DEVELOPING METRICS FOR CONCURRENT ENGINEERING AT RAYTHEON COMPANY'S SURFACE RADAR GROUP

by

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Bachelor of Science in Naval Architecture and Marine Engineering, Webb Institute of Naval Architecture 1994

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

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ABSTRACT

Although many commercial companies introduced concurrent engineering into their development process in the early 1990s, many defense contractors did not venture into this terrain until later in the decade. The nature of defense contractors' complex products and lengthy design cycles introduces additional challenges into the collaborative engineering process. One challenge faced by Raytheon's Surface Radar Group was the identification and development of relevant, consistent, metrics to measure the effectiveness of their evolving concurrent engineering process. Metrics need to be readily, quickly, and regularly measured. They need to encourage value-added activities from process participants, and provide insight into the actions that are necessary to improve individual processes.

This thesis describes how Raytheon's Surface Radar Group identified and developed concurrent engineering effectiveness metrics, and how these metrics are being used to support the goals of their concurrent engineering initiative.

Keywords: Concurrent Engineering, Metrics, Effectiveness

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Chapter 1: Introduction and Overview

This chapter presents the problem that this thesis addresses and a brief description of the project. It explains why the project is important to Raytheon's surface radar group at this point in time. It also describes the formal goals of the project and how the project has accomplished the stated goals.

1.1 Project Description

Raytheon's surface radar group has been actively trying to incorporate concurrent engineering (CE) practices into surface radar programs for the past two years. A system of metrics is required to evaluate the success of the CE processes. It is also necessary to evaluate the current processes with respect to best practices. The project outlines a set of ideal processes to support Raytheon's goals for concurrent engineering within the surface radar group and compares these processes to those currently in use. A system of metrics that can be used to measure the success of the CE process is identified. Finally, this research assists in the implementation of the CE metrics system.

1.2 Project Goals

Raytheon's management set three goals for the metrics project:

- Identify and implement a system of metrics to evaluate the success of the concurrent engineering (CE) process utilized by Raytheon on Surface Radar Projects.

- Provide additional information on best practices in CE to Raytheon's Surface Radar Management.

- Document the CE process, identify value-added sub-processes, and identify where the process can be improved.

The project has accomplished these goals. The listing of ideal supporting processes will provide insight into how other companies have overcome these challenges. The comparison with current supporting processes will identify gaps in the current processes that need to be addressed. The comprehensive metrics system will provide Raytheon's management with the tools required to measure the success of the concurrent engineering process and to improve this process over time. In addition, the system of metrics will provide Raytheon's management with feedback regarding the extent to which a design is meeting targets (such as cost) during the design process so that the design can be improved, rather than after it is built when the window of opportunity for improvement has already passed.

Chapter Two will provide a detailed description of the project setting and background.

Chapter 2: Project Setting and Background

This chapter describes the importance of the CE metrics project in the context of Raytheon's surface radar group's current growth programs. It also provides an overview of findings from the extensive literature search. This literature search was used to examine the theory and methods that were relevant to the CE metrics project.

2.1 The Need for Concurrent Engineering Metrics

Raytheon's surface radar group is currently working on the design of seven new surface radars. While all of these radars have different functions and exterior appearances, they all are made up of the same basic assemblies and use the same basic technology. These similarities magnify the opportunities for improving the designs in terms of cost, quality, and schedule adherence. The challenge is to ensure that both program specific and general support structures exist to encourage the full application of Concurrent Engineering (CE) concepts throughout the design process. To that end, a set of metrics was developed to provide feedback regarding the success of the CE process in Raytheon's surface radar group. The radars considered in this project are identified in Table 2.1-1.

2.2 Related Theory and Methods of Concurrent Engineering and Metrics

Concurrent Engineering was first defined in 1988 by the Institute for Defense Analysis as "a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support. This approach is intended to cause developers, from the outset, to consider all elements of the product life cycle from concept through disposal, including quality control, cost, scheduling, and user requirements" [SOCE, 2000]. CE takes advantage of the fact that 70-80% of the cost of a product is determined by activities that take place during the conceptual design phase [Flint and Gaylor, 1995, pg. 99]. It stands to reason that with most of the costs fixed in early design phases, the most significant benefits can be gained by improving the methods used during this phase.

Table 2.1-1: Raytheon Surface Radar Group Products

Theatre High Altitude Area Defense (THAAD) • Portable • Ground-based
Joint Land Elevated Netted Sensor (JLENS) • Portable • Tethered Aerostat
X-band Radar (XBR) • Fixed • Ground-based
Upgraded Early Warning Radar (UEWR) • Fixed (existing) • Ground-based
Dual band radar family: Surface Craft Radar – surveillance and control (SPY-3) • Fixed • Shipboard Volume Surveillance Radar (VSR) • Fixed • Shipboard
High Powered Discriminator (HPD) • Fixed • Shipboard

Companies have many different motivations for introducing concurrent engineering practices into their companies. For high-tech consumer product companies speed to market is one of the main reasons for its introduction while other slower "clockspeed" [Fine, 2000] industries are more interested in other issues like lower product costs. This is not to say that the two are mutually exclusive. General Dynamics space system division stated three goals for their CE process "shorter development cycles, continuous quality improvement, and cost reduction" [Kewley and Knodle, 1993, pg. 34]. In addition to shortening speed to market, cost reduction and continuous quality improvement, other common goals for CE include "reducing engineering changes, shortening development time, increasing return on assets", [Landeghem, 2000, pg. 296] developing a product that more closely meets customer needs, increasing market share, improved serviceability, increased product performance, longer product life, reduced product cost and so on [Maylor and Gosling, 1998, pg. 72]. Based on the wide variety of goals associated with concurrent engineering, it is clear that each company should select goals for its concurrent engineering process based on its own business environment and company culture.

Early practitioners of CE were frustrated by the lack of relevant material on implementation [Kewley and Knodle, 1993, pg. 34]. Happily that problem has been solved over the past five years. There are numerous books and articles on implementation tactics. Some of the most comprehensive include Concurrent Engineering: What's Working Where edited by Christopher Backhouse and Naomi Brooks [Backhouse (ed.) and Brookes (ed.), 1996], Concurrent Engineering – The Agenda for Success edited by Sa'ad Medhat [Medhat (ed.), 1997] and Successful Implementation of Concurrent Engineering Products and Processes edited by Sammy Shina [Shina (ed.), 1994]. While these and other references do not necessarily agree on the best techniques or address all of the same techniques for implementing concurrent engineering, there are some common threads in their recommendations. Some of these common threads are as follows.

All implementation techniques recommend the use of a cross-functional teams [Pillai, Lal and Rao, 1997, pg. 717] although they differ on the importance of collocation for team effectiveness [Backhouse and Brookes, 1996, pg. 2] and [Brookes and Backhouse, 1998, pg.

3036]. Most implementation techniques recommend additional involvement of suppliers in product development and including the supplier on the cross-functional team [Prasad, 1999], formal evaluation process for supplier feedback and criteria for reducing the number of suppliers of a given product [BMP, 1990, pg. 6]. Many methods recommend using product cost as means of trading off design decisions [Kroll, 1992, pg. 282 and Belson and Nickelson, 1992, pg. 443]. Finally a prevailing theme is high profile upper and middle management support for the concurrent engineering process [Tummala, Chin and Ho, 1997, pg. 277].

Another recent and widespread theme in implementing concurrent engineering is the importance of including metrics as part of the implementation process. One author goes so far as to say that "if a team member cannot measure what he or she is talking about, and is not able to express it in a quantitative or qualitative term, the team knows nothing about it" [Prasad, 1997, pg. 288]. In their paper "Performance Measurement for Product Design and Development in a Manufacturing Environment," Pawar and Driva describe what they refer to as " the Principles of Performance Measurement" [Pawar and Driva, 1999]. A key aspect of these principles is the need for metrics to provide both "macro-visibility" defined as being "directly related to strategic goals to gain top management support and to ensure high visibility of results", and "micro-visibility" defined as having high-visibility "within the team" to "ensure that everyone knows what is happening" [Pawar and Driva, 1999, pg. 66]. Unfortunately many metrics proposed by experts in concurrent engineering provide only one of these dimensions. Some of the more high level and loosely related metrics include items such as number of projects completed divided by number of projects started as a measure of job satisfaction, and incremental profit divided by project cost as a measure of return on investment [Shina, 1991, pgs 116-117]. While these metrics might be relevant to top level managers, they are not likely to be personally relevant to an individual team member. Other metrics extensively address one aspect of CE without devoting adequate attention to other issues, yielding an incomplete picture of performance. For example, one paper discusses organizational structure and seating arrangements in great detail but provides little insight into the other aspects of CE [Kusiak and Belhe, 1992]. Another theorizes that metrics should be developed through a detailed failure modes analysis for a given process (in this case creating aluminum extrusions) [Subramaniam and Ulrich, 1998]. While this method is likely to be very relevant to the individuals involved in the process in question, it is less likely to be meaningful to top managers.

The final and perhaps most pervasive breakdown in most of the systems of CE metrics is that the proposed metrics all measure the end results from a given project. Even those that emphasize the importance of developing metrics that are relevant throughout the design process provide little guidance on how to begin [Hight, Hornberger and Last, 1995, pg. 498]. One of the most popular metrics for concurrent engineering is the measurement of engineering changes or design defects [Rook and Medhat, 1996, pg. 6]. This is typical of a "reactive" metric that is measuring the existence of an undesirable event after it has already occurred. The objective should be to identify the processes that could have prevented the undesirable event from occurring, and measure those processes to ensure that they are effective. This is the intent of "process-oriented concurrency metrics" (POCMs) [Goldense, 1994]. These metrics include items such as core-team turnover [Goldense, 1994, pg. 28]. Another important category of metric is the predictive metric. The "as designed vs. as proposed" (ADAP) cost comparisons developed during this project and presented later in this thesis are a typical example.

Predictive metrics focus on estimating the end result (cost in this case) based on the best available knowledge of the design team at any given time. This estimate is repeated regularly (in this case for every design change or every two weeks whichever is longer) to provide an ongoing evaluation of the project's status with respect to the project goal.

2.3 Summary

This chapter discussed the significant potential for leveraging design improvements across the complete product line of surface radars. It explained the importance of concurrent engineering metrics in achieving these design improvements. Finally, it provided an overview of existing literature on concurrent engineering and concurrent engineering metrics. The development of the concurrent engineering metrics system was based on the observations above. A Raytheon specific set of goals for concurrent engineering was developed. The set of ideal processes was identified based on relevant literature to support these goals. Metrics were designed to be relevant at a low level and be easily summarized to be relevant at a high level (e.g. cost of an assembly which is relevant to a team member rolls up to cost of a product which is relevant to top management). Finally all metrics were designed to be either directly predictive (like ADAP) or process-oriented (like core-team turnover). Chapter Three describes the research methodology used in this project in greater detail.

Chapter 3: Research Methodology

This chapter describes the scope of the concurrent engineering metrics project and provides a detailed description of the process that was used to complete the project. How project goals were accomplished by implementing the process is explained.

3.1 Project Scope

While the project was completed within the bounds of the Surface Radar product line, it is intended to be useful in a general context. The deliverables of the project could easily be modified for use in other areas of Raytheon and other corporations. The project takes a systems view of the design process and focuses on concurrent engineering related to assemblies rather than components. The project motivation was a desire to measure the success of the concurrent engineering process and to continue to improve it.

3.2 Process Description

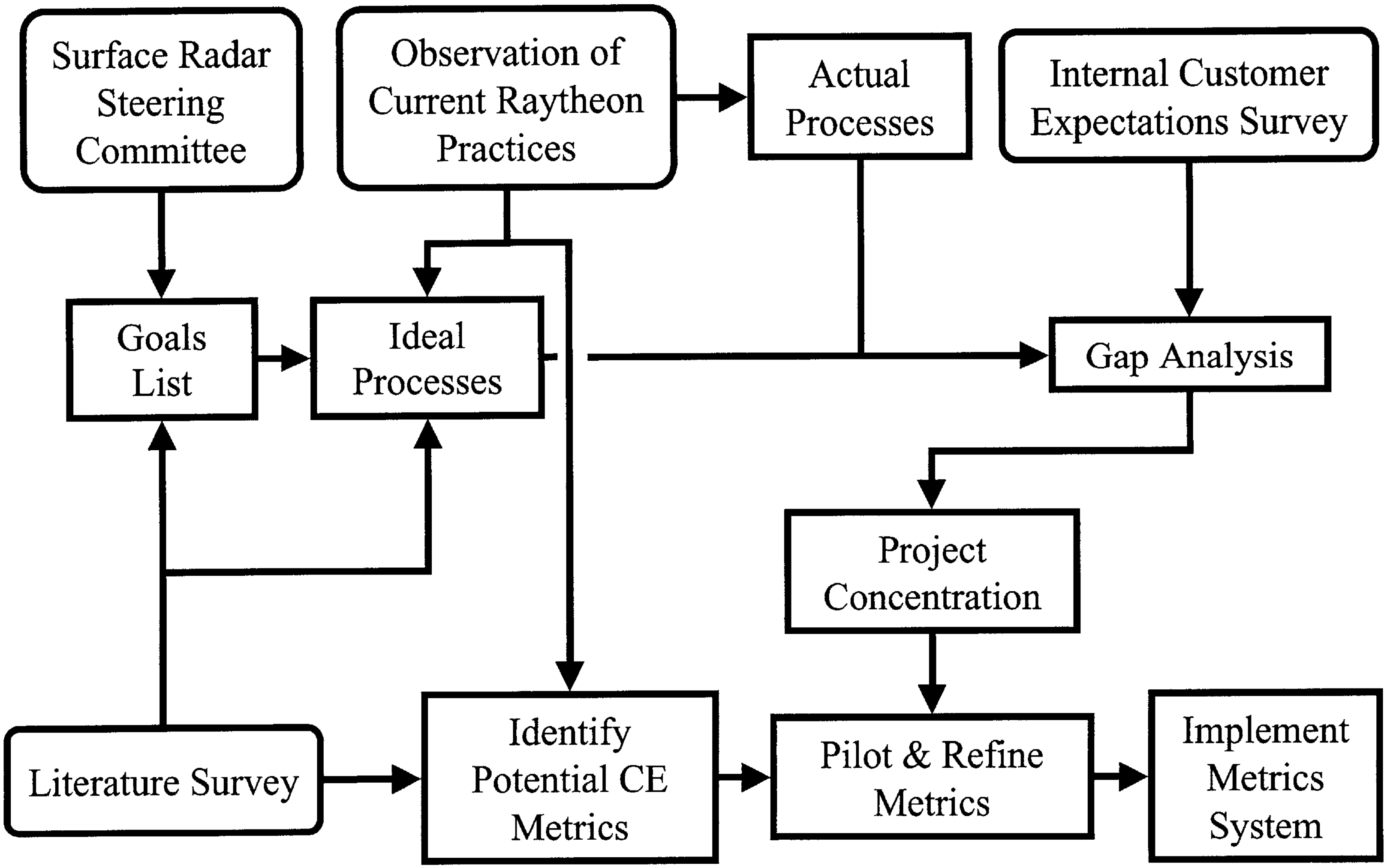
As illustrated in Figure 3.2-1, the following process was used to accomplish the project goals:

1. Identify the goals of Raytheon's surface radar group's concurrent engineering process.
   - Based on input from Raytheon's surface radar management team.
   - Aligned with Raytheon's Integrated Product Development System (IPDS).

2. Identify an ideal set of processes to support the concurrent engineering process goals.
   - Based on an extensive literature search for best practices in concurrent engineering.
   - Considering Raytheon's company culture.

3. Compare Raytheon's current concurrent engineering practices with the ideal processes.
   - Based on observation of current practices & interviews.
   - Reviewed by Raytheon's surface radar management team.

Figure 3.2-1: Project Approach



4. Identify internal customers of the concurrent engineering process and their expectations.
   - Identified approximately 60 customers in several categories (e.g. Program management, PDEs).
   - Surveyed them on relative importance of concurrent engineering goals and perceived performance against those goals.

5. Prioritize implementation of metrics project.
   - Based on gaps identified in customer survey and comparison of current CE processes to ideal supporting processes.

6. Create comprehensive set of CE metrics.
   - Based on ideal supporting processes.
   - Based on successful metrics and guidelines for successful metrics identified in literature search.

7. Create a phased implementation plan.
   - Based on guidance from Raytheon's surface radar management team.
   - Based on priorities from the customer survey.

8. Assist in implementation.
   - Following phased implementation plan.

The author served as an individual actor facilitating the metrics development process. Although there was no formal team created to develop the metrics system, it was essential to obtain input and 'buy-in' from the people within Raytheon who would be using the metrics system after the research was concluded. Therefore a series of ad hoc groups were formed on a voluntary basis to address specific issues throughout the life of the project. These groups formed and disbanded throughout the project under the general oversight of the surface radar management team. This core group was made up of representatives of program management, operations, and engineering who became involved with the project during the first month of the project.

3.3 Summary

This chapter described the formal project scope. It also indicated the applicability of the concurrent engineering metrics project to other design processes both internal and external to Raytheon. Finally, it described the process that was used to accomplish the goals of the CE metrics project. Chapters that follow will describe each of the process steps in greater detail. Chapter Four describes the process that was used to identify and prioritize Raytheon's surface radar group's goals for the concurrent engineering process.

Chapter 4: Identification and Prioritization of Goals

This chapter describes the process that was used to identify the goals of the concurrent engineering process and the process that was used to prioritize the goals once they were identified. The results of the survey used to prioritize the goals are discussed.

