entire ecosystem. The architecture must also help complementors, some of whom maybe competitors.

**Relationship with external complementors**
The platform leader must work on creating consensus among complementors, while watching out for a complementor trying to become the platform leader.

**Internal Organization**
The platform leader must have a structure consistent with sufficient separation from internal groups that maybe viewed by complementors as competitors.

Finding #7.7: Automation vendors need to decide between platform leadership and platform contribution. Process Automation market is largely fragmented and full of standards. Both market fragmentation and number of standards should be considered when choosing between platform leadership and contribution [Supports Hypothesis #4].

Finding #7.8: Platform leadership requires architecture for the entire ecosystem, and an internal organizational structure that will instill trust in platform contributors.
7.3 Team Dynamics

This section aims to identify important dynamics about Agile teams.

The primary objective is to test the following hypothesis:

- **Hypothesis #6**: Development personnel are knowledge workers whose effectiveness and efficiency is based on discernible factors.

The research methods used were:

- Reviewing Literature on State-Of-the-Art
- Reviewing Literature on State-Of-the-Practice

Agile teams, without defined plans and processes to guide team members, must be self-organized, and must consequently have self-driven team members. Austin (2007) however warns that never has the knowledge gaps between stewards (managers) and a special category of employees called creators (highly specialized employees) been greater. The reason is historical: traditionally managers grew from creators, and may even have been experts in their field. This is no longer true because technology is changing so fast and requires so much specialization that "a software developer more than four or five years removed from actual coding is no longer expert." As result, managers are no longer the principal sources of change. Sometime creators are best positioned to recognize and initiate change.

The roles of manager and creators exacerbate the tension: managers care about resource allocation while creators care about a social good or higher purpose in life. Creators are usually extremely committed to what they do, while Managers may be blind to this commitment, often insisting to look at only the bottom-line. Creators are often unwilling to accept their managers’ insistence on good enough.

Because the tension between managers and creators can get out of balance, Austin (2007) recommends the following guidelines to manage the relationship between the two types:

- Do not punish creators simply because their creativity angers managers
- Create balance by letting creators win sometimes, and managers other times.
- Cultivate personalities who can mediate between managers and creators.
- Use peer-review to evaluate creators as well as managers
- Structure innovation process to produce tangible artifacts
- Do not prohibit conflict, but encourage it to be viewed as ‘creative abrasion’.
- Avoid prescriptive control mechanisms which deny creators flexibility to explore widely enough.
- Manage rate at which a project reaches closure (not too fast or too slow).
Finding #7.9: The gap between Managers and Creators is a major threat to team cohesion in cases where team performance depends on collaboration rather than pre-defined processes. Senior Management must manage relationship the Manager ↔ Creator relationship especially during a process transition period.

Since adopting Agility would require changes to an established organization, the change process is important to successful adoption of Agility. Senge (2007) offers a general model for systemic change, and asserts that a “healthy learning ecology” is necessary for systemic change. Successful collaborative efforts require the interconnection of **conceptual work**, **relational work** and **action-driven work** creating an approach that is more personal and more systemic.

**Conceptual Work:** framing complex issues by applying systems-thinking skills, and developing a shared conceptual “systems sense”. Leaving difficult conceptual tasks to small groups of experts is not always the best approach as doing so by-passes collective intelligence embedded in different people and different groups, and undermines deeper and more widespread understanding of the concept.

Finding #7.10: Systems-Thinking is important when formulating transformation to, or adoption of, agility.

**Relational Work:** Dialogue and Collaborative Inquiry that forms relationships and shapes cooperation, trust and mutual learning. This is necessary to allow powerful questions to truly emerge, and for individuals to be recognized and engaged.

**Action-Driven Work:** Building Collaborative Change Initiatives to enable new levels of action, framing complex issues by applying ‘systems-thinking’ skills, and developing a shared conceptual “systems sense”.

Finding #7.11: Actual process must be customized to take into consideration general level of tension between Managers and Creators.
8. Prescriptive Guidance for Disciplined Agility

Collins (2001) argues that discipline and entrepreneurial attitude were key enablers for companies that transformed successfully from good to great.

Entrepreneurial Attitude is the opportunistic mindset towards risk-taking that inspires, excites and guides, among other things, practices and behavior that instill bias for persistent innovation. This set of practices and behavior is the manifestation of agility.

Discipline provides the balancing mindset of applying the principles of systems engineering, of respecting the principles of cognitive psychology, and of staying accountable to stakeholders.

Disciplined Agility therefore best describes the nimble, unrelenting, opportunistic and innovating behavior firmly focused on economic-value and sustainability.

Agile practices should be adopted to enable each individual to learn and drive him to act. They should facilitate individuals from different disciplines to collaborate with each other and encourage them to share lessons learned, across business units in the vendor’s enterprise and Manufacturers’ enterprises.

Transformation to Agility, through the adoption of agile methods and practices, is recommended thus:

**STEP #1.** Obtain clear understanding of company’s most pressing business drivers.

**STEP #2.** Select most suitable agile practices.

**STEP #3.** Based on affected organizational levels, determine Total Transformation for agility.

**STEP #4.** Address pre-requisites

**STEP #5.** Institutionalize Operational Agility

**STEP #6.** Practice agility (e.g., pilot project)

**STEP #7.** Reflect, learn and repeat STEP #1.

The decision to adopt agile methods is integral to STEP #2 which includes a Balancing Project Risks practice. This practice, proposed by this thesis, consists of a risk-based approach to selecting the balance of agile methods vs. plan-driven methods.

Practices that go beyond the Development Organization may be architected using the Lean Transformation framework. LaFon (2008) provides the framework for an Automation vendor’s Enterprise Process Architecture (for Lean Product Development), while Nightingale (2008) provides the framework for Lean Enterprise Architecture for a Manufacturer’s Enterprise. In general, the more the number of levels needed to implement a practice, the more difficult the practice. At the same time, the more difficult a proposed practice the greater its innovation potential.
**STEP #1: Sector-specific drivers**

Each Process Automation vendor has a number of specific drivers that should be the basis for any transformation to agility or for evaluating any actual implementation of agility. Below are some business drivers generic to process automation vendors:

**Manufacturers' view of process automation value**

- Process Automation as cost component of an RFP and not as a capital asset:
- Commoditization of automation offerings, with downward pressure on prices.
- Value of automation purchase is static, the commissioning cost in terms of plant type or capacity
- Vendors have less domain expertise
- Vendors have little knowledge of operator needs
- Vendors unable to successfully predict what customers need

**Vendors’ Operations Management:**

- Effectiveness-and-Efficiency profile important but not known.
- Customers growing bigger in size through Mergers & Acquisitions.
- Vendors can get more revenue from service offerings, but face higher structural costs.

**Development personnel’s needs:**

- Personnel are in general satisfied with defined processes.
- Personnel anticipate incremental process improvements.
<table>
<thead>
<tr>
<th>Automation Vendor's Dev. Organization</th>
<th>Automation Vendor's Enterprise</th>
<th>Manufacturer Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Code reviews</td>
<td></td>
<td></td>
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<tr>
<td>2. Test Driven Development</td>
<td></td>
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<tr>
<td>3. Pair programming</td>
<td></td>
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<tr>
<td>4. Automated testing</td>
<td></td>
<td></td>
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<tr>
<td>5. Continuous integration</td>
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<td></td>
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<tr>
<td>6. Malleable design</td>
<td></td>
<td></td>
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<tr>
<td>7. Define / build / test component team</td>
<td></td>
<td></td>
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<tr>
<td>8. Concurrent testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Vision + roadmap + JIT elaboration</td>
<td></td>
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<tr>
<td>10. Daily Cycle</td>
<td></td>
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<tr>
<td>11. Stand up meeting</td>
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<tr>
<td>12. Co-located Team</td>
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<td>13. Evocative Documents</td>
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<tr>
<td>14. Cross Functional Team</td>
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<tr>
<td>15. Information Radiators</td>
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<tr>
<td>16. Managing Critical System Parameters</td>
<td></td>
<td></td>
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<tr>
<td>17. Continuous System validation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Quality before features</td>
<td>Effective updated quality standards</td>
<td></td>
</tr>
<tr>
<td>19. Two-level planning and tracking</td>
<td>Two-level planning and tracking</td>
<td></td>
</tr>
<tr>
<td>20. Mastering the iteration</td>
<td>Agile Product Planning</td>
<td></td>
</tr>
<tr>
<td>21. Agile Release Train</td>
<td>RMT Configuration Management</td>
<td></td>
</tr>
<tr>
<td>22. Regular reflection and adaptation</td>
<td>Infrastructure to disseminate lessons</td>
<td></td>
</tr>
<tr>
<td>23. Managing Highly Distributed Teams</td>
<td>Unhindered global communication</td>
<td></td>
</tr>
<tr>
<td>24. Changing the organization</td>
<td>Measuring team effectiveness</td>
<td></td>
</tr>
<tr>
<td>25. Serum of Scrums</td>
<td>Multi-geography &amp; time zone scrums</td>
<td></td>
</tr>
<tr>
<td>26. Management Tests</td>
<td>Uncertainties for innovation-type</td>
<td></td>
</tr>
<tr>
<td>27. Transitioning to Agile</td>
<td>Co-existence Classic &amp; Agile</td>
<td></td>
</tr>
<tr>
<td>28. Investing in Agile Capability</td>
<td>Corporate funding for capability</td>
<td></td>
</tr>
<tr>
<td>29. Engineering System Robustness</td>
<td>User variations systems.</td>
<td></td>
</tr>
<tr>
<td>30. Balancing Project Risk</td>
<td>Efficient Defined processes</td>
<td></td>
</tr>
<tr>
<td>31. (Release often)</td>
<td>(Promote often)</td>
<td>(Upgrade often)</td>
</tr>
<tr>
<td>32. (Refactoring)</td>
<td>(Warranty Liabilities &amp; Certifications)</td>
<td>(Validate deployed application)</td>
</tr>
<tr>
<td>33. Intentional Architecture</td>
<td>Process Automation Value-Chain</td>
<td>Intentional Architecture</td>
</tr>
<tr>
<td>34. Impact on Customers and Operations</td>
<td>Release value-propoosition and licensing</td>
<td>Operators as Knowledge Workers</td>
</tr>
<tr>
<td>35. Measuring business performance</td>
<td>Agility Metrics framework</td>
<td>Real-Time Accounting</td>
</tr>
<tr>
<td>36. Demo</td>
<td>Value capture and Revenue recognition</td>
<td>Contractual agreement</td>
</tr>
<tr>
<td>37. Assuring Domain Expertise</td>
<td>Assessing domain knowledge gap</td>
<td>Domain knowledge expectations</td>
</tr>
<tr>
<td>38. Clarifying Ecosystem Role</td>
<td>Separate platform Leadership vs. Contribution</td>
<td>Promoting ecosystem</td>
</tr>
</tbody>
</table>
STEP #3: Total Agility Transformation