4.1 Identification of Goals

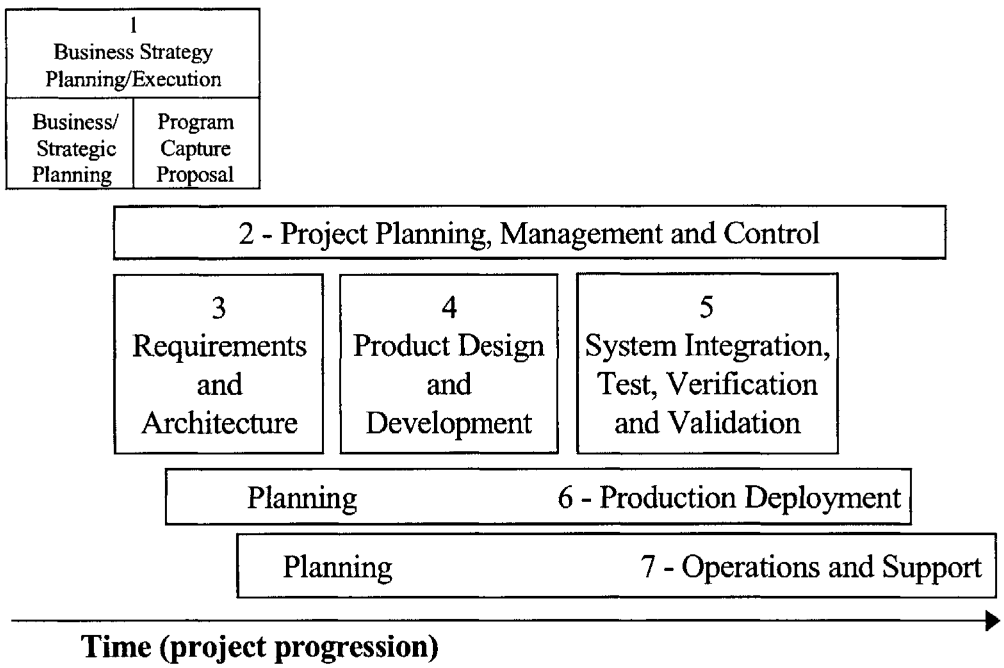
Raytheon's surface radar management team identified 19 goals for the concurrent engineering process. The identification of these goals was an iterative process including representatives from program management, operations, and engineering. The first round was based on a listing of typical goals for concurrent engineering processes, which was gleaned from the literature search. Subsequent rounds were based on input from all of the representatives until everyone agreed that the list was complete. The list was structured to align with Raytheon's Integrated Product Development System (IPDS) by mapping the goals to the seven phases of IPDS. IPDS is a master template that outlines standard processes and procedures from initial "program capture" activities throughout the program lifecycle. The seven phases are as follows:

- *Business Strategy Execution Phase*
  - Covers activities related to strategic business planning, program capture and proposals.
- *Project Planning Management and Control Phase*
  - Covers activities related to program management throughout the life of the program.
- *Requirements and Architecture Development Phase*
  - Covers activities related to conceptual design.
- *Product Design and Development Phase*
  - Covers activities related to detailed product design.
- *System Integration, Test, Verification and Validation Phase*
  - Covers activities related to pre-production testing and proof of design documentation.
- *Production and Deployment Phase*
  - Covers activities related to the planning and execution of full-scale production.
- *Operations and Support Phase*

- Covers activities related to the planning and execution of final operation and field support.

A diagram of IPDS is presented in Figure 4.1-1. The final list of goals is the cornerstone of both the evaluation of Raytheon's current concurrent engineering (CE) practices in surface radars and the CE metrics system. A complete listing of the goals including reference numbers is presented in Table 4.1-1.

Figure 4.1-1: Diagram of Raytheon's IPDS



Source: Raytheon Northeast Multidiscipline Resource Center IPDS Brochure

Table 4.1-1: Goals List

Number	Abbreviation	Goal
		Business Strategy Execution Phase
1	PDE involvement in proposal development	Systems product development engineer (PDE) involvement with program during proposal development
		Project Planning Management and Control Phase
2	PDE staffing	Identification of well trained PDE staff available to support programs
3	PDE empowerment & accountability	PDEs are empowered and accountable within a clearly defined scope of responsibility
4	Engagement & team cohesiveness	Engagement and team cohesiveness
		Requirements and Architecture Development Phase/Product Design and Development Phase:
5	Best value design	Design is focused on producing the best value for the customer (balances technical requirements with cost, quality, and schedule risk – i.e. product cost is as important a design tradeoff parameter as product technical performance)
6	Make or buy strategy	Design follows a clearly defined (corporate) make or buy strategy
7	Shortened design cycle	Shortened design cycle
8	Integration of product & process design	Product design is integrated with manufacturing (process design) following established design guidelines
9	Reduced product diversity	Reduced product diversity
10	Reduced lifecycle cost	Reduce lifecycle cost
11	Improved customer satisfaction	Improved customer satisfaction
12	Measure PDE value add	Measure value that product development engineers add to the design and production process
		System Integration, Test, Verification and Validation Phase
13	ITVV phase duration/ Knowledge stream	Minimize ITVV phase duration and product changes during prototype build, and ensure that the knowledge stream flows in both directions
		Production and Deployment Phase
14	Reduced ECNs	Reduced engineering change activity during product production
15	Reduced Eng. support in production	Reduced engineering support required for products in production
16	Reduced factory tooling	Reduced factory tooling
17	Increased production yields	Increased Production yields
18	Achieve planned production rates	Achieve planned production rates
		Operations and Support Phase
19	Field Feedback	Identify and feedback field product changes and operational issues

4.2 Prioritization of Goals

4.2.1 Structure of Customer Survey

An internal customer survey was conducted in order to accomplish the following objectives:

- Prioritize the goals of the concurrent engineering process.
- Baseline the current concurrent engineering process with respect to the stated goals.
- Identify gaps in the perceived importance of concurrent engineering goals between participants in the process.
- Determine the concentration of the metrics project.

The survey was sent out to approximately 60 internal customers of the metrics project and approximately 40% of the surveys were returned. The survey consisted of three main questions:

- Rate the importance of the 19 goals by allocating 1,000 points between them[1].
- Rate the success of each of the surface radar programs at achieving each of the goals.
- Rate the most successful instance for each program on a scale of 1 – 5.

4.2.2 Prioritization Results from Survey

There were some significant discrepancies in the perceived importance of goals. Even within respondent categories the standard deviation of the importance ratings was significant. The spread of responses from different respondent groups increased with the more important goals. However, in most cases the groupings of more important goals vs. less important goals were consistent between respondent groups. Some of the more interesting results are as follows:

- Everyone agreed that creating a "Best Value Design" was one of the most, if not the most, important goal of the CE process.
- "PDE Empowerment and Accountability" and "Engagement and Team Cohesiveness" were both ranked as very important by Senior Management/Program Management, Systems PDEs and Others, but were ranked relatively low by Engineering IPT Leads and PDE Management (about a 40/100 point spread).

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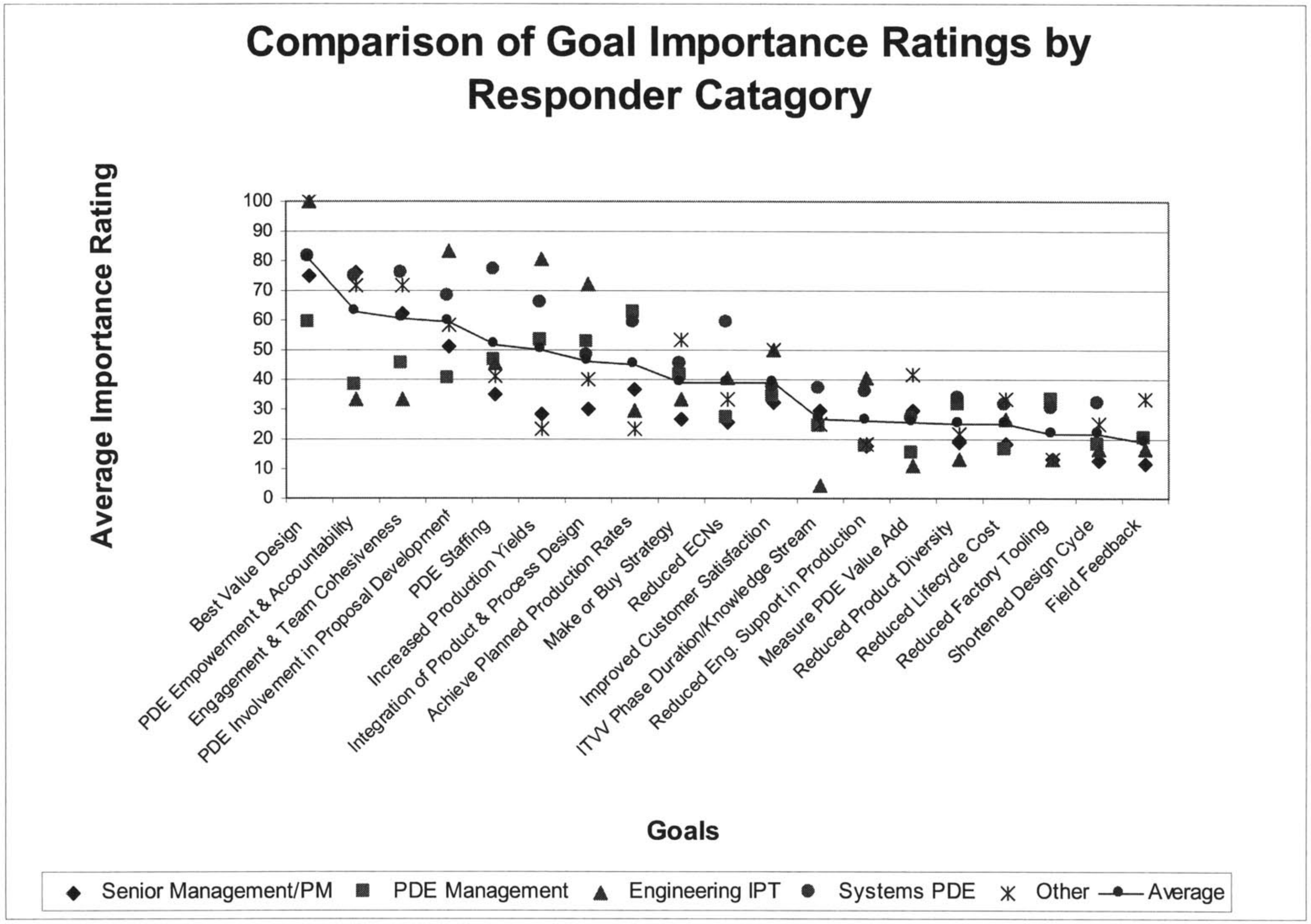
[1] Based on the method suggested in [Love, 1997, pg. 15]

- "PDE Involvement in Proposal Development" was ranked very high by Engineering IPT Leads and relatively low by PDE Management.
- Systems PDEs placed higher than normal rankings on "PDE Staffing" and "Reduced ECNs".
- Engineering IPT Leads ranked "Increasing Production Yields" and "Integration of Product & Process Design" higher than normal and "ITVV Phase Duration/Knowledge Stream" lower than normal.
- Senior Management/Program Management and Others had lower than normal rankings of "Increased Production Yields".

A graph comparing the goal importance ratings by responder category is presented in Figure 4.2.2-1.

Figure 4.2.2-1: Importance of Goals by Responder Category



The survey also generated a number of comments. These comments demonstrate that widely different perspectives existed at the outset of the project. In general the comments served to identify potential fears and roadblocks to change that would need to be addressed during the project. These comments have been divided into seven categories and are presented as follows.

General Comments:

- The [CE] process has a lot of merit.
- The PDEs are a talented group.
- CE seems to be implemented for the sake of being able to point to it.
- Presently the CE function seems overly bureaucratic, very inefficient, and only marginally effective.
- Every item that comes into Andover should go through a "Value Stream Baseline" evaluation.
- Do not treat people like a commodity – people respond better and work harder and smarter if they are part of a high performance culture (this must be established in both engineering and the factory but more so in the factories).

These concerns are addressed by the introduction of a concurrent engineering metrics system. The CE metrics system measures the impact of the CE process in key areas such as cost, quality and schedule adherence. This measurement will help focus the new product development process on performance to specific targets and the effectiveness of current product development processes in meeting those targets.

Organizational Structure:

- Interaction between COE, subassembly, and system PDEs needs to be streamlined. There is not enough communication between the different organizations. This interaction should be a given.
- PDEs are grouped around end items (e.g. BSG), but designers are grouped around programs [tend to focus only on their program].
- Since PDEs report to Andover, they are not free to express that something should be built outside.

- Process for supporting and collaborating with engineering, ILS, and PMO needs to be simplified.
- CE meetings should take place between facilities [Andover and Sudbury] on a 50/50 basis (Andover always has to go to Sudbury).

These comments reflect some rivalry between Raytheon locations with Andover as the primary manufacturing site and Sudbury as the primary engineering site. The CE metrics system focuses on team metrics rather than metrics by location in order to encourage common goals.

Programmatic Differences:

- Some programs take the PDE role more seriously than others do.
- Inclusion of PDEs/CE processes varies from program to program and appears to be totally at the discretion of the program office.

By measuring and improving the CE process, the introduction of the CE metrics system means value of the CE process will be readily quantifiable. In addition, formalizing the review structure (described further in section 7.6) provides a high level of visibility for the CE process.

Engagement:

- The amount of engagement [of PDEs] varies within programs.
- There remains a mindset in the design and PDE community that PDEs are engaged only when drawings are available for sign-off.
- Earlier PDE engagement on programs is required.

The metrics cover all phases of the design process. As such, it will be readily obvious at a high level in the organization if the recommended process are not being used.

Accountability/Empowerment:

- PDEs do not have the power to change things in the factory to meet the needs of new programs.
- Expanded accountability will enhance value and warrant increased levels of empowerment/contribution.

- The design community needs to be held accountable for achieving CE goals and should be measured accordingly to aid the process.

Team measurements incorporated in the CE metrics system hold all team members accountable for reaching program goals. Departmental metrics hold department managers responsible for supporting the CE process on an ongoing basis.

Quantifying the Value of the CE Process:

- Much more focus needs to be given to value provided by the [CE] efforts expended (i.e. deploy based on justifiable benefit instead of rote practice).
- We are staffing the PDE function but what are we really getting, where is the focus?
- The impact of PDE involvement is under-appreciated by management due to a lack of quantifiable metrics (i.e. hours and dollars avoided).

The CE metrics system lends focus to the CE process. The formal reporting structure ensures that all levels of management will be aware of the impact of the CE process.

Training/Information Dissemination:

- PDE goals & objectives need to be defined in a written format with appropriate training tools (i.e. PCATs, DFMA, etc.).
- The purpose and responsibilities of PDEs are vastly under publicized to management and the design communities.
- Design guidelines for CE should be created by the PDEs, approved by production, and made available on the intranet for use by the design community.
- There should be no such thing as professional PDEs – PDEs need to revolve in/out of the manufacturing floor at least once a year to keep their skills current.

These concerns were addressed by establishing training criteria for key participants in the CE process. Metrics to measure compliance with these criteria and other suggestions on this list were included in the CE metrics system.

The focus areas of the metrics project recommended by the results of the internal customer survey area are as follows:

Primary foci:

- "Best Value Design"
- "PDE Empowerment and Accountability"
- "Engagement and Team Cohesiveness"
- "PDE Involvement in Proposal Development"

Secondary foci:

- "Increased Production Yields"
- "Integration of Product and Process Design"
- "Achieve Planned Production Rates"
- "PDE staffing"

4.3 Summary

This chapter explained the process that was used to develop a Raytheon-specific list of goals for the concurrent engineering process. It also described the format of the customer survey that was used to prioritize the goals. Finally, it presented the groupings of goals that were identified as critical by the survey respondents. Chapter Five describes the process that was used to identify the ideal processes for supporting these goals.

Chapter 5: Identification of Ideal Processes

This chapter describes the process that was used to identify the ideal supporting process for each of the CE goals and how these processes were structured to form the first portion of the Ideal Processes Matrix.

5.1 Identification of Ideal Supporting Processes

The listing of ideal support processes is intended to identify critical concurrent engineering practices that are required to fully support each goal in the context of Raytheon's company culture and operating methods. As such, the listing of ideal support processes presented in this thesis should be evaluated within the context of each company and tailored accordingly prior to any application. The ideal supporting processes were derived from successful methods identified during an extensive literature search as well as successful methods observed by the author. The listing of ideal processes also went through an extensive iterative review similar to the goals list. This was critical, not only to ensure that the proposed support structure for the goals was as robust as possible, but to obtain 'buy-in' from the project's customers that the listing actually reflected an "ideal" state.

5.2 The Formation of the Ideal Processes Matrix

Like the goals list, the ideal processes matrix is divided up by the phases of IPDS. Since many of the goals for the requirements and architecture phase and the product design and development phase were the same, these goals have been combined into one section. The goals and their respective ideal supporting processes are divided up by phase. This forms the first two columns of the Ideal Processes Matrix. The complete Ideal Processes Matrix is presented in Appendix A. Starting with the ideal processes rather than the actual processes helped prevent mental 'anchoring' to the current processes. It also created an accepted set of criteria against which the actual processes could be evaluated. Index numbers, the method used for numerical evaluation of actual processes, are described in section 6.2.

5.3 Summary

This chapter discussed the methods that were used to identify the ideal supporting processes for the CE goals. It also discussed how they were used to create the first portion of the Ideal Processes Matrix. Finally, it explained the importance of starting with the ideal processes rather than the actual processes. Chapter Six describes the analysis of actual practices.

Chapter 6: Analysis of Current Practices

This chapter describes the two methods that were used to analyze Raytheon's surface radar group's concurrent engineering processes. The results of the internal customer survey provide customers perceptions of the performance of the concurrent engineering process. The comparison of actual process to ideal process in the framework of the Ideal Processes Matrix provides feedback regarding current practices.

6.1 Performance Results from Survey

As stated in section 4.2.1, the survey that was used to prioritize the CE goals was also used to measure the perceived performance against those goals. Perceived performance varied from program to program with Program A and Program B receiving CE performance ratings up to 60 and 50 respectively and Program E receiving a CE performance rating of approximately 30 on the same goal. The CE process generally appeared to be performing better on the more important goals; however, this trend was only a strong one on Program A and Program B. The graphs in Appendix B show the scores for each of the programs.[2] Respondent responses were converted to a 100-point index (i.e. ideally all performance scores would be 100). The goals are listed on the graphs in descending order of importance based on the survey results. In general, performance was aligned with importance in that performance against more important processes was better than or equal to performance against less important processes.