Figure 8-1: Asynchronous Multi-Level Lean Transformation
### STEP #4: Pre-requisites for Agility

<table>
<thead>
<tr>
<th>Learning</th>
<th>Action</th>
<th>Collaboration</th>
<th>Sharing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Career Development systems to encourage personnel to migrate between functions.</td>
<td>4. Processes that permit Manufacturers to submit late-breaking requirements</td>
<td>7. Check if customers can absorb more frequent releases.</td>
<td>10. Include individuals with experience in using agile methods.</td>
</tr>
<tr>
<td>2. Hiring systems that bring people from competitors</td>
<td>5. Process re-Architecting + infrastructure upgrade to enable all major development activities (including integration testing and system testing) to be completed in 6-8 week cycles.</td>
<td>8. Corporate-level sponsorship for enterprise-wide agility:</td>
<td>11. Set expectations for openness, and provide a tangible fabric that promotes openness at all levels.</td>
</tr>
<tr>
<td>3. Establish a Standards documentation structure:</td>
<td>6. Institutionalized defined processes provide leverage for certain personnel. The effect of re-architected processes on changes to net leverage positions should be understood.</td>
<td>9. In areas of platform leadership, there should not be internal collaboration that can be perceived by platform contributors as threatening.</td>
<td></td>
</tr>
<tr>
<td>• To promote and encourage learning rather than overwhelm personnel.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• That is agile, enabling rapid update and dissemination of new learning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• That is clear to all personnel, enabling clear identification of a people organizational structure that addresses the fundamental knowledge interfaces.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• To identify standards that channel knowledge among different standards.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## STEP #5: Operational Agility

### Learning
1. Innovation networks and forums that make subject matter experts available and accessible for exchange of tacit knowledge.

2. Physical layouts to maximize person-to-person communication, informed by Allen's Law.

3. Process Automation technology lags other types of IC2T, so knowledge from Automation technology might not provide productivity improvement opportunities for developers.

### Action
4. Tools, guidance and mentorship that promotes explorative and convergent experimentation.

5. Practices to minimize propagation of errors especially during co-existence of Agility and Planned Processes.

6. Test Engineers may have diminished institutional leverage over Developers. Agile practices must bear out real parity between Developers and Testers.

### Collaboration
7. Communication patterns and practices that enable Development personnel to get quick feedback from customers and for customers to access new features and provide feedback.

8. Although changes to requirements must be expected, those changes should be accompanied with an understanding of the root-cause for the change.

### Sharing
9. Infrastructure and tools that enable storage of results and knowledge for efficient retrieval, mining and analysis.

10. Assertive peer behavior to question assumptions and prevent propagation of errors.

11. Nurture and enforce the cardinality of openness.
9. Special Implications for process automation

Researching the business imperatives for automation vendors, the automation value-chain and process automation development practices provided inadvertent insight into a number of conflicting perspectives. These are summarized below and invite additional research, albeit beyond the scope of this thesis.

1. Automation Vendors are concerned about 'commoditization of offerings', but TRIZ principles show innovation vector (Law of Increasing Degree-of-Ideality) for process automation is towards more connectivity and greater flexibility of offerings, i.e. offerings with fewer unique automation capabilities.

   **Commoditization perspective:**

   *Observation #2.2:* Process Automation vendors are threatened by a complex value-chain and associated value-proposition. Manufacturers view at least some automation offerings as commodities.

   *Observation #2.4:* Manufacturers believe vendors are focusing on platforms (i.e. technology), and at the same time, vendors are making incorrect forecasts about offerings needed by manufacturers.

   *Observation #2.5:* Manufacturers concede they depend on interaction with vendors to convert needs into requirements. However, manufacturers believe automation vendors continue to lose domain expertise in key disciplines of manufacturing automation.

   *Finding #7.2:* A well-defined process, such as a Stage gate Approach, does not reduce technology or market uncertainty. Therefore, if the technology uncertainty is high, a Stage gate approach will not help.

   **TRIZ perspective**

   *Observation #2.9:* While manufacturers are conservative, they are at the same time looking for better technology offerings, and better business solutions.

   *Finding #3.3:* The overlap between Process Automation and IT is not clearly identified, but is generally increasing.

   *Finding #3.2:* In the case of process automation, the choice between architectures may depend on which drawbacks stakeholders can handle, and not which one provides the most functional benefit.

   *Finding #5.10:* Ending focus on re-usable code but emphasizing malleable design will enable higher productivity through re-use of design without the risk of re-usable code.

   *Finding #5.14:* Agile methods are most suitable for incremental innovation.
2. Development Organization perspective suggests limited impetus to adopt agility, yet the business drivers insist current innovation practices are insufficient.

<table>
<thead>
<tr>
<th>Business Drivers’ perspective:</th>
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<tbody>
<tr>
<td>Observation #2.2:</td>
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<tr>
<td>Observation #2.3:</td>
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<td>Observation #2.6:</td>
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<tr>
<td>Observation #2.5:</td>
</tr>
<tr>
<td>Observation #2.4:</td>
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</tbody>
</table>

| Finding #7.8: | Platform leadership requires architecture for the entire ecosystem, and an internal organizational structure that will instill trust in platform contributors. |

<table>
<thead>
<tr>
<th>Development Organization perspective</th>
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<tbody>
<tr>
<td>Observation #4.1:</td>
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<tr>
<td>Observation #4.2:</td>
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<td>Observation #5.8:</td>
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<tr>
<td>Observation #6.3:</td>
</tr>
</tbody>
</table>
3. While emphasis for development has been on design & development, 50% of development is testing. Should Automation vendors focus on testing excellence as a core competency?

**Design and Implementation excellence perspective:**

*Finding #3.1:* The Stakeholders for an Automation System means it is socio-technical system. The design heuristics associated with a Socio-technical system will place constraints on the technical design and greater demands on the management practices.

*Observation #5.9:* Process Effectiveness and Efficiency are not necessarily competing. They can also be mutually reinforcing: the higher the effectiveness the greater the efficiency.

*Observation #5.8:* For a process automation vendor studied, Developers and Functional Testing are already concurrent. Integration Testing is partly concurrent with Developers and Functional Testing, while System Testing and Requirements Engineering are not. Any substantial benefits in concurrency can therefore only come from making System Testing and Requirements Engineering concurrent. However, these only account for 1.6% of the total effort.

*Finding #5.12:* Expecting requirements to change is at the heart of Agility, but does introduce considerable uncertainty to a project, especially since there could be many different root-causes for a change in requirement.

**Testing Excellence perspective**

*Observation #4.10:* While SW Engineers did not value (internal) ‘Cost Savings’, many HW Engineers and Test Engineers did.

*Observation #4.2:* Test Engineers were most enthusiastic about defined processes, but the enthusiasm may be attributed to leverage over Software Engineers.

*Observation #4.7:* Most assignments for development are initiated by Product Management and Requirements Engineering disciplines. However, Requirements Engineering initiates most of the assignments with a clear beginning, while Product Management initiates most of the assignments without a clear beginning.

*Observation #4.8:* Test Engineering triggers the majority of work completions.

*Observation #5.3:* Automation Vendors’ personnel are in general very insular, with little cross-pollination with other industries, Automation Vendors or even functions. Transformation to Agility will therefore require external help.

*Observation #5.5:* Agile methods have a cycle-time of 6-8 weeks. This is longer most System-Testing cycles, so adoption of Agile may necessitate changes to System testing practices.

*Finding #5.8:* Test Driven Development is inadequate for negative testing since that must include test-cases to behavior that emerges from the implemented system

*Finding #7.6:* Process Automation vendors need technology strategies based business models requiring outsourcing, increased need for asset optimization and higher ‘Return-On-Asset’.
4. Automation offerings have potential to deliver significant bottom-line value to manufacturers, but manufacturers accounting systems present monumental barriers.

**Manufacturer value needs perspective:**

*Observation #2.6:* There was a strong consensus for better technology offerings for the Process Operator Environment and the Process Unit control processing.

*Observation #2.7:* Manufacturers showed a strong consensus for better business solutions for Supply Chain Management and managing production strategies.

*Observation #2.10:* While there was no preference for how to account for manufacturers’ expenditure on process automation, manufacturers expect the option of offerings that can be capitalized.

*Observation #3.3:* Manufacturers are not seeing the ROI promised for process automation.

**Automation vendor value-proposition perspective**

*Observation #3.5:* Little has been done to change Cost-Accounting practices to better capture the actual cost of finished goods that can be used to calculate automation ROI.

*Observation #3.1:* Value proposition of process automation to manufacturers comprises: Improving production value, reducing the use of raw material, reducing energy costs, improving plant safety and improving Regulatory Compliance.

*Finding #3.4:* Manufacturers’ cost-accounting practices support financial reporting and not Operations Management.

*Finding #7.4:* Automation vendors need to have a strategy that is clear about products vs. services. Services need an ‘economies of scale’ strategy while products need an ‘economies of sale’ strategy. Products however, may include hardware product components, which traditionally require an ‘economies of scale’ strategy.
5. Automation vendors are interested in platform leadership, but automation platform offerings rely on 2 dominant platform offerings: PC platform to execute the automation offering, and highly-reliable highly available networking platform, to enable the value of the automation offering.

Platform play perspective:

Finding #5.19: The following dynamic large-scale business value practices are not covered:

- **Assuring Domain Expertise**, to ensure all assumptions and expectations about domain knowledge are understood, assessed and challenged, and to access the latest in state-of-the-practice.

- **Clarifying Ecosystem Role**, to ensure team’s vision and other selected practices reinforce and support either good platform leadership or good platform contribution.

Finding #7.7: Automation vendors need to decide between platform leadership and platform contribution. Process Automation market is largely fragmented and full of standards. Both market fragmentation and number of standards should be considered when choosing between platform leadership and contribution.

Proprietary offerings perspective

Finding #3.1: The Stakeholders for an Automation System means it is socio-technical system. The design heuristics associated with a Socio-technical system will place constraints on the technical design and greater demands on the management practices.

Finding #3.2: In the case of process automation, the choice between architectures may depend on which drawbacks stakeholders can handle, and not which one provides the most functional benefit.

Finding #5.9: The following Large-Scale system complexity practices are not covered:

- **Managing Critical System Parameters**, to ensure architectures and designs preserve essential system (emergent) properties expected by stakeholders. (see PDSS (2006))

  **Engineering System Robustness**, to confirm the implemented (constructed) architecture fulfills “intent associated with the externally delivered processes which are traceable to customer needs.” (see Crawley (2007) and Frey (2007))

Finding #7.8: Platform leadership requires architecture for the entire ecosystem, and an internal organizational structure that will instill trust in platform contributors.
References


Elssamadisy, A., (2009), Agile Adoption Patterns: A Roadmap to Organizational Success, Addison-Wesley.