6.2 Actual Processes in the Ideal Processes Matrix

The actual processes were added to the Ideal Processes Matrix and mapped one-to-one against the ideal supporting processes. This actual (or current) processes listing is comprised of brief descriptions of how Raytheon's current processes for new product development in surface radars are aligned with the ideal support processes. It is based on interviews with Raytheon personnel and personal observation and was reviewed by many of the managers involved in the concurrent engineering process. Each process was assigned a corresponding index

[2] Program F & Program G did not receive enough responses to provide significant program specific analysis. The responses for these programs are included in the overall performance graph. Overall performance was an average of the performance of all programs.

number. An index number is a subjective rating of the compliance of current support processes with their respective ideal support processes. The rating is essentially a five level scale with 100 possible points (i.e. possible ratings are 20, 40, 60, 80, or 100). The ratings also translate into red/yellow/green ratings of each process to enhance the visual management potential of the matrix[3]. A rating of 100 (world class/green) indicates a process that is matched with the ideal and typically implemented. A rating of 80 (established/green) indicates a process that largely matches the ideal and is typically implemented. A rating of 60 (defined system/yellow) indicates a process that partially matches the ideal and may not always be implemented. A rating of 40 (ad hoc/red) indicates a process that is inconsistent in nature and application. A rating of 20 (not performed/red) indicates that a process is non-existent.

The index numbers are also used to evaluate the compliance with ideal processes at a goal level. This rough evaluation is established by averaging the index numbers for each support process related to a given goal. This index number is listed in the goal column and is also color-coded for quick inspection. While this method inherently assumes an equal importance weighting for all of the support processes, it is useful in the context of a general overview.

6.3 Summary

This chapter described the perceived performance results from the internal customer survey. It also described the documentation of actual processes with respect to ideal processes. Finally, it described the rating system that was used to provide a rough comparison of the ideal processes to the current processes. Chapter Seven describes the set of CE metrics that was developed based on the CE goals and ideal supporting processes.

[3] The color-coding is not shown in the appendix due to MIT thesis formatting standards, but was a key part of the management tool.

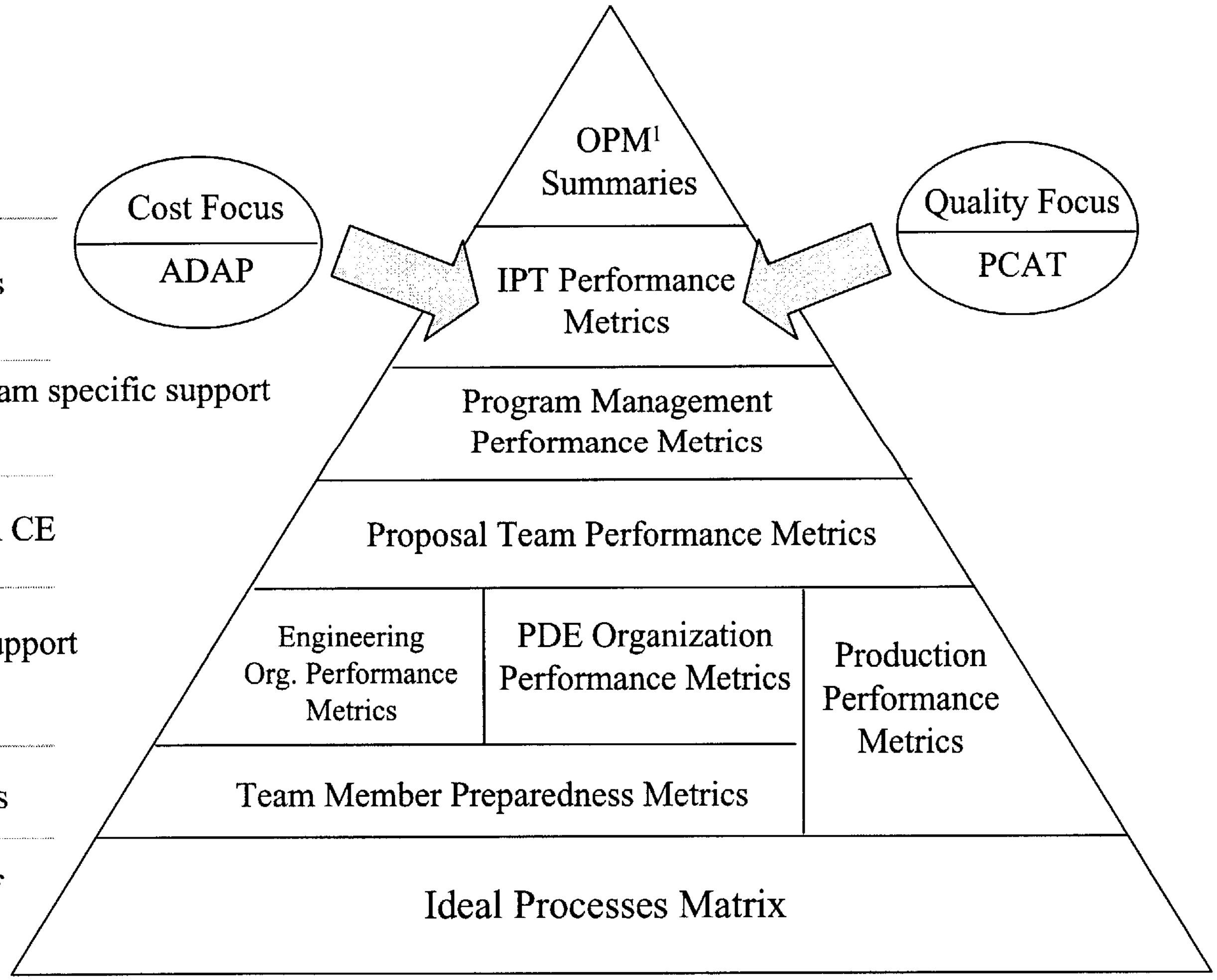
Chapter 7: Developing a Set of CE Metrics

This chapter will describe the complete set of CE metrics that was developed for this project. Unless otherwise noted, the selection of metrics and proposed presentation of metrics are direct results of this research. It will also explain how they interrelate to provide feedback to all levels of the organization. Finally, it will describe the reporting structure that was developed to ensure that data collected is presented at the appropriate levels of the organization.

7.1 Overview of the CE Metrics System

The CE metrics system is made up of three main categories. The first category, overall self-evaluation metrics, consists of the measures included in the Ideal Processes Matrix. The second category, continuous improvement and CE support metrics, consists of the Team Member Preparedness Metrics, the Product Development Engineering (PDE) Organization Performance Metrics, Engineering Organization Performance Metrics, and Production Organization Performance Metrics. The third category, program specific performance metrics, consists of Proposal Team Performance Metrics, Program Management Performance Metrics, and Integrated Product Team (IPT) Performance Metrics. Program specific performance metrics are at a team level rather than a department level to help break down departmental barriers and encourage teamwork [BMP, 1992, pg. 5]. The continuous improvement and CE support metrics and the program specific performance metrics are designed to roll up into Oregon Productivity Matrices (OPMs) for summary, tracking, and goal setting purposes. OPMs were developed by the Oregon Productivity Center at Oregon State University in 1986 [Viken, 1995] and are described in more detail in section 7.5. A diagram illustrating the concurrent engineering metrics system is presented in Figure 7.1-1. Raytheon management is responsible for determining the target values for each metric based on their strategic goals and current performance. The calculations presented in this thesis were created for demonstration purposes.

Figure 7.1-1: Diagram of the CE Metrics System



- Increases visibility
- Streamlines goal setting
- Tracks progress

- Measures success
- Establishes common goals
- Encourages cooperation

- Measures quality of program specific support structure for CE

- Encourages early focus on CE

- Measures quality of CE support structure

- Establishes personal goals

- Provides system level self evaluation

[1]Oregon Productivity Matrix

7.2 Overall Self-Evaluation Metrics – The Ideal Processes Matrix

The ideal processes matrix consists of four components. The first component is the goal column. This is made up of the 19 goals described earlier in Table 4.1-1 divided by IPDS phase. The second component is the list of ideal supporting processes. The third component is the current support processes. The fourth component is the index number. The index numbers are also used to evaluate the compliance with ideal processes at a goal level.

The ideal processes matrix serves as a guide for the further development of the concurrent engineering process. It identifies not only where the concurrent engineering process should be, but also the locations of the biggest performance gaps. The ideal processes matrix created for this project is included in Appendix A.

7.3 Continuous Improvement and CE Support Metrics

7.3.1 Team Member Preparedness Metrics

Team member preparedness metrics are divided into three major categories. The first category of team member preparedness metrics is team skills. The development of these skills is intended to support the goal of increasing engagement of CE processes (and PDEs) and team cohesiveness. This category consists of:

- General team training
- Team leader training
- Facilitator training
- A 360-degree evaluation
- Communication for personality types training
- A personal Myers-Briggs evaluation

In the self-managed team environment core team members need to have not only basic team skills but also the more advanced skills of team leader and facilitator. This enables all the team members to step in and keep the team on target throughout the design process. Accessible team members are only expected to participate in general team training so that they are familiar with working in a team environment. The 360-degree evaluation, communication for personality types training, and personal Myers-Briggs evaluation are intended to make each team member aware of their own work styles as well as the work styles of their teammates so that they can modify their own behavior to best achieve the team objectives. This training is recommended for all team members.

The second category is CE skills. The development of these skills is intended to support the goal of having well trained staff to support programs. This in turn is divided up into four categories. The first, general CE skills, includes:

- Program management[4] training
- Leadership[5] training
- Negotiation/conflict resolution[6] training
- Cost as an independent variable (CAIV)[7] training (i.e. design to cost (DTC) training)
- As designed vs. as proposed (ADAP)[8] training
- Design for manufacture and assembly (DFMA)[9] training
- Voice of the customer (VOC)[10] training
- Quality function deployment (QFD)[11] training
- Communication for managers[12] training
- Risk management[13] training
- Six sigma training (awareness[14] and specialist[15])

[4] Includes conceptions such as identifying tasks, identifying goals, scheduling, and tracking program progress against a schedule.
[5] Includes concepts such as identifying your own leadership style, situation based leadership, listening, and articulating a vision.
[6] Includes concepts such as negotiation tactics, identifying the priorities of all parties, and how to use this information to maximize value for all parties.
[7] Includes conceptions such as setting cost goals, deploying these goals to a team level, and tracking team performance to cost goals.
[8] Described in section 7.4.3.3.
[9] Includes concepts such as part reduction, assembly friendly features and identifying critical vs. flexible tolerances.
[10] Includes concepts such as asking open-ended questions, listening, identifying latent needs, and collecting and analyzing customer needs based on interviews and observation.
[11] A technique to translate customer needs into key performance metrics.
[12] Includes concepts such as presentation skills and writing skills.
[13] Includes concepts such as the different types of risks and techniques for identifying, tracking, and neutralizing them.
[14] This is a basic introduction to the concepts of Raytheon six sigma including concepts such as the purpose of the process, success stories, and an overview of common techniques.
[15] Includes concepts such as statistical process control (SPC) and provides practice through the use of simple cases in enough depth that people would be ready to solve simple problems on their own.

Program management training is recommended for all members of the core team in order to aid in their self-management. Leadership training, communication for managers training, and negotiation/conflict resolution training is recommended for the product development engineers (PDEs) only. Traditionally technical criteria have dominated the design, with cost reduction, quality improvement, and manufacturability considered secondary. The PDEs are involved in the design processes to advocate these traditionally disadvantaged design characteristics and are therefore in need of extra training in the leadership, communication, and negotiation/conflict resolution fields. CAIV training, ADAP training, risk management training, and DFMA training are recommended for all team members (core and accessible) since all team members will be expected to participate in the cost reduction, risk mitigation, and design improvement efforts. VOC training and QFD training are recommended for all core team members since these skills are essential in determining customer requirements. This training is recommended only for the core team since this is the most likely group to be involved in VOC and QFD activity. Six-sigma training (awareness and specialist) is recommended only for the PDEs since they will likely be leading any process improvement initiatives within the team. PDEs also need these skills since they are included in the team as the advocates of designing in quality and production yields.

The second category of CE skills is software training. This includes:

- Process capability analysis tool (PCAT) training (introduction and user)
- Pro-Engineer (Pro-E) basic training
- Pro-Process training (a module of Pro-E)
- Product view training
- Mentor graphics overview training
- Integrated product development system (IPDS) training (overview and tailoring)
- Microsoft Visio training
- Microsoft Project training
- Risk Manager training
- DOE/KISS training

- Geometric dimensioning and tolerancing training
- PRACS training
- Power builder standards training

PCAT training and power builder standards training are recommended for PDEs since PCAT is used to determine the standard labor hours (of some components) and the designed quality (of most components) inherent in a design. Power builder is used to determine the standard labor hours in designs (assemblies) and provide a defect opportunity count. This information can then be used by the PDEs to identify cost and quality drivers and provide this information the other members of the design team, so that the team can work on improving these measures. The Pro-E (design package for all systems except circuit cards) basic training, Pro-process (module that creates manufacturing plans/work instructions from the Pro-E database) training, Product view (viewer for Pro-E database intended for the casual user) training, and Mentor graphics (CAD package for circuit cards) overview training are all recommended for PDEs, so that they can view engineering information during creation and prototype development. IPDS overview training is recommended for all team members to ensure that they understand the product development processes presented as Raytheon's standard. IPDS tailoring training is recommended for PDEs, since some of them will be participating in tailoring sessions with program management, and all of them will need to understand how this process affects their scope of work. Microsoft Visio is recommended for the PDEs as a means of documenting their processes assumptions and sketching out ideas. Microsoft Project training is recommended for all team members, so that it can be used a means of communicating status throughout the team and to their customers. Risk manager (software supporting risk management) training is recommended for the PDEs, so that they can track the risks that their team has identified. DOE/KISS (design of experiments software package) training is recommended for all core team members, so that they can use it to optimize their experimentation throughout the design process. Geometric dimensioning and tolerancing training is also recommended for all core team members, so that they can interact successfully with the metal fabrication design documentation. PRACS (production release and control system) training is recommended for the PDEs, so that they can reference bill of material data.

The third category of CE skills is basic problem solving training. This includes:

- Brainstorming
- Root cause analysis
- Pareto charts
- Flowcharting
- Statistical process control

Basic problem solving training is recommended for all team members so that it can be fully integrated into the team processes.

The fourth category of CE skills is independent study in CE or Engineering field. This includes:

- Attending conferences, meetings, and workshops presented by the Society of Concurrent Engineering (SOCE)
- Attending conferences, meetings, and workshops presented by relevant engineering societies (e.g. the American Society of Mechanical Engineers)
- Reading relevant books and journals recommended by the Raytheon Multidiscipline Resource Center (MRC) library or their supervisor

SOCE conferences and relevant books and journals are recommended for all team members. The engineering society conferences are recommended for the core team, the accessible team members would typically be involved in other societies closer to their core disciplines.

The third category of team member preparedness metrics is production experience. Developing skills in this area is intended to increase the integration of product and process design as well as reduce engineering support in production through improved designs. It is also intended to encourage PDEs to rotate back out into production. This segment includes:

- Workcenter capability training
- Production work experience
- Frequency of full-time rotations into production

- Hands-on build weeks in production

Workcenter capability training is a general overview of the capabilities of Raytheon's workcenters. This overview is recommended for all team members. Production work experience and full-time rotations into production are recommended for the PDEs. Since they are included on the design team to represent manufacturing, it is critical that they have credibility in this area and that their skills remain fresh. Hands-on build weeks in each of the major production areas are recommended for all core team members. This production contact will provide all team members with a systems view of production and a greater appreciation of the impact of their design work.

Different recommendations are made for the training of PDEs, other core team members, and accessible team members. Additionally, the importance of each training item is weighted relative to the other training items for each type of personnel. Team members can then score themselves against the appropriate standard using a binary scale. Their overall score is reached by multiplying their binary scores against the item weightings given for their function and dividing this sum by the total possible score for their function. A sample team member preparedness evaluation is presented in Appendix C.

7.3.2 Product Development Engineering (PDE) Organization Performance Metrics

PDE Organization performance metrics are comprised of two major categories. The first category of PDE Organization performance metrics is PDE training. This supports the goal of providing well-trained PDEs to support programs. This metric is designed to measure the quality of PDEs that are being provided to support the IPTs and the consistency of this quality. It consists of a table of PDEs and their team member preparedness scores from which the average training score and the standard deviation of the training scores are calculated.

The second category of PDE Organization performance metrics measures performance related to the creation of CE tools. It includes:

- Facility books
- Design checklists

- Production simulation tools
- Standard manufacturing plans
- Lessons learned documentation
- An engineering change notice (ECN) cause and impact database
- A first article assembly review form (FAARF) database

The facility books score is based on a listing of all major production areas and a binary score indicating whether or not they have a current facility book. The development of facility books is intended to support the goals of integrating product and process design and reducing factory tooling at the equipment level. The number of current facility books is divided by the total number of desired facility books to create the facility books score. A facility book is considered current if has been updated within a six-month period. A typical facility book would include, but is not limited to:

- A map of the area indicating the location of all equipment
- A brief plain language description of each piece of equipment and its function(s)
- A sketch of the piece of equipment
- A possible range of operation for each piece of equipment
- A preferred range of operation for each piece of equipment
- An explanation of why the preferred range of operation differs from the possible range
- An explanation of the consequences of exceeding the preferred range of operation (e.g. quantify the reduction in yield)

The design checklist score consists of three categories: tooling checklists, design guideline checklists, and error rates for design details. All of these metrics are calculated by dividing the number of current checklists by the number of desired checklists. A checklist is considered current if it has been updated within a six-month period. Tooling checklists are intended to support the goal of reducing factory tooling. A typical tooling checklist would include, but is not limited to:

- A listing of currently available tooling and fixturing by function and equipment
    - A brief description of each tool's/fixture's function

    - Diagram of each tool/fixture
    - A brief description of each tool's/fixture's boundaries of operation
    - Any preferences for certain tools/fixtures are identified and explained
- A field for the design engineer to indicate if they are using a given tool
- An area for the design engineer to indicate any new functionality that they might need which is not already covered
- An area for the design engineer to estimate the cost of this new tool/fixture as well as the quantity required

The tooling checklist with the engineer's annotations for his/her specific design can be used as a review tool for IPTs and engineering supervisors.

Design guideline checklists are intended to support the goal of integrating product and process design. A typical design guideline checklist would include, but is not limited to:

- Sections by typical product categories and products (e.g. circuit cards)
- A preference ranking of material types for each function (e.g. heat sinks)
- Explanation of why one material is preferred over another (rough relative cost ratios, producibility, environmental, etc.)
- A preference ranking of joining methods for each application (e.g. solder, snap fit features)
- Explanation of why one connection method is preferred over another
- A preference ranking of typical configurations for each function (e.g. layer, bracket types)
- Explanation of why one configuration is preferred over another
- A field for the design engineer to indicate his/her frequency of use for each material, joining method, and configuration
- A field for the design engineer to highlight any unusual (defined as not on the list) materials, joining methods, or configurations

The design guideline checklist with the engineer's annotations for his/her specific design can be used as a review tool for IPTs and engineering supervisors.

Providing error rate data to engineers while they are creating a design is intended to support the goal of increasing production yields. Typical error rate data would include, but is not limited to:

- Tables of defect rates for each connection type or configuration
- A pop-up window/table integrated into the detailed design CAD program (i.e. presented to the designer when he/she is making a decision)

A log of the designer's choices would be available to the designer, the IPT, and the designer's supervisor.

The production simulation score consists of two categories: cycle time simulation and assembly process simulation. Both of these metrics are calculated by dividing the number of current simulation tools by the number of desired simulation tools. A simulation tool is considered current if it has been updated within a six-month period. Encouraging the development of cycle time simulation tools is intended to support the goal of achieving planned production rates. A typical cycle time simulation tool would include, but is not limited to:

- The ability to simulate (based on production data) the cycle time and variation of all workstations for a given work scope
- The ability to estimate (based on production data) the cycle time of transfers between stations
- The ability to combine the above items to simulate the cycle time of a variety of production paths
- The ability to actively identify bottlenecks for a given work scope and/or combination of work

The cycle time simulation tools should be designed for use by both engineering personnel and production management.

The assembly process simulation tools are intended to support the goal of increasing production yields as well as increasing the integration of product and process design. A typical assembly process simulation tool would include, but is not limited to:

- The ability to simulate any automated portions of the assembly process
- The ability to simulate standard hand functions such as soldering
- Simulations should concentrate on mechanical integration items such as interferences, clearances for tool heads, manipulation/handling of parts, and clearances for hand work

The assembly process simulation tools would be available to the design engineer, the IPT, and the engineering supervisor as a means of improving the manufacturability of the design.

The development of standard manufacturing plans is intended to support the goal of reducing engineering support in production by increasing the quality and uniformity of work instructions. The manufacturing plan score is calculated by dividing the number of standard manufacturing plans by the number of desired standard manufacturing plans. A typical standard manufacturing plan would include, but is not limited to:

- An isometric sketch showing the finished item
- An isometric sketch showing the configuration and order in which the parts are to be assembled/manufactured
- A diagram showing the assembly sequence and configuration of each subassembly
- Instructions for manufacturing all Raytheon manufactured parts
- All part numbers labeled
- Written instructions included for each assembly/manufacture diagram
- Standard manufacturing plans available in an electronic template

The standard manufacturing plans would be available to the engineers that are responsible for creating work instructions for reference purposes and all manufacturing plans would be expected to have the same layout and content as the applicable standard manufacturing plan.

The development of lessons learned documentation is intended to support the goal of reducing ECNs. The lessons learned score is calculated by dividing the number of lessons learned databases by the number of desired lessons learned databases. A typical general lessons learned databases/analysis would include, but is not limited to:

- Lessons learned entered by PDEs, other IPT members, program management, production, etc. excepting items documented through formal ECNs
- Entries cross-referenced by program, program stage and a descriptive category
- Analysis consisting of Pareto charts and tables to turn the database into some general guidelines for improving future programs

Summaries of all lessons learned from these databases should be distributed to incoming personnel on new programs as part of the kick-off process.

The ECN cause and impact database and the first article assembly review form (FAARF) database are intended to support the goal of reducing ECNs. The ECN feedback score is calculated based on a binary scoring system for each of the following tasks:

- Maintenance of a central ECN database – updated at least every two months
- Analysis of this database (root cause, Pareto charts) – updated at least every six months
- Incorporating the results of these findings into checklists (can be treated as a percentage score) – updated at least every six months
- Awareness of ECN cost (cost of an ECN is calculated and published to IPTs) – updated at least every six months

The FAARF feedback score is calculated the same as the ECN feedback score with the exception of the cost item, which is not applicable. The FAARF database is an early warning system that will point out problems during the prototype run. It also points out suggestions for improvement that might not become ECNs due to the extent of the changes required to implement them at the end of the design process.

Summaries of all lessons learned from these databases should be distributed to incoming personnel on new programs as part of the kick-off process. A sample of the PDE Organization performance metrics is presented in Appendix D.

7.3.3 Engineering Organization Performance Metrics

Engineering Organization performance metrics are comprised of three major categories. The first category of Engineering Organization performance metrics is engineer training. This supports the goal of providing well-trained engineers to support programs. This metric is designed to measure the quality of engineers that are being provided to support the IPTs and the consistency of this quality. It consists of a table of engineers and their team member preparedness scores from which the average training score and the standard deviation of the training scores are calculated.

The second category is designer feedback. This supports the goal of reducing ECNs. The metric is designed to encourage designers and their supervisors to maintain records of their errors that were caught during the checking process and take action to prevent these errors in the future. It is made up of the following items scored (binary) against each designer every two weeks:

- Posted check sheet of errors discovered in checking (weighted 25%)
- Pareto diagram of root causes (e.g. did not spell check notes section) posted (weighted 50%)
- Run chart of accuracy improvement maintained (weighted 25%)

The details of the detected errors are intended for review between the designer and his/her supervisor. The metric is intended to measure if an improvement process is in place, not specific error rates of a given designer.

The third category of Engineering Organization performance metrics is associated with change management plans. Change management plans are intended to reduce the number of ECNs as well as streamline the treatment of those ECNs that cannot be avoided. The metric consists of a binary score for each of four change types:

- Customer initiated changes
- Cost reduction changes
- Error correcting changes
- Performance improvement changes

A typical change management plan would include, but is not limited to:

- A definition of the type of change
- An indication of when this type of change will be considered during the design cycle
- A flowchart indicating the appropriate course of action for a proposed change that will not be incorporated into the current design
- A flowchart indicating the appropriate course of action for a proposed change that will be incorporated into the current design

The change management score is calculated by dividing the number of current change management plans by the number of desired change management plans. A plan is considered current if it has been updated within a nine-month period. All engineering supervisors should be trained in each of the change management plans.

The development of field lessons learned documentation is intended to support the goals of improving customer satisfaction and capturing field feedback. The field lessons learned score consists of two categories: field feedback databases/analysis and field feedback interviews. The lessons learned score is calculated by dividing the number of lessons learned databases and field feedback interview databases by the number of desired lessons learned databases and field feedback interviews. A typical field feedback database/analysis would include, but is not limited to:

- Any formal modification requests and comments that came back from the field (e.g. items requested in a query system)
    - Divided up into general categories (e.g. hardware problems, software problems, procedure problems)

- Analysis by category, consisting of Pareto charts and tables to turn the database into some general guidelines for improving future programs

A typical field feedback interview database would include, but is not limited to:

- Voice of the customer segments cross referenced by program and equipment segment, software segment, or procedural segment
- Analysis consisting of Pareto charts and tables to turn the database into some general guidelines for improving future programs

Summaries of all lessons learned from these databases should be distributed to incoming personnel on new programs as part of the kick-off process. A sample of the Engineering Organization performance metrics is presented in Appendix E.

7.3.4 Production Organization Performance Metrics

Production Organization performance metrics are comprised of four major categories. The first category of Production Organization performance metrics is Integration, Test, Verification and Validation (ITVV) phase duration/knowledge stream. This supports the goal of minimizing ITVV phase duration and product changes during the prototype build and ensuring that the knowledge stream flows in both directions. This metric is designed to measure the quality of production support for the ITVV phase. It consists of a weighted[16] average of the following sub-components:

- Passive communication with engineering customer:
  - Percentage of prototypes with exact status and location tracked online
  - Worth 10%
- Active communication with engineering customer:
  - Percentage of prototypes where the IPT/cognizant engineer was notified of the construction schedule 24 hours in advance
  - Worth 30%
- Rapid delivery of product to customer:

[16] This and all subsequent weighting were based on the author's judgement.

- Average cycle time target divided by the actual average cycle time
- Worth 30%
- Reliable delivery of product to customer:
  - Target standard deviation of prototype delivery divided by average standard deviation of prototype delivery
  - Worth 30%

The second category of Production Organization performance metrics is reduced engineering support in production, which supports a goal of the same name. The metric is designed to measure production empowerment with respect to handling issues that would otherwise need an engineering consultation. It consists of an average of the following two components:

- Percent of production areas with a dedicated liaison engineer
- Percentage of production areas with electronic viewing capability for engineering information

The third category of Production Organization performance metrics is control of production processes. This supports the goal of achieving planned production rates. This metric is designed to measure the percentage of production processes that are in control. It consists of a weighted average of the percentage of typical production paths for each area that are tracked and in control multiplied by the number of paths in that area. A path is considered tracked if the configuration of its output is measured on a run chart (e.g. variation of width in a cutting process). A path is considered in control if its output is between the upper and lower control limits. Although a process that it is in control is not necessarily highly capable (i.e. producing output within the specification range), a controlled process will produce predictable output. This gives management the ability to compensate for process yield when they are trying to achieve planned production rates.

The fourth category of Production Organization performance metrics is flexible tooling[17]. This supports the goal of reducing factory tooling. This metric is designed to measure

[17] [Stoll, 1995] provides an overview of flexible fixturing.

production support of flexible tooling development. It consists of a weighted average of the following sub-components:

- Collection of data on tooling spending:
    - Database of tooling spending by area
    - Updated every two months
    - Binary score
    - Worth 10%
- Analysis of tooling spending:
    - Pareto analysis of tooling spending for the past three years
    - Updated every six months
    - Binary score
    - Worth 10%
- Identification of possible solutions:
    - Brainstorming possible solutions (by area)
    - Updated every six months
    - Binary score
    - Worth 10%
- Quantification of specific cost reduction proposals:
    - Actual dollar value of proposals divided by the target value of proposals
    - Percentage score
    - Worth 20%
- Quantification of actual savings:
    - Actual dollar value of savings divided by the target value of savings
    - Percentage score
    - Worth 50%

Flexible tooling development needs to include line personnel as well as production management. A sample of the Production Organization performance metrics is presented in Appendix F.

7.4 Program Specific Metrics

7.4.1 Proposal Team Performance Metrics

Proposal Team performance metrics are comprised of six categories. The first category of Proposal Team performance metrics is Lead Systems PDE involvement. This also supports the goal of increasing PDE involvement in proposal development. This metric is designed to measure the Lead Systems PDE's involvement with the proposal team. It is based on a binary scoring of each of the following three items:

- Lead Systems PDE's inclusion on the proposal team.
- Lead Systems PDE's participation in selecting and pricing the baseline design.
- Lead Systems PDE's participation in the IPDS tailoring session.

The Lead Systems PDE involvement score is calculated by dividing the sum of the actual binary scores by the sum of the target binary scores.

The Lead Systems PDE involvement score is the first of a series of metrics that are incorporated throughout the program specific metrics categories to address the issue of teambuilding. Other metrics that address this issue are team staffing (described in section 7.4.2), facilitation of cross-team communication (also described in section 7.4.2), and team building (described in section 7.4.3.1). These metrics work together to measure the degree to which program structures are designed to facilitate the creation of a true team. A true team is not a team only on program organization charts, but is also a team in practice [Willaert et al., 1998, pg. 92]. A true team talks, not only about the project, but also about 'unrelated' items such as personal hobbies. These seemingly unimportant conversations serve to improve the quality of work-related communications thereby making the team more effective as a unit [Reinertsen, 1997, pg. 113]. Program structures can encourage the development of a true team by deliberately bringing the team together for team building training and events (e.g. barbecues) and by breaking down communication barriers by providing intranet team forums, encouraging early program involvement by core team members, and co-locating teams.

The second category of Proposal Team performance metrics is business strategy execution phase (BSEP) PDE services plan and funding. This supports the goal of increasing PDE involvement in proposal development. This metric is designed to measure the support and organization of the CE process during the BSEP. It consists of a list of PDE services proposed jointly by the lead systems PDE and the proposal team. Each item has the corresponding negotiated hours to accomplish the task and the actual funding provided listed. The funding score is the sum of the actual hours provided divided by the sum of the negotiated hours.

The third category of Proposal Team performance metrics is the design/build strategy. This also supports the goal of increasing PDE involvement in proposal development. Encouraging the creation of the design/build strategy not only provides a standard means of documenting proposal assumptions but also pushes manufacturing concerns and therefore the involvement of PDEs into this critical development phase. A typical design/build strategy would include, but is not limited to:

- Identification of build locations for significant subassemblies and components.
- Identification of technological standards that will be used in the design.
- Identification of one-time investments (e.g. new equipment).
- Identification of other major estimate assumptions.

The design/build strategy score is calculated by dividing the sum of the actual binary scores for each of the design/build strategy components by the sum of the target binary scores.

The fourth category of Proposal Team performance metrics is the identification of customer needs. This supports the goal of improving customer satisfaction [Ulrich and Eppinger, 2000]. This metric is designed to measure the completeness of the customer needs identification process. It is comprised of a weighted average of the following four items:

- Customer surveys:
    - The number of customer surveys received.
    - Percentage score based on the target (some percentage of the number sent out)
    - Worth 10%
- Customer observation sessions:
    - The number of sessions conducted.
    - Percentage score based on the target

- Worth 20%
- Customer interviews:
    - The number of interviews conducted.
    - Percentage score based on the target
    - Worth 20%
- Database of customer needs:
    - A database of all requests is maintained and ranked based on stated importance to the customer.
    - Binary score
    - Worth 50%

The fifth category of Proposal Team performance metrics is integration of customer needs. This also supports the goal of increasing customer satisfaction. This metric is designed to measure the degree of integration of customer needs and wants into the proposed design. The customer satisfaction score is comprised of the number of items in the customer needs database that are incorporated into the design (weighted by importance to the customer) divided by the total number of items in the customer needs database also weighted by importance. The weightings are based on the following assumptions:

- A high importance item is nine times more important than a low importance item.
- A medium importance item is three times more important than a low importance item.

The sixth category of Proposal Team performance metrics is establishing cost targets. This metric is intended to push cost consciousness into the proposal development phase as well as provide the basis for establishing target costs later on in the design development. The cost target score is based on the sum of the binary scoring of a series of tasks divided by the sum of the target scores. The tasks are as follows:

- Procurement cost:
    - Procurement cost baseline is identified by area.
    - Procurement cost opportunities are identified by area.
    - Procurement cost targets are identified by area.

    - Other procurement cost baselines and targets are identified (e.g. equipment purchases).
- Operating cost:
    - Operating cost baseline is identified.
    - Operating cost opportunities are identified.
    - Operating cost targets are identified.
- Support cost:
    - Support cost baseline is identified.
    - Support cost opportunities are identified.
    - Support cost targets are identified.

A sample of the Proposal Team performance metrics is presented in Appendix G.

7.4.2 Program Management Performance Metrics

Program Management performance metrics are comprised of six categories. The first category of Program Management performance metrics is improvement plan and funding. This supports the goal of increasing PDE empowerment and accountability. This metric is designed to measure the support and organization of the CE process throughout the program. It consists of a list of PDE services proposed jointly by the lead systems PDE and program management. Each item has the corresponding negotiated hours to accomplish the task, scheduled funding released at the time the metric is updated, and the actual funding released listed. The funding score is the sum of the actual hours released divided by the sum of the scheduled hours released.

The second category of Program Management performance metrics is team staffing. This supports the goals of identifying well trained PDE staff to support programs, improving engagement and team cohesiveness, minimizing ITVV phase duration, and reducing engineering change activity during product production. This metric is designed to measure the consistency, preparedness, and cohesiveness that is built into the IPTs by program management. It consists of an evaluation of each team deployed on the program that includes the following items:

- A listing of core and accessible team members and their functions
- Percentage of positions filled at project kickoff (separate calculations for core and accessible team members)
- Turnover measured as the percentage of positions still being held by the original people (separate calculations for core and accessible team members)
- Percentage of team co-located within 20 feet (separate calculations for core and accessible team members)[18]
- Average training score (separate calculations for core and accessible team members)

A table of importance weightings is provided for each of the above characteristics with a total of 75% of the weight put on the core team and 25% of the weight put on the accessible team. The team staffing score is calculated by multiplying each percentage (above) by its weighting and totaling the products. The team staffing score can be calculated at a team level or for the program as a whole.

The third category of Program Management performance metrics is facilitation of cross-team communication [Swink, 1998, pg. 105]. This supports the goal of improving engagement and team cohesiveness. This metric is designed to measure the propensity for cross-team communication that is built into the IPTs by program management. It consists of binary scoring of the following functions:

- Establishment of a program intranet or collaborative engineering management system.
  - Posting of an organization chart of all manned teams.
  - Posting of names, functions, and contact information of all team members with links to this information from the team organization chart.
  - Posting links to other related program webpages.
  - Posting links to counterparts on other related programs (e.g. the mechanical engineer working on the Receiver/Exciter (REX) for one program would have 'one click' access to his counterpart on a related program).

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[18] This will almost triple the probability of the team members communicating at least once a week relative to locating them farther away (a baseline of 4% probability of communication) according to the work of Thomas J. Allen reprinted in Managing the Design Factory by Donald Reinertsen (pg. 114).

- Posting area provided for major design decisions.
- Automatic e-mail notification sent to counterparts and program management when a new posting is added.

The facilitation of cross-team communication score is based on the sum of the binary scoring of this series of tasks divided by the sum of the target scores.

The fourth category of Program Management performance metrics is establishing targets for design cost and quality. This supports the goal of focusing the design on producing the best value for the customer. This metric is designed to measure the completeness of cost and quality targets provided by program management. It consists of a count of the number of items that have cost and quality targets divided by the count of the number of items that require cost and quality targets. The targeting scores are calculated and tracked separately for cost and quality.