Thebeau, R., (2001), Knowledge Management of System Interfaces and Interactions for Product Development Processes, MIT SDM Thesis


Appendix A: Value-Chain for LEGO's mindstorm

<table>
<thead>
<tr>
<th>Economic Factors</th>
<th>College Students</th>
<th>Needs</th>
<th>LEGO’s Ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase, &amp; Shipping &amp; Revenue</td>
<td>Distribution and Logistics</td>
<td>Supply of cooperative robots</td>
<td>Mission definition and management</td>
</tr>
<tr>
<td>Time Wastage</td>
<td>Deployed Robots</td>
<td>Mission Decomposition</td>
<td>Tasks Execution Systems</td>
</tr>
<tr>
<td>Placing Robots</td>
<td>Confirmation of objectives</td>
<td>Optimizing task allocation</td>
<td>Configuration Environment</td>
</tr>
<tr>
<td>Assembling robots</td>
<td>Available Robots</td>
<td>Assigning tasks</td>
<td>Operating Environment</td>
</tr>
<tr>
<td>Demarcation costs</td>
<td>Theatre</td>
<td>Coordinated Tasks</td>
<td>Configuring Robotic Tasks</td>
</tr>
<tr>
<td>Spare parts Expense</td>
<td>Purposeful maneuver</td>
<td>Action Step</td>
<td>Coordinated Robotic Actions</td>
</tr>
<tr>
<td></td>
<td>Motion Elements (motors, microphones ..etc)</td>
<td>Action Loops</td>
<td>Action Control Processing</td>
</tr>
<tr>
<td></td>
<td>Surroundings</td>
<td>Temperature, Pressure, Speed, Sound</td>
<td>Signal Input/Output</td>
</tr>
</tbody>
</table>

- Application Software
- Manufacturing Execution Systems
- Simulation toolset
- Visualization Engine
- Validation & Verification
- Productivity tools
- High Scalability Computer
- Robust Communications
- High Reliability Computer
- Embedded Computer
- Signal Conditioning
- Assembly & Packaging
- Mounting
- Power source
Appendix B: System Development personnel

1: Which one of the following is closest to your role today?

☐ SW Engineering
☐ Test Engineering
☐ HW Engineering
☐ System Engineering
☐ Product Management
☐ Configuration Engineering or Management
☐ Customer needs Management
☐ Requirements Engineering
☐ Project Execution
☐ Information or Documentation Engineering
☐ Regulatory Compliance or Certification
☐ Database Engineering
☐ Process Engineering or Conformance
☐ Other, please specify

2: Which of the following best describes your main assignment?

☐ Has a beginning phase, a middle phase and an ending phase.
☐ Has no beginning phase and no ending phase.
☐ No clear beginning phase, but a clear ending phase.
☐ Has a beginning phase, but no clear ending phase.

3: How would you describe the beginning part of your assignment?

☐ Has a clear starting date or event or notification
☐ Largely unclear or difficult to pinpoint to a date or event
☐ Assignment is on-going, and has no beginning.

4: How would you define the ending part of your assignment?

☐ Marked by a completion event or announcement or notification
☐ Marked by a completed deliverable or notification from me
Can never tell whether my assignment has ended.

5: Which one is closest to your primary (most important) deliverable?

- SW source code
- Test Results
- SW Design
- User Requirements
- Architecture design
- Testing Design
- HW Design
- Electronic or electrical module
- Mechanical modules
- Schedule
- Work Plan
- Work Procedure
- User Instructions
- HW Module
- Engineering Process Design
- Other, please specify

6: Who is most important to approve your primary deliverable?

- Product Management
- Test Engineering
- SW Engineering
- Project Execution
- I require no approval
- HW Engineering
- Configuration Engineering or Management
- System Engineering
- Process Engineering or Conformance
- Regulatory Compliance or Certification
- Requirements Engineering
7: Who provides most important info to start your assignment?

- Product Management
- SW Engineering
- Requirements Engineering
- Test Engineering
- I get no input from anyone
- HW Engineering
- System Engineering
- Project Execution
- Configuration Engineering or Management
- Database Engineering
- Information or Documentation Engineering
- Process Engineering or Conformance
- Regulatory Compliance or Certification

8: Who provides most important feedback to complete your deliverable?

- Test Engineering
- SW Engineering
- Product Management
- Project Execution
- Process Engineering or Conformance
- I get no input from anyone
- HW Engineering
- Requirements Engineering
- System Engineering
- Configuration Engineering or Management
- Information or Documentation Engineering
- Database Engineering
- Regulatory Compliance or Certification
9: Which is your most important measure of the value of your deliverables?

- Fewer defects in our product
- Improved productivity for the User
- More functionality for Customers
- Better product performance
- I don't know the value
- Cost savings to the company
- I never consider the value
- Cost savings to our customers
- Other, please specify

10: How effective is the process you use in your assignment?

- Written process is helpful to me.
- There is no defined process to use in my assignment.
- Written process is too different from how I must work

11: How efficient is the process you use?

- Most of process steps are necessary, but some are repeated.
- The process is 'lean' and has only the required steps.
- The process has a lot of overlap, and people sometime step on each other.
- The process has gaps, and too many things 'fall thru the cracks'.
- The process seems random.

12: Check all that influence what you include in your assignment.