The fifth category of Program Management performance metrics is the completeness of the make or buy strategy. This supports the goal of creating a design that follows a clearly defined corporate make or buy strategy. This metric is designed to measure the completeness of make or buy guidance provided by program management. It consists of a count of the number of parts/groupings of parts that have final or preliminary sourcing divided by the count of the number of parts/groupings of parts that require sourcing. The calculation of the sourcing definition score weights a part with final sourcing as three times more valuable than a part with preliminary sourcing.

The sixth category of Program Management performance metrics is support for pre-production testing. This supports the goal of achieving planned production rates. This metric is designed to measure the support for pre-production testing provided by program management. It consists of a listing of high-risk items identified by the IPTs and program management. Each item has an estimate of the duration, hours, and dollars required to perform the necessary testing. The percentage of the requested duration allowed for in the program schedule is worth 50 percent of the pre-production testing support score. The labor hours are converted to dollars at a fully burdened rate (e.g. $100/hour) and the percentage of the total of the labor and material cost allowed for in the program budget is worth 50 percent of the pre-production testing support score. The overall pre-production testing support score is calculated based on the average duration and budgets provided of all the projects.

A sample of the Program Management performance metrics is presented in Appendix H.

7.4.3 IPT Performance Metrics

7.4.3.1 General IPT Performance Metrics

General IPT performance metrics are comprised of eleven categories. The first category of IPT performance metrics is team building. It is common knowledge that "putting a team together does not guarantee teamwork" [Willaert, Graaf and Minderhound, 1998, pg. 92]. Teambuilding supports the goal of increasing engagement and team cohesiveness. This metric is designed to measure the IPT's commitment to team building. It consists of:

- Duration of team building training
- Percentage of the team participating in team building training

The team building rating is calculated by dividing the actual duration of team building training by the standard duration of team building training and multiplying this number by the percentage of team members in attendance. The team building rating can be calculated at an IPT level or for the program overall.

The second category of IPT performance metrics is improvement plan cost adherence. This supports the goal of increasing PDE empowerment and accountability. This metric is designed to measure the IPT's cost adherence to the budget laid out in the design improvement plan. It consists of the improvement plan established jointly by the lead systems PDE and program management with an earned hours calculation based on percentages complete of each task compared to the actual hours spent on each task. Individual efficiencies are calculated for each line item, at the IPT level and for the program overall.

The third category of IPT performance metrics is risk readiness. This supports the goal of producing a design that focuses on the best value for the customer by balancing technical requirements with cost, quality, and schedule risk. This metric is designed to measure the IPT's risk awareness and preparedness. It consists of a database of risks maintained by the IPT. The risks are categorized high, medium, and low. A high risk is considered to be nine times more risky than a low risk item. A medium risk is considered to be three times more risky than a low risk item. Assigning action for a risk is allocated 25% of the credit for neutralizing it. The risk readiness score is calculated as the total of the risks neutralized or actioned multiplied by their respective weightings divided by the total possible points that would be achieved by neutralizing all risks. The risk readiness score can be calculated at the IPT level or for the program overall.

The fourth category of IPT performance metrics is design cycle time. This supports the goal of shortening design cycle time. This metric is designed to measure not only the average cycle time for different design products, but the consistency of those results as well. Design products are divided up into a small number (3 – 5) categories (e.g. drawings, material lists) with a target cycle time (start to finish duration) provided by engineering management for each category. Cycle time records for each product type are used to calculate the average cycle time and standard deviation of cycle times for each product type. The critical path for each design product is analyzed to identify opportunities for cycle time reduction. The design cycle time score is calculated by equally weighting the target average cycle time divided by the actual average cycle time and the target cycle time standard deviation divided by the actual cycle time standard deviation. The cycle time score can be calculated at the IPT level or for the program overall.

The fifth category of IPT performance metrics is product design integration with process design. This supports the goal of integrating product and process design. This metric is designed to measure the degree of integration between product and process design (includes reducing process diversity). Parts or assemblies are evaluated as follows:

- Percent flowcharted (detailed process flow of construction process)
- Percentage with design guideline checklists complete
- Percentage of items with both flowcharts and checklists complete

- Percentage of those items which are flowcharted and checked that are free of non-standard processes
- Average number of non-standard processes for items that contain non-standard processes
- Number of parts and assemblies with more than five non-standard processes

The product/process integration score is calculated by summing the number of parts and assemblies that are flowcharted and checked, subtracting the number of parts and assemblies that have more than five non-standard processes, and dividing the total by the total number of parts and assemblies. The product/process integration score can be calculated at the IPT level or for the program overall.

The sixth category of IPT performance metrics is design commonality. This supports the goal of reducing product diversity. This metric is designed to measure the degree of commonality in the design. Designs are evaluated as follows:

- Total number of parts
- Total number of different parts (e.g. an assembly with three A's and five B's would have two different parts)
- Percentage of different parts (low is better)
- Total number of standard parts (a standard part is used across more than one product)
- Percentage of standard parts (high is better)

The product commonality score is calculated by weighting the standard parts percentage twice as much as the complement of the different parts percentage. The product commonality score can be calculated at the IPT level or for the program overall.

The seventh category of IPT performance metrics is life cycle cost. This supports the goal of reducing lifecycle cost. This metric is designed to measure the reduction in lifecycle cost due to the efforts of the IPT as well as the compliance of the design with life cycle cost targets. Life cycle cost (LCC) is divided into procurement cost, operating cost, and support cost. A baseline value is calculated for each of these components. As the design evolves, each of these values is reevaluated and an estimate current with the design is produced. The percent change is calculated from the baseline as well as the percent deviation from the target for each component of LCC as well as the LCC as a whole. The LCC score is calculated by dividing the target life cycle cost by the estimated life cycle cost. The LCC score can be calculated at the IPT level (estimate) or for the program overall.

The eighth category of IPT performance metrics is measuring and publicizing the value of the CE process. This supports the goal of measuring the value that product development engineers add to the design and production process. This metric is designed to measure the extent to which the IPT is developing and advertising high level metrics that reflect the overall success of their efforts. In the interest of empowering the entire IPT, this metric is kept at a team level. The measuring portion of this metric consists of the following:

- LCC dollar value estimated saved by IPT to date (vs. baseline)
- LCC cost percentage estimated saved by IPT to date (vs. baseline)
  - Worth 20%
- Average percent estimated reduction in defects per million opportunities (vs. baseline)
  - Worth 20%
- Critical path cycle time reduction (vs. baseline)
  - Supported by mapping of critical path
  - Worth 20%

The publicizing section of this metric includes:

- Percentage of program reviews at which the above data are displayed
  - Worth 20%
- Number of articles published about the IPT's CE activities (divided by a target number of articles)
  - Worth 20%

The measuring/publicizing score is calculated by multiplying each measure divided by its target by its weighting and summing the products. The measuring/publicizing score can be calculated at the IPT level or for the program overall.

The ninth category of IPT performance metrics is preparedness and proactiveness with respect to the system integration, test, verification, and validation (ITVV) phase. This supports the goals of minimizing the ITVV phase duration and product changes during prototype build, ensuring that the knowledge stream generated by the ITVV phase flows in both directions, and increasing production yields. This metric is designed to measure the preparedness and proactiveness of the IPT with respect to the ITVV phase. This metric is made up of two major parts. The first relates to monitoring critical design interfaces and includes:

- Percentage of critical design interfaces assigned to IPT members for monitoring
  - Worth 20%
- Percentage of inter-connection diagrams (ICDs) current with the design
  - Worth 20%

The second part of the ITVV preparedness/proactiveness score relates to prototype construction and includes:

- Percentage of prototypes modeled/simulated prior to prototype construction
  - Worth 20%
- Percentage of prototypes visited by IPT members during construction
  - Worth 10%
- Percentage of prototypes with checklists available to production personnel
  - Worth 10%
- Percentage of prototypes followed up with an interview of construction personnel
  - Worth 20%

The ITVV preparedness/proactiveness score is calculated by multiplying each measure by its weighting and summing the products. The ITVV preparedness/proactiveness score can be calculated at the IPT level or for the program overall.

The tenth category of IPT performance metrics is test requirements development. This supports the goal of integrating product and process design. This metric is designed to measure the degree of integration of testing requirements into the design. The test requirements development score is comprised of ratings in the following five categories:

- A review of the product design
- A review of the factory test equipment design
- Development of a test strategy

- A testability review (overview of the product design, the design of the factory test equipment, and the test strategy)
- A review of the test requirements specification

The rating scale is as follows:

- 1 = completely unsatisfactory
- 2 = Needs improvement
- 3 = Satisfactory
- 4 = Exceptional (e.g. testing at reduced cost/scope)

A score of three is equivalent to a score of 100 percent. Each of the five categories is equally weighted. Only items with a draft that can be evaluated are included in the average (i.e. there is no zero or not complete score).

The eleventh category of IPT performance metrics is the integration of customer needs. This supports the goal of improving customer satisfaction. This metric is designed to measure the degree of integration of customer needs and wants into the design. The customer satisfaction score is comprised of the number of items in the customer needs database that are incorporated into the design (weighted by importance to the customer) divided by the total number of items in the customer needs database also weighted by importance. The weightings are based on the following assumptions:

- A high importance item is nine times more important than a low importance item
- A medium importance item is three times more important than a low importance item

The customer satisfaction score can be calculated at the IPT level or for the program overall.

A sample of the IPT performance metrics is presented in Appendix I.

7.4.3.2 Process Capability Analysis Tool Based IPT Performance Metrics

Process capability analysis tool (PCAT) based IPT performance metrics support the goal of focusing the design on producing the best value for the customer. This metric is designed to show where the design stands with respect to its design quality targets as well as the maturity of the design. PCAT based IPT performance metrics consist of two segments. The first is a graphical status update intended for presentation at program reviews. It consists of:

- A pie chart delineating the percentage of final PCAT models, preliminary PCAT models, and PCAT models yet to be completed
- A series of bar charts divided by technology (e.g. CCA) and subassembly (e.g. beam steering generator) showing PCAT scores in terms of sigma vs. the target sigma for the technology being analyzed

A sample of the PCAT based IPT graphical performance metrics is presented in Appendix J.

The second segment of PCAT based IPT performance metrics is a tabular summary that results in the cost target score. It consists of:

- The total number of PCAT analyses planned
- The percent of PCAT analyses baselined
- The percent of PCAT analyses with a first round (after baseline and some design improvements) model complete
- The average percent change between the baseline and current design (in defects per million opportunities – DPMO)

The cost target score is the percent of planned PCAT analyses that have been baselined which are meeting the target sigma. An example of the tabular summary is provided with the IPT performance metrics in Appendix I.

7.4.3.3 As Designed vs. As Proposed (ADAP) Based IPT Performance Metrics

As designed vs. as proposed (ADAP) based IPT performance metrics support the goal of focusing the design on producing the best value for the customer. This metric is designed to show where the design stands with respect to its cost targets. ADAP based IPT performance metrics consist of three segments. The first is the rough order of magnitude (ROM) cost estimating format that is used to estimate the cost of the current design. It consists of a material worksheet, a labor worksheet, and total product cost table, an area for supporting worksheets (if applicable), a list of assumptions for surface radar ADAP estimates and a design log.

The material worksheet is made up of six columns. The first is the item description. This should be designed so that any PDE could look at a drawing and identify the individual part. If a part number is available this should also be included. The second column is the part quantity. The calculation of part quantity for all subassemblies and parts is based on the number of assemblies that the ADAP is representing (i.e. if there are two part A's in assembly X and the number of assembly X's are changed from one to two, the number of part A's should automatically change from two to four). The third column is the material unit cost. This is the cost, including vendor non-recurring costs, of each part. If vendor non-recurring costs are known, the material unit cost should be calculated as: (non-recurring costs)/(quantity) + recurring costs. If the PDE is making any assumptions that are different than the proposed assumptions for Raytheon's Non-Recurring Expenses (NRE), the delta in NRE caused by these assumptions should be entered in at the bottom of the material worksheet. The fourth column is for identifying sources of all material costs. Examples of sources include, but are not limited to:

- Current cost returns (date/reference part number)
- Catalogue pricing (date/catalogue)
- Vendor A quote (date)
- Quote from another Raytheon location
- Estimator's judgement

The fifth column is the material burden factor. All material except quotes from other Raytheon locations and COE's should have a material burden factor (the material burden factor should already be included in these quotes). The material burden factor for use in each estimate is provided in the assumption list. The sixth column is the material cost. This is the product of the quantity, the material unit cost, and the material burden factor.

Material costs are totaled as follows:

- The subtotal material cost number is the sum of the material cost column.
- The allowance for material under $10 unit cost is five percent of the subtotaled material cost[19]. This material should not be included in the material table except in the rare

[19] Based on the analysis of typical radar assemblies.

circumstance that an individual item appears in such quantities as to consume a significant portion of this five- percent margin.

- A second margin is added to the sum of the material subtotal and the under $10 material allowance to account for items that the PDE does not know about yet. This margin starts at ten percent during the earliest phases of the design and is reduced to three percent as the design matures. This margin is never reduced beyond three percent[20].

The labor worksheet is made up of five columns. The first column is the item description. This column is designed so that any PDE could look at a drawing and identify the individual processes/part. If a subassembly number/part number is available this should also be included. The second column is the subassembly/part quantity. The calculation of subassembly/part quantity for all subassemblies and parts is based on the number of assemblies that the ADAP is representing (i.e. if there are two part A's in assembly X and the number of assembly X's are changed from one to two, the number of part A's should automatically change from two to four). The third column is the labor unit hours. These are standard hours and should include setup hours as follows: (setup hours)/(quantity) + recurring hours. In deciding on setup costs the PDE should make reasonable assumptions about the number of different setups that will be required depending on the build schedule (i.e. three identical parts should not be assigned a single setup if they are required several months apart). The fourth column is for identifying the sources of labor estimates. Examples of sources include, but are not limited to:

- Current cost returns (date/reference number)
- Production estimate
- Time study
- Estimator's judgement

The fifth column is labor hours. This is the product of labor unit hours and quantity.

Labor hours are totaled as follows:

- The subtotal labor hours is the sum of the labor hours column.

[20] The three percent margin is based upon the author's experience with uncertainty in the estimation of large, complex products and will be refined as more Raytheon specific information is collected.

- A margin is added to the labor subtotal to account for items that the PDE does not know about yet. This margin starts at ten percent during the earliest phases of the design and is reduced to three percent as the design matures. This margin is never reduced beyond three percent.

The total product cost table is made up of the following items:

- Labor unit cost
  - The conversion factor from hours to dollars
  - Based on assembly quantity provided in the standard assumptions table.
  - Includes:
    - K factor (converts standard labor hours to actual labor hours)
    - A factor for direct charge support
    - An average wage rate
    - Fringe benefits
    - Overhead
    - Other direct charges
- Labor cost
  - The product of labor unit cost and labor hours
- Material cost
  - Total material cost from the material worksheet
- Total cost
  - The sum of labor cost and material cost

The supporting worksheet should be used to break out any component parts that are built in house if they are not accounted for in the primary ADAP form. This estimate should follow the format of the primary ADAP form. The final cost for the component can be included as a material cost with a material burden factor of one.

The list of assumptions for surface radar estimates includes the following additional assumptions:

- The estimator should include parts that he knows will be required in the ADAP even if they are not yet depicted on the drawings (this should be noted in the part description column).
- Estimator's judgement should not account for more than ten-percent (target) of the subtotal product cost (labor and material)[21].
- Material lot sizes should be estimated based on the quantity that Raytheon currently has under contract (i.e. it should not include options).
- Costs are intended to roll up to the manufacturing cost level (similar to product cost level – PCL).
- Production management in relevant areas should review the estimates.

The estimates created using these methods should be considered as ROM estimates accurate to plus or minus ten percent.

The design log is comprised of the following categories:

- Revision name/list of changes between revisions
- Material dollars
- Labor hours
- Total cost (total dollars)
- Date of change
- Change initiator

At a minimum the log should consist of the cost information for each revision and a list of major changes between the revisions.

The second category of ADAP based IPT performance metrics is a graphical status update intended for presentation at program reviews. It consists of:

- ADAP schedule update:
  - A bar chart showing the schedule compliance for ADAP submittals, the mean, and standard deviation of ADAP submittals
  - A listing of the top ten upcoming ADAP estimates by due date

[21] This target was agreed to by Raytheon Management.

    - A pie chart showing the ADAP estimates complete as a percent of total ADAP estimates (design maturity)
    - A pie chart showing the ADAP estimates complete as a percent of the ADAP estimates planned to be complete

- ADAP cost performance:
    - ADAP performance by category (e.g. REX, BSG) in tabular and bar graph form
    - The mean and the standard deviation by category
    - A color code evaluation of the percent change between the target (proposal) cost and the current ADAP estimate
        - Blue = exceptional performance (over 15% reduced from target)
        - Green = satisfactory performance (between 15% reduced from target to 5% over target)
        - Yellow = needs improvement (between 5% to 15% over target cost)
        - Red = unsatisfactory (more than 15% over target cost)

A sample of the ADAP based IPT ROM estimating format and graphical performance metrics is presented in Appendix K.

The third segment of ADAP based IPT performance metrics is a tabular summary that results in the cost target score. It consists of:

- The total number of ADAP analyses planned
- The percent of ADAP analyses baselined
- The percent of ADAP analyses with a first round (after baseline and some design improvements) model complete
- The average percent change between the baseline and current design
- The overall percent change between the baseline and current design
- The cost target score is the percent of planned ADAP analyses that have been baselined which are meeting the target cost.

An example of the tabular summary is provided with the IPT performance metrics in Appendix I.

7.5 Oregon Productivity Matrix Summaries

The OPM summaries are used to relay the current scores on all of the continuous improvement and CE support metrics as well as the current scores on the program specific metrics. There are nine OPM summaries as follows:

- PDE organization
- Engineering organization
- Production organization
- Proposal team:
  - Naturally stable items
  - Naturally growing items[22]
- Program management:
  - Naturally stable items
  - Naturally growing items
- IPT:
  - Naturally stable items
  - Naturally growing items

In addition to summarizing current scores, the OPM format provides a clear means of setting goals, tracking and projecting performance, and factoring in the importance of performing well in an individual metric.