- Defined processes
- Training you have taken
- Defined Engineering Standards
- Organization's experience
- Organization's capability
- Training taken by your managers
13: Check all that influence how quickly you complete your assignment.
   - Organization's capability
   - Training you have taken
   - Organization's experience
   - Defined processes
   - Defined Engineering Standards
   - Training taken by your managers

14: Check all that influence which errors you uncover in your assignment.
   - Organization's experience
   - Training you have taken
   - Defined processes
   - Organization's capability
   - Defined Engineering Standards
   - Training taken by your managers

15: Check all that influence the knowledge you use in your assignment.
   - Training you have taken
   - Organization's experience
   - Defined processes
   - Defined Engineering Standards
   - Organization's capability
   - Training taken by your managers

16: How long have you been working on Control Systems?
   - Less than 5 years
   - 5 years or more
Appendix C: Manufacturer Leaders and Experts

1. What is your relationship with process automation vendors? Check all.
   - [ ] I buy process automation products/services
   - [ ] I recommend process automation products/services
   - [ ] I provide services based on automation products
   - [ ] I consult for process automation vendors
   - [ ] I consult for process automation buyers
   - [ ] Other, please specify

2. What are the top 3 threats to process automation vendors?

3. What threat is or has been the most important?

4. Are process automation products becoming commoditized?
   - [ ] Yes
   - [ ] Not yet, but likely in near future
   - [ ] Some products, but not all.
   - [ ] Not in the foreseeable future
   - [ ] Other, please specify
   - [ ] View Responses

5. What do you think of Automation Vendors’ domain expertise? Check all that apply.
   - [ ] Vendors becoming less knowledgeable about process engineering
   - [ ] Vendors becoming less knowledgeable about process control
   - [ ] Vendors becoming less knowledgeable about operator needs.
   - [ ] Vendors less knowledgeable about manufacturing business needs

6. Which one of the following is true about process automation vendors?
   - [ ] Vendors tend to lag behind manufacturers’ needs
   - [ ] Vendors barely keeping up with manufacturers' needs
   - [ ] Vendors very knowledgeable about manufacturers' needs
Vendors ahead of market, and know manufacturers' latent needs

7. What problems or challenges have been on-going for process automation vendors?

8. Which one is closest to your process automation requirements?
   - We know exactly what we want, and our requirements don't change.
   - We know what we need, but it is hard to express clear requirements
   - We rely on vendors' feedback to clarify our requirements
   - Facts change so our requirements must change
   - Other, please specify

9. How responsive are Process Automation vendors?
   - Vendors need to be faster
   - Vendors are generally fast enough for the industry
   - Vendors are too fast for this industry

10. How innovative are process automation vendors?
    - Vendors don't offer some capability I really need.
    - Vendors' offerings are largely in line with the industry's needs.
    - Vendors offer much more than I really need.

11. Check all you consider true about common industry needs.
    - My needs represent closely what the industry needs
    - I am comfortable other companies can represent my needs.

12. Check all where manufacturers yearn for a better or different offering.
    - Enterprise Resource Planning
    - Manufacturing Execution System
    - Engineering Environment
    - Process Operator Environment
    - Specifying automation strategy
    - Distributed Process control
Process Unit control processing
Field input/output
Field sensors/actuators
System security

13. Check all where manufacturers want better or different business solution.
- Managing supply-chain
- Managing production strategies
- Plant utilization
- Mass-and-energy balance
- Managing design of process flows
- Managing process units
- Managing process loops
- Measuring temperature, pressure, flows, mass, volume.

14. Which one best characterizes manufacturers’ embrace of innovation?
- Manufacturers are conservative, and cautious about new technology
- Manufacturers are in some cases open to try out new technology.
- Manufacturers are comfortable being early adopters

15. How do manufacturers view expenses for automation products?
- Manufacturers prefer capitalizing process automation products
- Manufacturers prefer expensing process automation products
- Manufacturers are largely indifferent to the accounting method

16. Which of the following are true about the process automation market?
- the space is largely fragmented
- the space has too many standards
- conditions now favor a company to emerge as a platform leader
- manufacturers are wary of the clout of platform leaders
17. Check all you use as criterion to select a process automation vendor.

- Company's overall profitability
- Commissioning cost per control loop
- Engineering time per control loop
- Commissioning cost per I/O point
- Engineering time per I/O point
- Annual maintenance cost per control loop
- Annual maintenance cost per I/O point
- Annual Operating cost per control loop
- Annual Operating cost per I/O point
- Commissioning cost per plant capacity
- Engineering time per plant capacity
- Commissioning cost per plant type
- Engineering time per plant type
- Other, please specify
### Appendix D: Process Automation Value Chain

<table>
<thead>
<tr>
<th>Concept</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Value Chain</strong></td>
<td>1. What layers are missing from the value-chain?</td>
</tr>
<tr>
<td><strong>Value Chain</strong></td>
<td>2. Do you anticipate new layers in the future?</td>
</tr>
<tr>
<td><strong>Value Chain</strong></td>
<td>3. What factors should a Process Automation vendor consider when choosing a position in value-chain?</td>
</tr>
<tr>
<td><strong>Value Chain</strong></td>
<td>4. How do you decide if there is sufficient economy of scale?</td>
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<tr>
<td><strong>Value Chain</strong></td>
<td>5. Does decision take into account whether customer will likely capitalize or expense his purchase of a product or service?</td>
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<tr>
<td><strong>Value Chain platforms</strong></td>
<td>6. Which layers provide opportunity for platform leadership?</td>
</tr>
<tr>
<td><strong>Customer Value Chain</strong></td>
<td>7. Do you know any unfulfilled needs in customers’ value-chain?</td>
</tr>
<tr>
<td><strong>Agility</strong></td>
<td>8. How do you choose the time-to-deliver requirements for a new value-chain offering?</td>
</tr>
<tr>
<td><strong>Agility</strong></td>
<td>9. How do you select the definition of and the <strong>acceptable level</strong> of <strong>Quality</strong> for 'early adopters' of new value-chain offering?</td>
</tr>
<tr>
<td><strong>Agility</strong></td>
<td>10. What differences, if any, would you expect in the Development process for a new value-chain offering?</td>
</tr>
</tbody>
</table>