A typical OPM will start off with a baseline score in each column (metric) that is automatically assigned a value of three. A score corresponding to a good goal is then assigned values of seven. The values above and below are calculated by dividing the difference between the good goal value and the baseline into equal parts, each of which constitutes the step between one value (e.g. 6) and the next (e.g. 7). A weighting is assigned

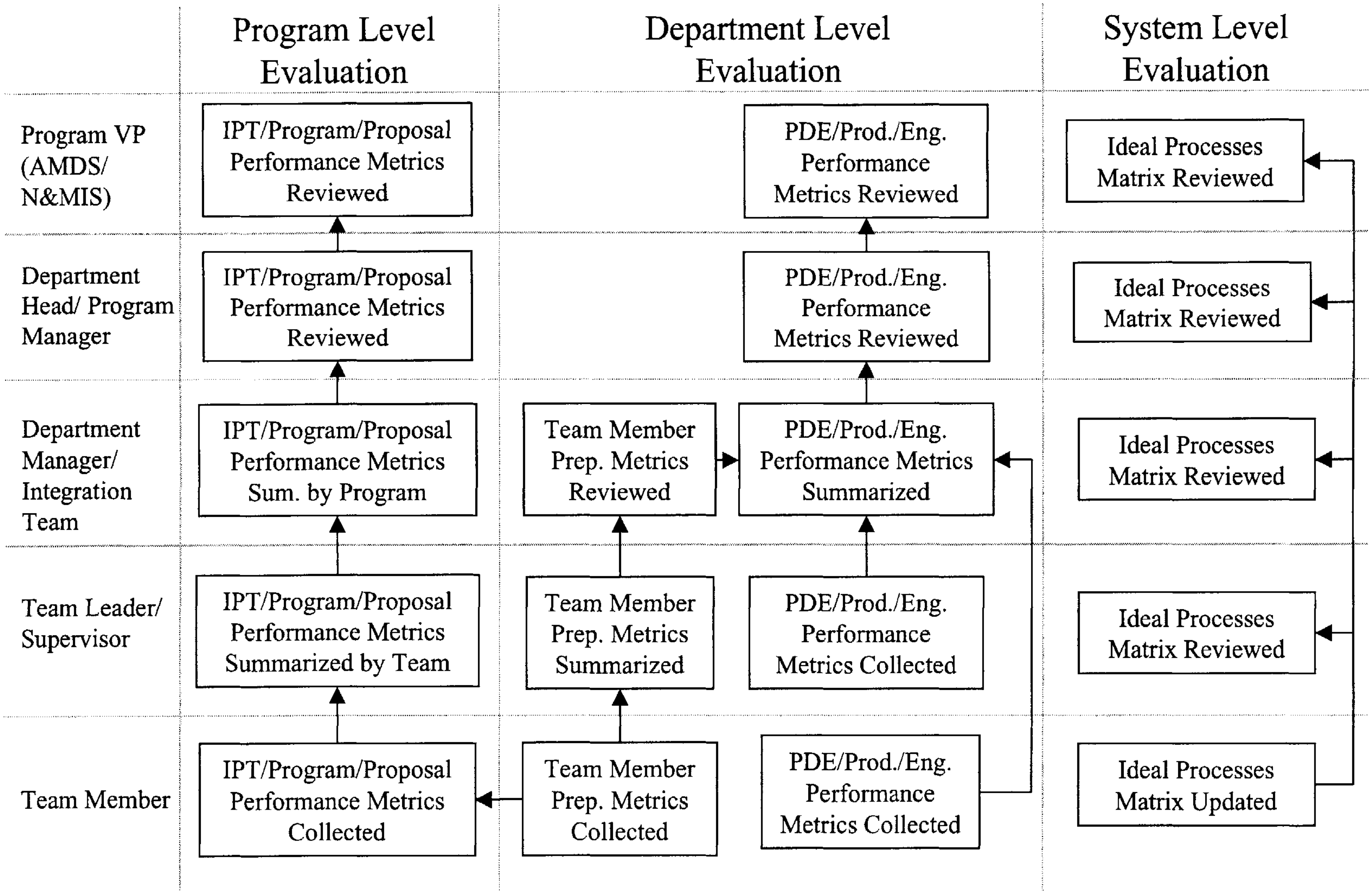
[22] A "naturally growing" item would tend to get a better score as the program progressed. A metric that gave points for the completion of a series of program specific tasks (e.g. creation of a build strategy) would tend to grow as the program progressed. A "naturally stable" item would not tend to grow in this manner.

to each column based on the importance of that item. Once the table is created, a score at the next update is identified, the corresponding value is identified using the OPM, and the sum of all the products of values and weightings is plotted on a graph. Also plotted on the graph are the good goal (produced by an average value of seven) and great goal (produced by and average value of ten). This is repeated for each reporting period producing a performance history. The performance history is used to produce a trend line. The OPM summaries are presented in Appendix L.

7.6 Metrics Reporting Structure

A reporting structure has been established in order to ensure that the metrics measuring the CE process remain visible. Systems level evaluation information (i.e. the ideal processes matrix) is gathered at the team member level and reviewed with all levels of management. Department level evaluation information (e.g. PDE organization metrics) is gathered at the team member and supervisor level. It is summarized by the department managers and reviewed with the department head and the program vice-presidents. Team member preparedness metrics is collected by the team members, summarized by their supervisors, reviewed by the department managers, and added to the summary of the department metrics. Program level evaluation information (e.g. IPT performance metrics) is gathered at the team member level, summarized by the team leaders, summarized at a program level by the integration team, and reviewed by the program managers and the program vice-presidents. The reporting structure for concurrent engineering metrics is presented in Figure 7.6-1.

Figure 7.6-1: Reporting Structure for CE Metrics



7.7 Summary

This chapter provided an in-depth description of the CE metrics system. It also described the high level structure of the CE metrics system and how the different portions of it work together. Finally, it described the reporting structure for the CE metrics. Chapter Eight describes the implementation process.

Chapter 8: Implementation

This chapter describes the recommended phases of implementation for the CE metrics and the transition plan that was used to ensure that the project maintained its momentum at the conclusion of this research.

8.1 Phases of Implementation

In order to facilitate implementation, a three-phased plan was developed. Metrics from each category (e.g. PDE organization performance metrics) were assigned to one of the three phases based on a combination of importance (defined by the internal gap analysis) and ease of implementation. The implementation is currently in phase one. A matrix showing the CE metrics by phase as well as suggested reporting periods is presented in Table 8.1-1.

8.2 Transition Plan

A transition plan was created in order to ensure the smooth implementation of the CE metrics. The transition plan contains three parts. First, a Raytheon six sigma expert-in-training has been appointed to continue working with Raytheon management on the implementation processes as the CE Metrics Lead. Second, the CE metrics system was submitted as enabling material to the integrated product development process (IPDP) in the integrated product development system (IPDS). The IPDS change control board has appointed a team to work with the CE Metrics Lead to ensure that the CE metrics system is integrated into IPDS. Third, a matrix of co-sponsors for each metric has been created and the relevant metrics have been reviewed with each sponsor (98% complete). This matrix is presented in Appendix M.

8.3 Summary

This chapter described the phases of implementation agreed to for the metrics project. It also identified suggested reporting periods for the metrics. Finally, it described the procedure that was used to transition the project oversight to Raytheon personnel. Chapter Nine presents conclusions and recommendations based on the concurrent engineering metrics project to date.

Table 8.1-1: Phases of Implementation and Reporting Periods

Item	**Phase 1**	**Phase 2**	**Phase 3**	**Measurement Frequency**
Ideal processes matrix	• 19 Goals • Ideal Supporting Processes for each goal • Actual processes compared to each ideal process • Index score of actual processes			3 months
Team member preparedness metrics	• Overall preparedness rating			1 month
PDE organization performance metrics	• PDE training score	• Design checklists score • FAARF feedback score	• Facility books score • Production simulation score • Manufacturing plan score • Lessons learned score • ECN feedback score	1 month
Engineering organization performance metrics	• Engineer training score	• Designer feedback score	• Change management score • Field lessons learned score	1 month
Production performance metrics		• ITVV production support score	• Production empowerment score • Control of production processes score • Flexible tooling score	1 month

Table 8.1-1: Phases of Implementation and Reporting Periods

Item	**Phase 1**	**Phase 2**	**Phase 3**	**Measurement Frequency**
Proposal team performance metrics		• Lead systems PDE involvement score • Funding score • Design/Build strategy score • Customer needs identification score • Customer satisfaction score • Cost target score		1 month *Implemented on next new proposal*
Program management performance metrics	• Funding score • Cost targeting score • Quality targeting score	• Team staffing score • Facilitation of cross-team communication score • Sourcing definition score • Pre-production testing support score		1 month
IPT performance metrics	• CE efficiency • Cost target score (ADAP) • Quality target score (PCAT) • Design cycle time score • Test requirements development score	• Team building rating • Risk readiness score • Product/process integration score • Measuring/publicizing score • ITVV preparedness/proactiveness score • Life cycle cost score	• Product commonality score • Customer satisfaction score	2 weeks
OPM Summaries	• Summaries for phase 1 material	• Summaries for phase 2 materials	• Summaries for phase 3 materials	1 month

Chapter 9: Conclusions and Recommendations

This chapter provides a brief summary of the final results of the CE metrics project. It also touches on the acceptance level of this project. Finally, it discusses the longer-term prospects for this project.

9.1 Conclusions and Recommendations

The project accomplished all three of the goals set out for it. It identified and implemented a system of metrics that evaluates the success of the concurrent engineering (CE) process utilized by Raytheon on Surface Radar Projects. The concurrent engineering metrics system is designed to provide ongoing feedback regarding the health of the concurrent engineering process. It incorporates both forecasting metrics (e.g. ADAP cost models) and process monitoring metrics (e.g. team training metrics). All of the metrics are intended as early warning systems for the final outcome of the concurrent engineering process. This will ensure that issues such as cost overruns can be addressed early in the design process. The concurrent engineering metrics system is designed to encourage process improvement in conjunction with goals established by Raytheon's management. It provided additional information on best practices in CE to Raytheon's Surface Radar Management through the ideal processes list. Finally, it identified where the process can be improved using both the ideal vs. actual process comparison and an internal customer survey.

The acceptance level of this project was high. The implementation plan is extensive and strongly supported by senior management. It emphasizes personal accountability by assigning specific people to sponsorship roles. The changes implemented through this project will be sustainable as long as top management support for the metrics collection continues. So far the metrics have been enthusiastically accepted by customers and have been incorporated into basic planning systems. Therefore it is reasonable to expect that top management support for this process will also continue. While the learning within the surface radar group as a result of this project was extensive, the learning was only transferred to other organizational units informally. This situation should improve with the full incorporation of the metrics project into IPDS, since this system is the program process template for all of Raytheon.

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Appendix A

Ideal Processes Matrix

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
Business Strategy Execution Phase:			
• Systems product development engineer (PDE) involvement with program during proposal development IN 52.5	• Scope, budget and schedule for PDE services throughout the BSEP are assigned by an upper management steering committee[3]	100	Typically implemented
	• Lead systems PDE is appointed for each program and included on the proposal development team[4]	60	A PDE is typically involved in the proposal, but it is not typically the person who later functions as the lead systems PDE
	• Lead systems PDE works with proposal team to select and price baseline (similar to) design[5]	60	A PDE is typically involved in the selection and pricing, but it is not typically the person who later functions as the lead systems PDE
	• Lead systems PDE identifies and prices potential design improvements (from baseline design). Existing lessons learned documents from previous programs are reviewed as part of this process.	40	Inconsistent application. Proposal teams are typically expected to include a section on lessons learned in the proposal. Limited lessons learned documentation. Limited access to previous proposals.
	• Program team selects design improvements that will be included in the proposal	100	Typically implemented

[1] Phases are based on Raytheon's Integrated Product Development System (IPDS). This is a phased gate review process as recommended by [Shina (ed.), 1994, pg. 11].
[2] Index Number: Green = 100 (World Class, Process matched ideal + typically implemented) or 80 (Established, Process largely matches ideal + typically implemented), Yellow = 60 (Defined System, Process partially matches ideal + may not always be implemented), Red = 40 (Ad Hoc, inconsistent process + inconsistent application) or 20 (not performed). The index number for each process was determined by the author based on the completeness of the current support processes. The score for each goal is calculated by averaging the process score. This is intended for rough evaluation only.
[3] In keeping with the project management plan recommended by [Shina (ed.), 1994, pg. 12]
[4] [McVinney, C., 1995, pg. 113] (part of establishing project expectations and parameters as well as a commonly held vision, mission, goals, and objectives)
[5] Ensures knowledge of baseline is transferred to IPTs

Goals for each IPDS Phase[1]:	*Ideal Support Processes*	*IN[2]*	*Current Support Processes*
	• Lead Systems PDE maintains a database of potential manufacturing related design improvements (even if they are not included in the proposal assumptions) and communicates this information to the PDE team as they become involved in the program. This database is maintained throughout the design process and is cross-referenced by subject area and net benefit.	20	Not typically implemented
	• A design/build strategy is developed to document objectives and preliminary strategies. The design/build strategy is signed off by upper management steering committee.	20	Some key decisions of this type are made at this stage in the program but it is not compiled in a single document or formally signed off.
Project Planning Management and Control Phase:			
• Identification of well trained PDE staff available to support programs IN 43.3	• Once a program enters this phase a team of systems and center of excellence (COE) PDEs is assigned	100	Typically implemented
	• The PDE organization projects the need for PDEs across all programs over a ~ two year window	40	Some projections in place, however data is not readily available (in one location) and the accuracy of these projections is questionable. Constant reorganization of business units complicates this task.
	• The PDE organization establishes skills standards for lead and support PDEs	40	In the process of establishing these standards (early implementation)
	• The PDE organization identifies training and capability gaps and sets development goals with individual PDEs[6]	40	Some early implementation through personnel evaluation forms
	• The PDE organization ensures that all PDEs are trained in standard concurrent engineering tools such as DFMA and CAIV[7]	20	Not typically implemented, tools training opportunities in the Northeast are limited
	• The PDE organization takes an active role in identifying and developing potential PDEs that meet lead and support PDE skills standard	20	No formal training track for PDEs, difficulty extracting qualified candidates from their present positions

[6] [BMP, 1992, pg. 15-16] also personal work process/weekly status forms suggested by [Armitage, 2000]
[7] [Moffat, 1998, pg. 57]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes*
• PDEs are empowered and accountable within a clearly defined scope of responsibility[8] IN 26.7	• The lead systems PDE works with the program manager to develop a design improvement plan (what CE tools will be used) based on the goals established during BSEP and provides the program manager with a cost estimate for the agreed upon services[9]	40	Some attempts at implementation. Typically the basis of PDE budget is mutually agreed to, however it is not always divided up into discrete activities. There is not a specific list of services provided by the PDEs.
	• The lead systems PDE manages the design improvement budget and provides regular progress reports to the program manager[10]	20	Not typically implemented
	• The lead systems PDE communicates the design improvement plan to the support PDEs and monitors their progress in conjunction with the PDE management team[11]	20	Not typically implemented
• Engagement and team cohesiveness IN 45.5	• Lead systems PDE participates in the IPDS tailoring workshop resulting in the integrated master plan (IMP)/integrated master schedule (IMS)[12]. Producibility activities are included in the program IMP/IMS.	60	Limited participation, particularly with the IMP/IMS details
	• Lead systems PDEs disseminate information about program goals (cost, schedule, and performance) to the IPTs	20	Not typically implemented
	• All PDEs participate in team building training (general)	20	Although team building training is available through some programs it is not typically implemented
	• Team building exercises for each IPT involving PDE personnel[13]	20	Although team building training is available through some programs it is not typically implemented

[8] The importance of team scope definition is discussed in [Shina (ed.), 1994, pg. 66]
[9] Two way expectations suggested by [Cote and Stanmeyer, 2000] also [McVinney, C., 1995, pg. 113] (part of establishing roles and responsibilities)
[10] [McVinney, C., 1995, pg. 114] (part of establishing communication strategies and project management methodologies)
[11] [McVinney, C., 1995, pg. 113] (part of establishing project expectations and parameters as well as a commonly held vision, mission, goals, and objectives)
[12] In keeping with the project management plan recommended by [Shina (ed.), 1994, pg. 12]
[13] [BMP, 1990, pg. 15] also [Shina (ed.), 1994, pg. 46]

Goals for each IPDS Phase[1]:	*Ideal Support Processes*	*IN[2]*	*Current Support Processes*
	• PDEs are co-located (same office area) with designers involved in their IPT.[14] Designers are assigned to the IPT but are still the responsibility of the functional managers with respect to technical training and development.[15]	40	Some PDEs have been located near designers (same facility, not the same office area)
	• The IPT is structured as a core team and an accessible team. The core team is small (~5 people) and cross-functional (Eng., PDE, other Mfg.). The accessible team is larger (SCM, ILS, Finance, etc.). The program manager or designee oversees the team activities.[16]	60	The IPTs are typically much larger and the division between the core team and the accessible team is blurred. This makes it difficult for small working meetings to occur.
	• PDEs on distribution for all meetings related to their IPTs as well as for schedule updates and other updates	80	Typically implemented (master schedule for program meetings is not always available)
	• Performance standards for contact with engineering and manufacturing counterparts (based on matrix of engineering and manufacturing counterparts)	60	Performance standards with respect to meeting attendance but not with respect to one on one interaction (not central or standard)
	• Integrated Data Environment	40	Very early implementation
	• Team activities and successes are documented and publicized[17]	40	Partially implemented in some programs
	• Raytheon and its managers support an environment that fosters continuous quality improvement (CQI)[18]	60	Support varies across programs and departments

[14] [Huang, G.Q. and Mak, K.L., 1998, pg. 260] also [Reinertsen, 1997, pg. 113]
[15] [Sobek, Liker, and Ward, 1998, pg. 4] (Toyota is so concerned about maintaining functional proficiency that they do not collocate their IPTs)
[16] [Cote and Stanmeyer, 2000] and [Flint and Gaylor, 1995, pg. 101]
[17] [Huang, G.Q. and Mak, K.L., 1998, pg. 260]
[18] [Hindson, Kochhar, and Cook, 1998, pg. 253] also [Shina (ed.), 1994, pg. 6]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
Requirements and Architecture Development Phase/Product Design and Development Phase:			
• Design is focused on producing the best value for the customer (balances technical requirements with cost, quality, and schedule risk – i.e. product cost is as important a design tradeoff parameter as product technical performance) IN 50	• Design to cost practices (i.e. CAIV) are followed:[19] • Identify target cost of completed product both at a systems level and a work group IPT level • Deduct a management reserve • Identify budgets for each assembly based on the remaining budget[20] • Hardware IPTs work on cost reduction ideas in each area including out-sourced parts (teams can buy and sell functionality with the help of program management) • Create an initial ROM of the current/baseline design[21] (including all lifecycle costs). This ROM is based on the same assumptions (scope and financial) used in the proposal. • Ensure that teams have all the necessary resources including access to DFMA workshops[22], DTC training, pricing, and labor rate information • IPTs document all pricing assumptions and review them with the lead systems PDE • Make adjustments to the cost of the design at a low and high level as the teams make trade off decisions • Recognize the status of the team's design to cost exercises at a high level of the company	40	Designers and PDEs are typically not aware of first of class cost goals for their segment of the product. The PDE organization has started a process of ADAP (as designed vs. as proposed) costing that will partially fill this gap.

[19] The CAIV process is outlined in [Texas Instruments Corporation, 1993, pg. 4-3]
[20] [Reinertsen, 1997, pg. 208]
[21] [BMP, 1992, pg. 15] (costing process improvement baselines)
[22] [Shina (ed.), 1994, pg. 49]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
	• Designed quality is evaluated and improved in a cycle that mirrors the design to cost cycle	60	The PDE organization has created a PCAT summary sheet to track designed quality vs. designed quality targets throughout the design process. This process is limited by the unavailability of PCAT scores for subassemblies and above.

	• Technical and production risks are identified[23]
	  • Plans to address technical risks are created
	  • Production and vendor representatives are invited to review the design and identify risks from their point of view
		60	Typically designers identify technical risks. They are included in a risk management plan that is carried from the proposal through to the design. Production risks are also identified (by PDEs). The 'top ten' risks are usually captured but lower level items (typically manufacturing) are not.

	• Cost, quality and schedule risks such as long lead-time items and difficult to obtain materials are tracked and (if possible) eliminated as the design is in process[24]	40	Some of these risks are identified but there is no formal process for tracking and eliminating these items.
	• Specific 'public' status updates include segments on cost, quality, schedule, and technical risk	60	Implemented in some programs
	• A consistent trade study methodology is used for identifying criteria, identifying alternatives, assessing alternatives and reporting results.[25] The design team is educated regarding decision aids and techniques.	40	While trade studies are performed frequently, there is not an agreed to standard for the process.
• Design follows a clearly defined (corporate) make or buy strategy IN 32	• Corporate supply chain management (SCM) team creates make or buy guidelines based on Raytheon's business plan and core competencies[26]	20	Not available. A Raytheon six sigma team is attempting address this issue.

23 [Moffat, 1998, pg. 81]
24 [Agile Software White Paper, 2000]
25 [Sobek, Liker, and Ward, 1998, pg. 5]
26 [Fine, 2000] also [Chambers, 1996]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
	• Make or buy guidelines are distributed to design teams in a user friendly format (integrated into design software and/or in the form of a decision flowchart)[27]	20	Not implemented
	• Suppliers are prescreened for cost, quality, and schedule adherence. A listing of Raytheon's preferred internal and external suppliers are available to the team so that they can be included in the IPT as appropriate[28]	40	Parts engineering works on prescreening external suppliers and PE representatives are included on the IPTs. Individual designers heavily influence internal subcontracting decisions. There is no clear corporate policy in this area.
	• Deviations from the make or buy guidelines must be jointly approved by an engineering manager and a supply chain management expert[29]	40	A system is in place to address nonstandard vendor call outs prior to parts ordering. Systems for early detection and internal subcontracting decisions are not consistent.
	• PDEs verify that the design conforms with the approved make or buy strategy during their drawing reviews[30]	40	Make or buy decisions are reviewed – however there is not a clear make or buy strategy against which they can be evaluated
• Shortened design cycle IN 33.3	• Phased gate review process is used throughout the design process to reduce rework by identifying problems early	100	IPDS review process includes design review milestones and PDEs are included in this process
	• Design guideline checklists (see next goal) as well as component and system design standards (see reduced product diversity) are used		See other listings
	• The signoff process is streamlined so that it does not require a meeting – preferably electronic	20	Not implemented, a process is currently under development for CCA related products

27 Example in [Fine, 2000]
28 [BMP, 1989, pg. 7] also [Prasad, 1999, pg. 194] also [Shina (ed.), 1994, pg. 134]
29 In process monitoring
30 Final review 'gate'

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*

	• The checking function is streamlined
	  • Designers are trained to check other designer's drawings (referencing checklists & design standards) to eliminate the checking department (bottleneck)
	  • In areas where the design process is fully in control the checking function can be eliminated
		20	Not implemented

	• All design products are tracked through the design cycle on a regular basis (electronic), and bottlenecks are identified. It may also be possible to use production techniques such as reducing lot size to reduce cycle time.[31]	20	Some products are tracked (program dependent). No production throughput techniques are implemented.

	• Scope of drawings/design product is reduced to the lowest reasonable level
	  • Increases throughput by reducing batch size
	  • Simplify information included on drawings/design products to reduce the opportunities for error
		20	Not implemented

	• Schedules showing the relationship between the drawing schedule date and the production need date (including required interim steps) are posted in public areas[32] or on the intranet[33]	20	Not implemented
• Product design is integrated with manufacturing (process design) following established design guidelines IN 45	• Checklist of design guidelines for typical components and subsystems are maintained. These checklists are maintained by designers and PDEs and used as a final review of new designs as well as an in process design guide[34]	20	Not implemented (some individuals have their own checklists). Some webbased design guidelines exist but they are not centralized or kept up to date.
	• Designed quality is assessed using tools that have manufacturing process capability models[35]	60	PCAT models exist for components but not at the subassembly levels.

[31] [Hindson, Kochhar, and Cook, 1998, pg. 256] also [Reinertsen, 1997, pg. 247]
[32] Common visual management technique (used in shipyards)
[33] Possible virtual alternative
[34] [Sobek, Liker, and Ward, 1998, pg. 9]
[35] [Shina (ed.), 1994, pg. 14]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
	• All design representatives are selected to do short apprenticeships (1 week) in their respective production areas —including working with union personnel to build some of their designs[36]	40	Not implemented (some individuals have done this)
	• Particularly well respected design representatives are rotated into production for 6 month periods to work in production support/engineering liaison roles	20	Not implemented
	• Facility books showing the capabilities of all present processes and work centers are maintained so that designers can try to design to the current capabilities- the facility books should identify the hard constraints of the work centers as well as the "preferred" ranges	40	Some books and webbased materials exist but they are not centrally located or well maintained.
	• Designers work with PDEs to plan and identify the processes that will be used to build their designs	80	Typically implemented
	• A check for production unfriendly design features is incorporated into the 3-D modeling program based on the facility manual (i.e. clearances, bend radii)	40	Available in some areas, not uniformly deployed. In some of the areas where these tools are available they are not always used.
	• PDEs work with testing personnel to ensure that products are designed to reduce the need for testing/enable testing to occur early in the production process	60	Preliminary implementation, -- involved too late in the process. This is complicated by the fact that test requirements are often identified too late to allow maximum correction to the design.
• Reduced product diversity IN 33.3	• A comprehensive set of design standards for interim products is integrated into the CAD system (e.g. instead of designing their own bracket designers can pick from a menu of available brackets).[37] The cost and quality metrics associated with each standard part are also integrated into the design system.	40	Have some design guides and part libraries, not fully integrated into the CAD system

[36] [Willaert, Graaf, and Minderhoud, 1998, pg. 92] also [Munro, 1995]
[37] [BMP, 1988, pg. 5]

Goal for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
	• Designs are graded based on the percentage of standard parts. Provide percentage to each designer. This percentage can be aggregated as a target for the entire design team.	20	Not typically implemented
	• Design files for standard building blocks such as T/RIMMs are readily available to designers in an electronic format. This will encourage copying these standards.[38] This file could be censured to only include desirable designs and will also include cost and quality metrics associated with each design. The design files should show the product tree and how lower level interim products are used to build higher level ones.	40	Not readily available in a censured/rated form. Many programs are separated by secured IDE space (firewalls). Some programs have made a concerted effort to reuse design building blocks.

[38] BMP, 1992, pg. 6] also [BMP, 1989, pg. 5]

Goal for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
• Reduce lifecycle cost IN 50	• Components with low reliability, high maintenance costs, or high operating costs are identified and eliminated ◦ Collect data on reliability, maintainability, and availability (RMA) ◦ Include RMA requirements in purchase specifications when applicable ◦ Collect data on planned and unscheduled maintenance requirements ◦ Assess operating costs (manpower and consumables) ◦ Inform all engineers and designers about findings ◦ Score designs based on RMA and maintenance costs– this would really be done by doing either an RMA block diagram analysis or a quantitative or qualitative fault tree analysis ◦ Trade-off higher reliability/availability components with redundant design ◦ Conduct reliability centered maintenance analyses to eliminate planned maintenance tasks ◦ Consider conditioned based monitoring alternatives	60	Occasionally feedback from manufacturing on production issues, however very limited feedback on field issues is relayed to the design teams. The parts engineering group reviews all designs and works with vendors on RMA issues. They also keep a library of failure information from previous production runs (including field data). Reliability handles the same issues at a systems level and Logistics collects field data on lifecycle costs [they are all part of the applied technology group] but it is not typically relayed to the design teams.

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
	• A life cycle cost model for major components is maintained so that tradeoffs between acquisition costs and operating/support costs, etc. can be quantitatively traded off and documented for explanation to the customer.	40	Exists but not fully utilized by design teams
	• A LCC model (or work breakdown structure) for the entire product is maintained and LCC reduction is tracked throughout the design process. Components would aggregate to procurement, operating and support, and disposal.	40	Exists but not fully utilized by design teams
	• Tradeoff studies are performed similar to those that are described for acquisition cost	60	Tradeoffs are performed during the proposal phase, but these tools are not typically used by the design team during design
• Improved customer satisfaction IN 40	• Customer needs are identified up front[39] • Survey the customers • Observe customers using current products[40] • Conduct one-on-one interviews with product users and to identify overt and latent needs[41]	40	Some internal customer satisfaction surveys, limited contact with external customers. Primary customer voice is the specification.
• Measure value that product development engineers add to the design and production process IN 20	• The characteristics of changes brought on by the CE process (use of DFMA workshops, IPTs, etc.) are documented and publicized • Quantify these changes (ROM price, Designed Sigma, Critical path cycle time reduction) • Standard format for Quantification • Standard assumptions for Quantification • Qualified person assigned to Quantify changes[42]	20	Not implemented
	• A central file & database of change descriptions and savings is maintained	20	Not implemented

[39] Customer needs used as a basis for product development (QFD process) described in [Katz, 2000] also [Chambers, 1996]
[40] [Cote and Stanmeyer, 2000]
[41] [Shina (ed.), 1994, pg. 22-23]
[42] [Huang and Mak, 1998, pg. 266]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
System Integration, Test, Verification and Validation Phase:			
• Minimize ITVV phase duration and product changes during prototype build, and ensure that the knowledge stream flows in both directions IN 37.1	• PDEs work with testing personnel to ensure that products are designed to reduce the need for proof of concept testing	40	Not typically implemented, interaction with testing is too late in the design process
	• Interfaces between subassemblies and functional design features (i.e. electrical and mechanical) are fixed and monitored by the IPT to reduce integration problems[43]	60	Design maintains inter connection diagrams (ICD) to document interfaces. However, some of this information is produced late.
	• Design is modeled/simulated prior to prototype construction	40	Very early implementation
	• Prototypes are fast-tracked through production process[44]	20	Not implemented
	• The progress of prototypes through the production process is tracked online (so that cognizant engineer can check on its progress)	20	Not implemented
	• Cognizant engineers are notified when their prototype is under construction so they can observe it being built/tested[45]	40	Informal process, implemented occasionally
	• Cognizant engineers provide production personnel with a checklist of requested observations. Cognizant engineers can also interview production personnel.	40	Not typically implemented, left up the individual designer
Production and Deployment Phase:			
• Reduced engineering change activity during product production IN 32.5	• The IPT product development structure is used (including PDEs)[46]	60	IPT processes is only partially implemented (see team cohesiveness above)

[43] Technique used at Boeing and most shipyards
[44] [BMP, 1992, pg. 8]
[45] [BMP, 1989, pg. 6] (have testing room for external customer viewing)
[46] [Shina (ed.), 1994, pg. 236]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
	• Establish change management plan that addresses all potential types of changes • Customer initiated • Cost reduction • Error correcting • Performance improvement	20	Not implemented
	• Integrated PDE drawing & design reviews (preventative measures along with previous IPDS stages) • PDEs in contact with engineers/designers on a regular basis (see above) • PDEs participate in supervisory review of concepts and drawings	40	Partial implementation of integrated review process, PDEs typically not invited to supervisory reviews
	• After a drawing (model) is designated complete all errors found in the review process are documented on a check sheet. (feedback for the designers)[47] • The check sheets are used to create a run chart of errors which is posted by the designer's desk • Designers and their supervisors are encouraged to create pareto diagrams be error type and explore and eliminate the root causes of these errors • Documentation of the accuracy improvement effort is also posted by the designer's desk	20	Not implemented, although drafting keeps some record of errors
	• PDEs follow the product into production (feedback for the PDEs)	40	Occasional implementation
	• The cost of processing an ECN (IR) is documented – production based PDEs can trade off this cost with the cost savings from the request. If the suggestion does not satisfy the cost savings criteria, it should be incorporated in future designs but not the current design.	20	Information for this type of trade is not readily available

[47] This process & sub-processes is inspired by a process used by software engineers to write error free code from [Armitage, 2000]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
	• A database is maintained of all changes: how they were identified/initiated, their status, and action/responsibility. This database is analyzed (pareto, etc.) to look for and eliminate root causes	20	Decentralize records are maintained but the data is not centralized or analyzed
	• Lead PDE publishes lessons learned documents between programs	40	Occasional implementation, individually based
• Reduced engineering support required for products in production IN 46.7	• Standard manufacturing plans are maintained. These can be used as guidelines for development of manufacturing plans for all assemblies.	60	Not typically implemented at a systems/subsystems level, partially implemented at a component level and at an overview level
	• Specific liaison engineers are provided to streamline interaction between production and engineering[48]	20	Not implemented
	• Common CAD tools are used to share models with production[49]	60	Very early implementation
• Reduced factory tooling IN 33.3	• Product diversity is reduced (see above)		See above
	• Facility books are maintained showing the capabilities of present equipment and tools so that designers can try to design to the current tooling	20	Not implemented
	• IPTs are required to identify (as part of a check list) that a design either can be built on current tooling (list) or needs some new tooling (list)	40	Not required, tend to find out too late
	• PDEs and design engineers work with production personnel to develop flexible, low volume production tooling (e.g. adjustable templates, customizable jigs)[50]	40	Very early implementation
• Increased Production yields IN 40	• The use of DFMA during the design will help achieve this goal (the number of steps in the assembly process is reduced, etc.)[51]	40	DFMA is not typically deployed but its use is increasing

[48] Provides good customer service to production while minimize interruption to most of engineering (liaison engineer can bring in designers if they will learn something from the interaction)
[49] Empowers production personnel to answer their own questions – don't have to rely on engineering
[50] [Shina (ed.), 1994, pg. 151, 243]
[51] [Munro, 1994]

Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
	• The error rates for different design features are documented and provided to engineers and designers in a standard so they know which design features to choose	40	Not implemented, this information is partially available in PCAT but not readily available to designers
	• Unconventional assembly processes are simulated to ensure that they can be performed accurately and consistently[52]	40	Occasional implementation (e.g. ribbon bonding)
• Achieve planned production rates IN 40	• The production process is simulated accurately[53] • Collect actual throughput data • Compare it to existing throughput simulation • Update simulation to reflect actual processes • Add any adjustment factors to mimic actual results within acceptable range of error • Continue to track and adjust actual vs. simulation results	40	Some success at the component level with PCAT, otherwise not typically implemented
	• Risk analysis described in design phase is used to eliminate risks early		See above
	• Standard design and production practices as described above are also used to support this goal[54]		See above
	• Test production runs are conducted on early designs of high risk items to identify and eliminate problem areas[55]	40	Typically implemented on an informal basis
	• Production processes are in control so that in production testing can be reduced/eliminated[56]	40	Typically implemented in some production areas (CCA)[57], scattered implementation elsewhere

[52] [BMP, 1988, pg. 9] (references computer simulation as a means to achieve six sigma)
[53] Identify bottlenecks prior to start of production, manage these bottlenecks to achieve planned production rates
[54] Contribute to a predictable production process
[55] Used extensively by GM to ensure smooth ramp ups, LFM Plant Tour 2000
[56] Shortens cycle times
[57] Single process initiative (SPI)