#1: ____________________________
#2: ____________________________
#3: ____________________________
#4: ____________________________
#5: ____________________________
<table>
<thead>
<tr>
<th>Concept</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agility</strong></td>
<td>11. What knowledge networks should be created to support a new value-chain offering?</td>
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<td>#1: __________________________________________________________________</td>
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<td>#2: __________________________________________________________________</td>
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<td></td>
<td>#3: __________________________________________________________________</td>
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<td></td>
<td>#4: __________________________________________________________________</td>
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<tr>
<td></td>
<td>#5: __________________________________________________________________</td>
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<tr>
<td></td>
<td>12. What do Development personnel need to learn about a new value-chain offering?</td>
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<td>#1: __________________________________________________________________</td>
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<td>#4: __________________________________________________________________</td>
</tr>
<tr>
<td></td>
<td>#5: __________________________________________________________________</td>
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<tr>
<td><strong>Adjacent markets</strong></td>
<td>13. Which markets would you consider to be adjacent to Process Automation?</td>
</tr>
<tr>
<td></td>
<td>14. What threats do you see from adjacent markets?</td>
</tr>
<tr>
<td>Market</td>
<td>No-threat</td>
</tr>
<tr>
<td>1. Industrial Robotics</td>
<td></td>
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<tr>
<td>2. Consumer Robotics</td>
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<td></td>
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<tr>
<td>3. Nano-materials manufacturing</td>
<td></td>
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<tr>
<td>4. Solar Energy + Wind</td>
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<tr>
<td>Concept</td>
<td>Question</td>
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</tr>
<tr>
<td><strong>Value Chain: Market Strategy &amp; Technology Strategy</strong></td>
<td>Energy mega farms</td>
</tr>
<tr>
<td>Value Chain</td>
<td>15. Which parts of value-chain are essentially commoditized today?</td>
</tr>
<tr>
<td>Value Chain opportunity</td>
<td>16. What time frame do you expect between seeing a new value-chain opportunity and releasing an offering in response?</td>
</tr>
<tr>
<td>Value Chain offerings</td>
<td>17. What is a typical lifecycle of a successful offering?</td>
</tr>
<tr>
<td>18. What is a typical lifecycle of a failed offering?</td>
<td></td>
</tr>
<tr>
<td>Tech. Strategy</td>
<td>19. For a process Automation vendor, do you recommend a different strategy between entering a new position in the value-chain vs. extending position in value-chain?</td>
</tr>
<tr>
<td>Market strategy</td>
<td>20. What success factors do you consider when enter a new position in value-chain?</td>
</tr>
<tr>
<td>Value capture</td>
<td>21. How do you determine the business model (i.e. value-capture) to accompany new position in value-chain?</td>
</tr>
<tr>
<td>Value-Creation vs. Value Capture</td>
<td>22. In your experience, what comes first: An attractive value-chain position (great value-creation opportunity) that needs a good business-model <strong>OR</strong> An attractive business-model (great value-capture model) that needs a realistic value-chain position?</td>
</tr>
<tr>
<td>Value Chain</td>
<td>23. Do you find the concept of value-chain helpful at all in making decisions?</td>
</tr>
</tbody>
</table>
Appendix E: Process Automation Dev. Operations Leaders and Experts (I)

1. Check all that is true about yourself.
   - Work for/with process automation vendors
   - Work for/with customers of process automation vendors
   - Work for/with manufacturers
   - Work for/with technology companies not in process automation
   - Work for/with software only companies
   - Work for/with system of systems companies

2. What are top 3 challenges unique to automation vendors?

3. How would you characterize innovation practices by Automation Vendors compared to state-of-the-art? Check all that apply.
   - Vendors are behind in their processes
   - Vendors are behind in their methods
   - Vendors are behind in their tools
   - Vendors are behind in their personnel skill-set
   - Vendors are behind in product design
   - Vendors are behind in product development infrastructure

4. How would you characterize operations management practices by Automation Vendors compared to state-of-the-practice? Check all that apply.
   - Vendors are behind in the organizational structures
   - Vendors are behind in their accountability practices
   - Vendors are behind in their incentive practices
   - Vendors are behind in their operational metrics
   - Vendors are behind in their quality practices
   - Vendors are behind in their operations cost structure
   - Vendors are behind in operations infrastructure (IT)
   - Vendors are behind in their accounting practices
   - Vendors are behind in their quality management practices
5. What problems or challenges have been on-going for process automation vendors?

6. Should Automation Vendors adopt agile methods?

- Don't know
- No
- Yes

7. Which is best for product development by Automation Vendors?

- Agile methods
- CMMI
- Stage Gate Development
- Lean Product Development
- Six Sigma
- Other, please specify

8. What top 3 benefits do you expect from your recommendation?

9. Check all product development chronic failings by Automation Vendors.

- Identifying manufacturers' latent needs
- Converting needs into requirements
- Delivering products on time
- Delivering products that meet requirements
- Delivering products that excite customers
- Clear profiles of customers and users
- Effective processes
- Efficient processes

10. Check all culture related chronic failings by Automation Vendors.

- Personnel with sufficient domain expertise
- Managing risk-taking
- Managing business uncertainties
- Managing technical uncertainties
- Commitment to customer problems
- Commitment to customers' experience
- Commitment to customers' programs

11. Check all market-related chronic problems for Automation Vendors.

- Fragmentation of market
- Clarity of Value-Chain
- Dependency of Value-Chain on economies-of-scale
- Opportunity for platform leadership
- Regulation of sector
- Vertical integration
- Horizontal integration

<table>
<thead>
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<th>Concept</th>
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<tbody>
<tr>
<td><strong>Process Automation as a Technology Industry</strong></td>
<td>1. What is your impression of Development practices in process automation industry compared to state-of-the-art?</td>
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<tr>
<td><strong>Process Automation as a Technology Industry</strong></td>
<td>2. What is needed ... incremental change in processes, or quantum change?</td>
</tr>
<tr>
<td><strong>Process Automation as a Technology Industry</strong></td>
<td>3. Does the industry know how to discover the appropriate balance, or does it need help from the outside?</td>
</tr>
<tr>
<td><strong>Process Automation as a Technology Industry</strong></td>
<td>4. Moving people between functions is a basic a management practice. Why do senior managers not do this?</td>
</tr>
<tr>
<td><strong>Agile Methods</strong></td>
<td>5. How would go about identifying the appropriate Agile Methods?</td>
</tr>
<tr>
<td><strong>Agile Methods</strong></td>
<td>6. Customers are not concerned about current time-to-market. But they’re unhappy with needs not being addressed. What then is the advantage of Agile?</td>
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<tr>
<td><strong>Agility</strong></td>
<td>7. What have been the determining factors in the successful adoption of Agile methods?</td>
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<tr>
<td><strong>Agility</strong></td>
<td>8. If a PA vendor wants to adopt agile methods, what would you tell him to worry about?</td>
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<td>Operations</td>
<td>Management: Agile methods and practices</td>
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<tr>
<td>Agility</td>
<td>9. What should the agile strategy be for new offerings vs. legacy offerings?</td>
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<tr>
<td>Agility</td>
<td>10. Do you see adoption of Agile being done as part of other Enterprise-wide changes?</td>
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### Appendix F: Process Automation Dev. Operations Leaders and Experts (II)

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<td>11. When deciding on a feature to be developed, what <strong>business-driven</strong> factors do you take into consideration?</td>
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<td><strong>Product vs. Services</strong></td>
<td>12. When deciding on a feature to be developed, what <strong>Product vs. Services</strong> factors do you take into consideration?</td>
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<tr>
<td>14. When deciding on a feature to be developed, what <strong>people-skills and</strong></td>
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Knowledge
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<td><strong>knowledge</strong> factors do you take into consideration?</td>
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<td><strong>Value Chain / Strategic</strong></td>
<td>15. What are good measures of the <strong>Effectiveness</strong> of a Development process?</td>
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<td>(a)</td>
<td>17. What Effectiveness vs. Efficiency tradeoffs have you actually witnessed or experienced in a decision?</td>
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Effectiveness vs. Efficiency

![Graph showing Effectiveness vs. Efficiency]

Suppose the Effectiveness vs. Efficiency of the general Development process is as depicted above, and the latest estimates, commitments and history place a specific project place on the ‘X’.

18. What would persuade you to permit the project to move to ‘P’?

#1: _________________________________

#2: _________________________________

#3: _________________________________

#4: _________________________________

#5: _________________________________

19. What would persuade you to permit the project to move to ‘Q’?
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<td><strong>Agile</strong></td>
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<td>20. Are Agile methods appropriate for Process Automation Vendors?</td>
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<td>21. What benefits, in any, would you expect from Agile to a Process Automation Vendor?</td>
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<td>22. What challenges or drawbacks, if any, would you expect?</td>
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Appendix G: Clusters for Engineering Standards

### Cluster Member List

#### (a) Cluster #1
- 1100.01 (159)
- 4221 (299)
- 5885 (300)
- 5911 (301)
- 8738 (302)
- 8760 (303)
- 8773 (304)
- 8775 (305)
- 8777 (306)
- 8800 (307)
- QMS2 (308)
- QMS3.1.1 (309)
- QMS3.19.4 (310)
- ISO9001 (311)
- IQA100-07 (312)
- IQA106-22 (313)

#### (b) Cluster #2
- 313.53 (31)
- 313.531 (265)
- 313.63A (266)
- 313.55A (267)
- 313.55C (268)
- 313.655D (269)
- 313.55E (270)
- 313.556 (271)
- 313.559 (272)
- 313.55H (273)
- 313.55I (274)
- 7929 (275)
- 8620 (276)

#### Cluster #3
- 280.03 (15)
- 260.23B (64)
- 260.39 (80)
- 261.3 (80)
- 261.11 (90)
- 260.3A (94)
- 260.3B (95)
- 260.3C (95)
- 260.3D (97)
- 261.3 (95)

#### Cluster #4
- 278 (72)
- 268.00 (188)
- 268.42 (229)
- 268.59 (241)
- 268.60 (242)
- 268.65 (248)
- 268.66 (249)
- 268.69 (251)
- 351 (297)

#### Cluster #5
- 313.60 (46)
- 280.5Q (57)
- 257 (64)
- 288.44 (227)
- 288.58 (240)
- 288.61 (243)
- 288.62 (244)

#### Cluster #6
- 300 (254)
- DFS4080 (255)
- DFS4054 (256)
- DFS4055 (257)
- DFS4564 (258)
- 30193RY (259)

#### Cluster #7
- 280.11 (49)
- 140.50 (55)
- 280.15 (58)
- 280.11 (111)
- 280.38 (112)
- 280.57 (114)
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| 280.32 (120)                    |                                    |                                  |
| 280.3A (121)                    |                                    |                                  |
| 280.28 (122)                    |                                    |                                  |
### Cluster Member List

**16-Mar-2009 23:06:08**

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