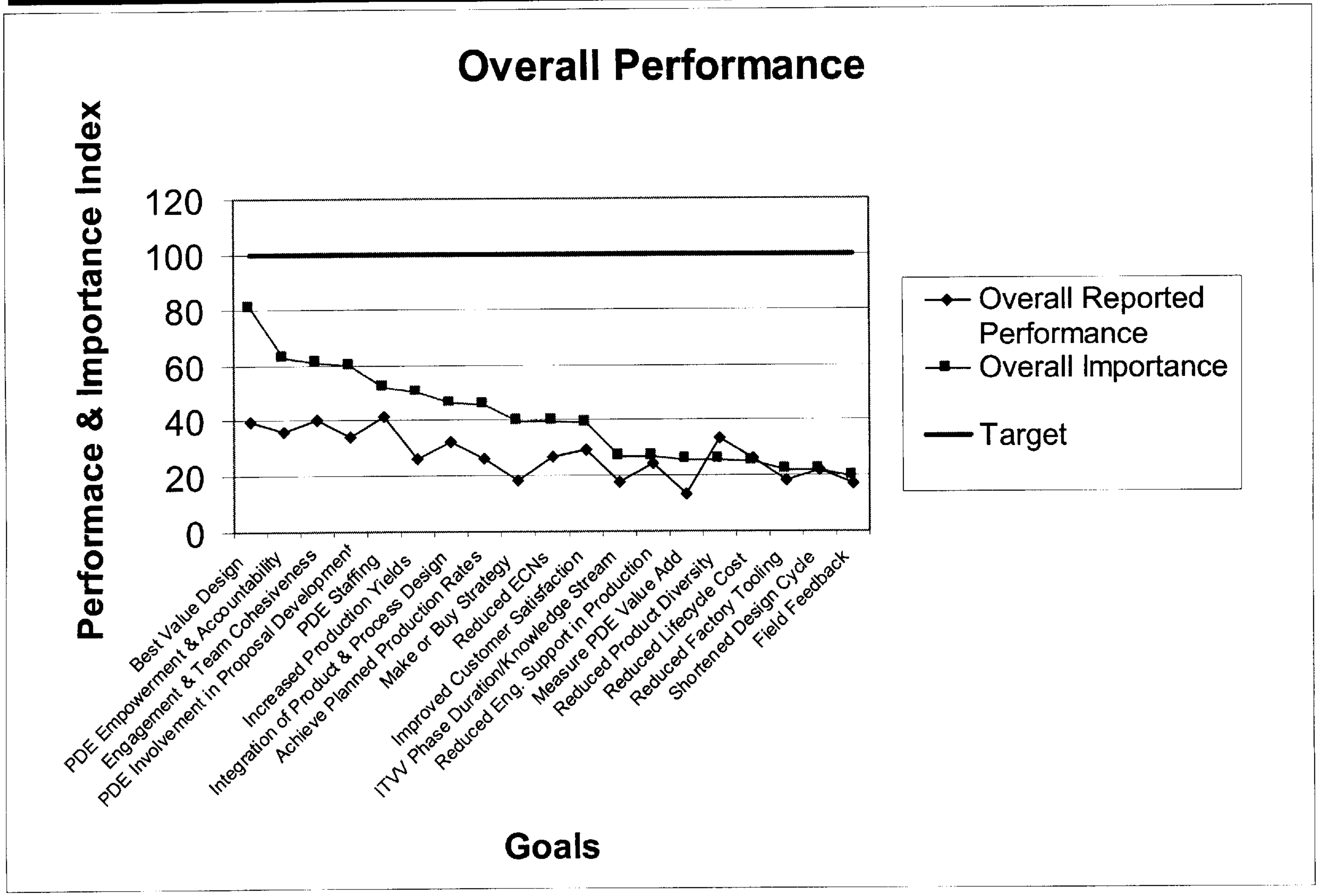
Goals for each IPDS Phase[1]:	*Ideal Support Processes:*	*IN[2]*	*Current Support Processes:*
Operations and Support Phase:			
• Identify and feedback field product changes and operational issues IN 20	• Subsystems/component PDEs interview field support personnel for their area of expertise[58]	20	Not implemented
	• A database of field corrective actions/repairs is maintained including types of problems and associated costs/downtime	20	Not available
	• PDEs analyze this database for key repair costs drivers and avoid these issues in future designs	20	Not implemented
	• Information from these activities is documented in a lessons learned database that is reviewed during the BSEP of other programs	20	Not implemented

[58] [Munro, 1995]

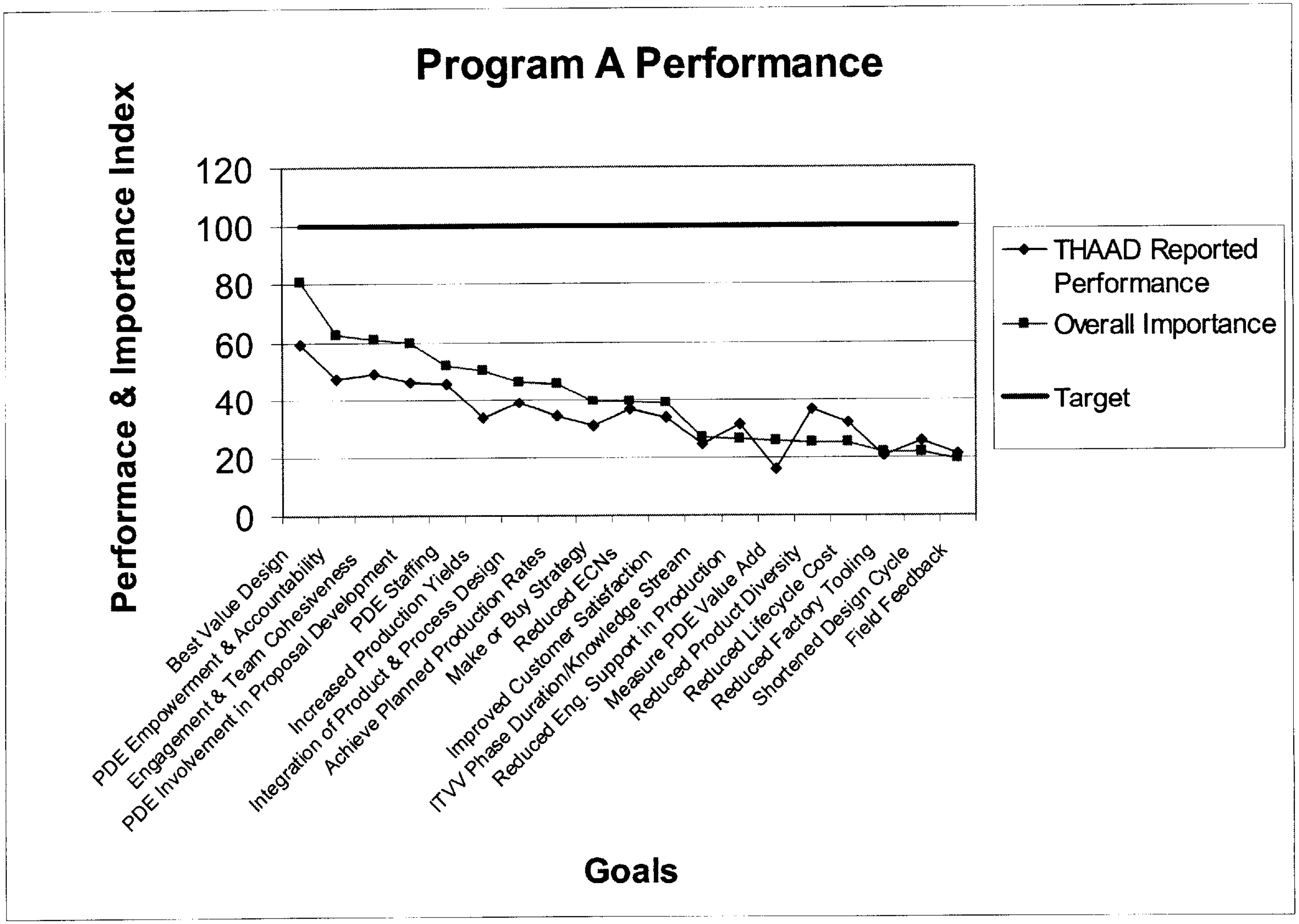
Appendix B

Performance Survey Results by Program and Overall

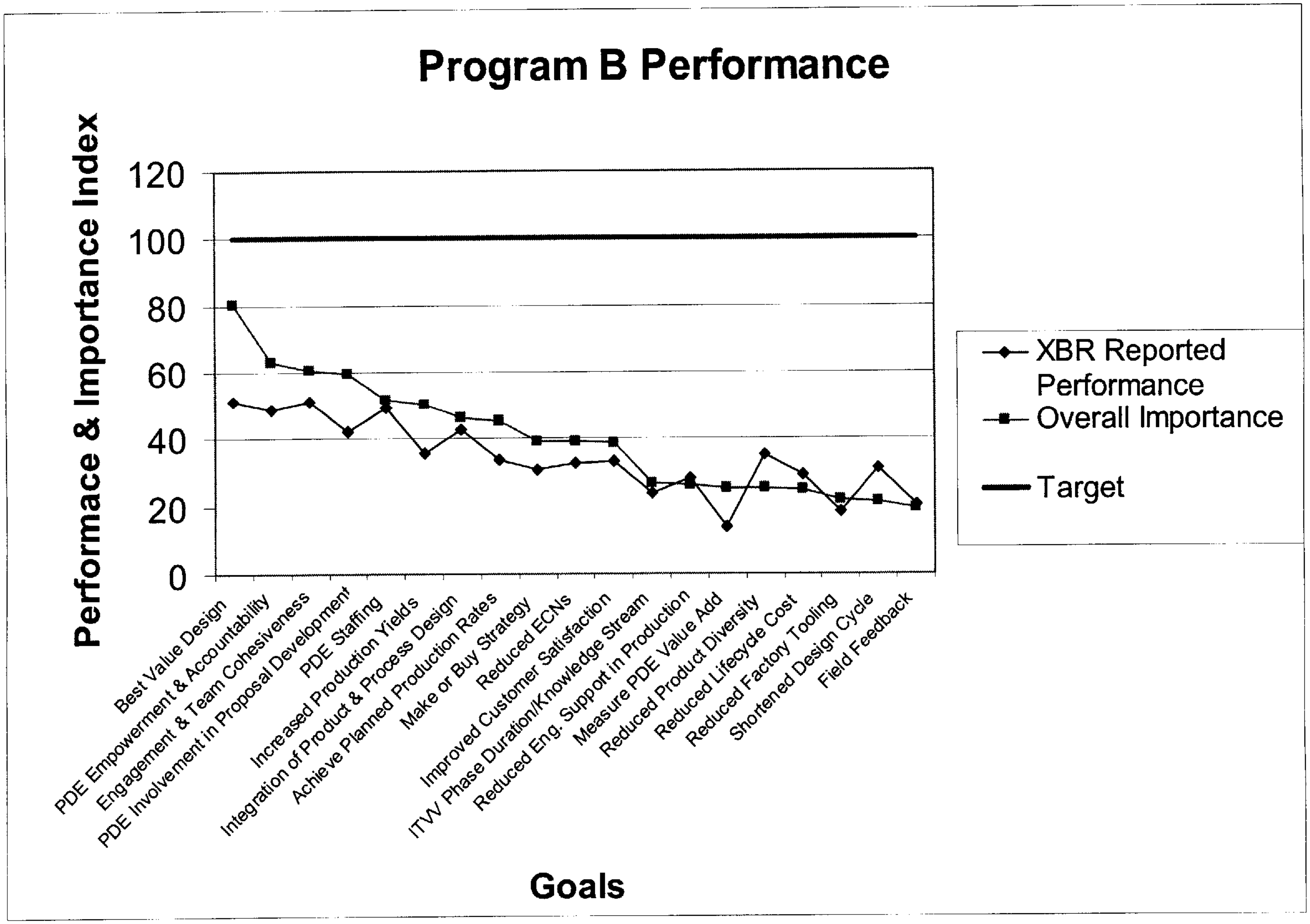
Appendix B: Performance Survey Results by Program and Overall



Appendix B: Performance Survey Results by Program and Overall



Appendix B: Performance Survey Results by Program and Overall



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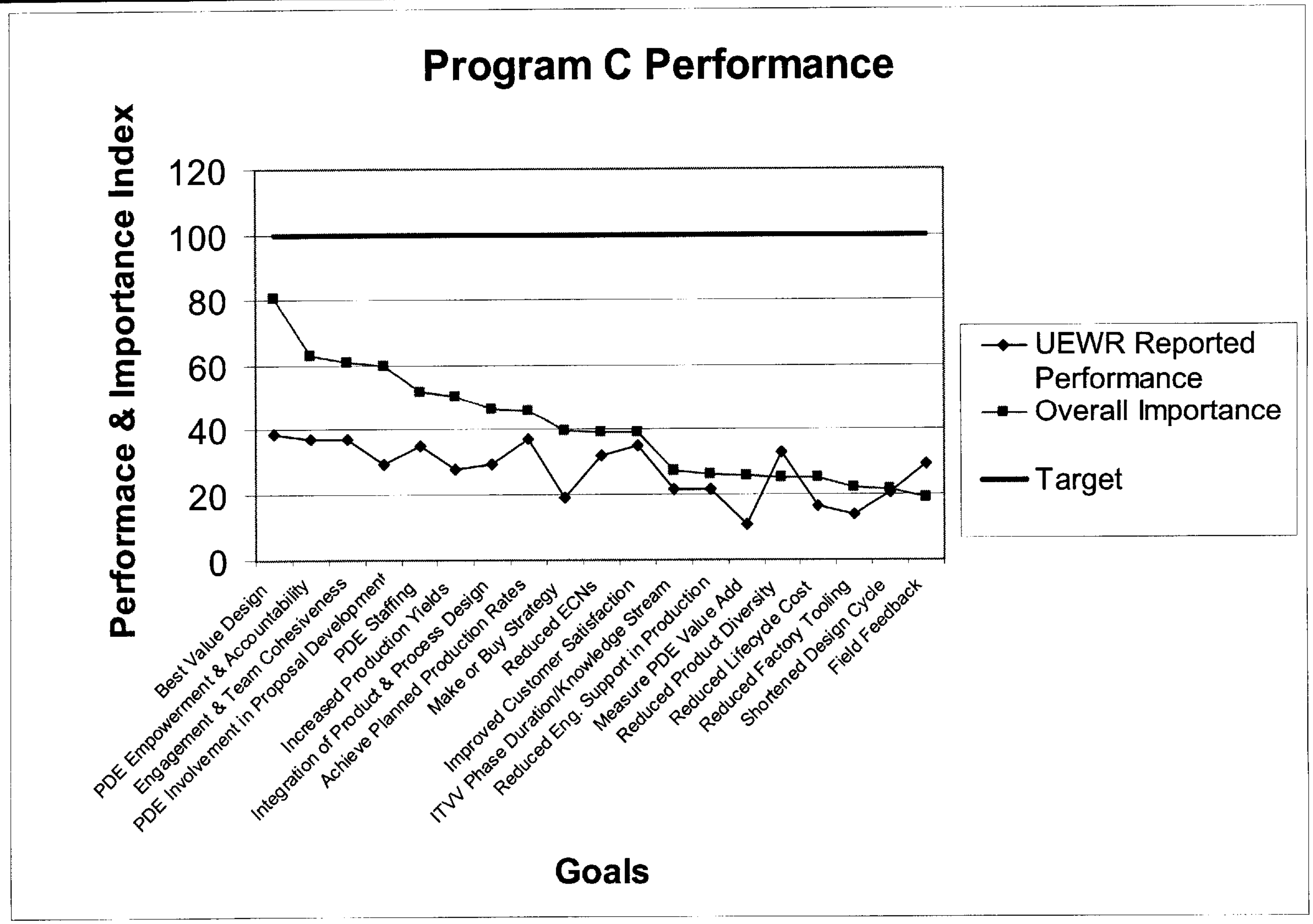

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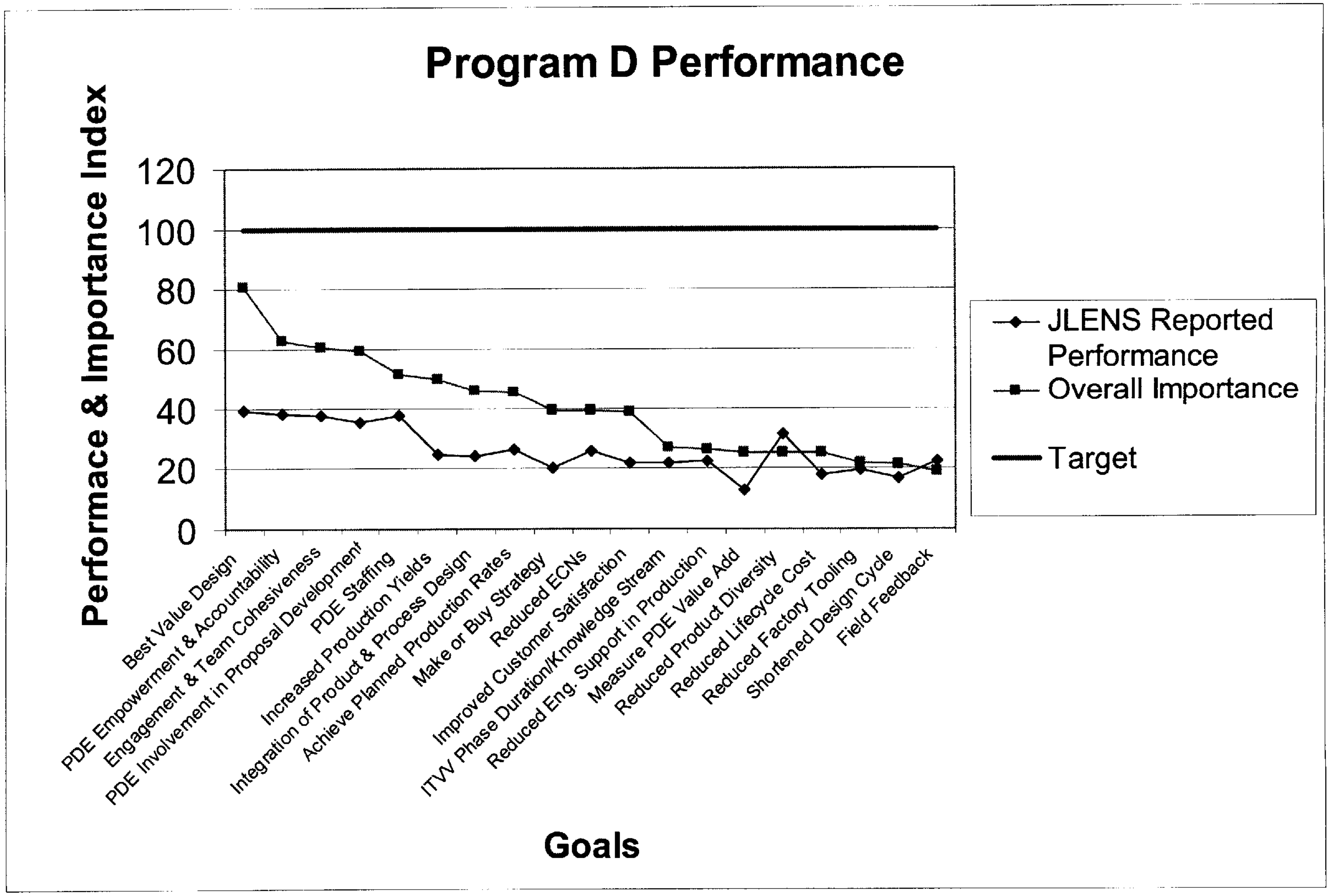

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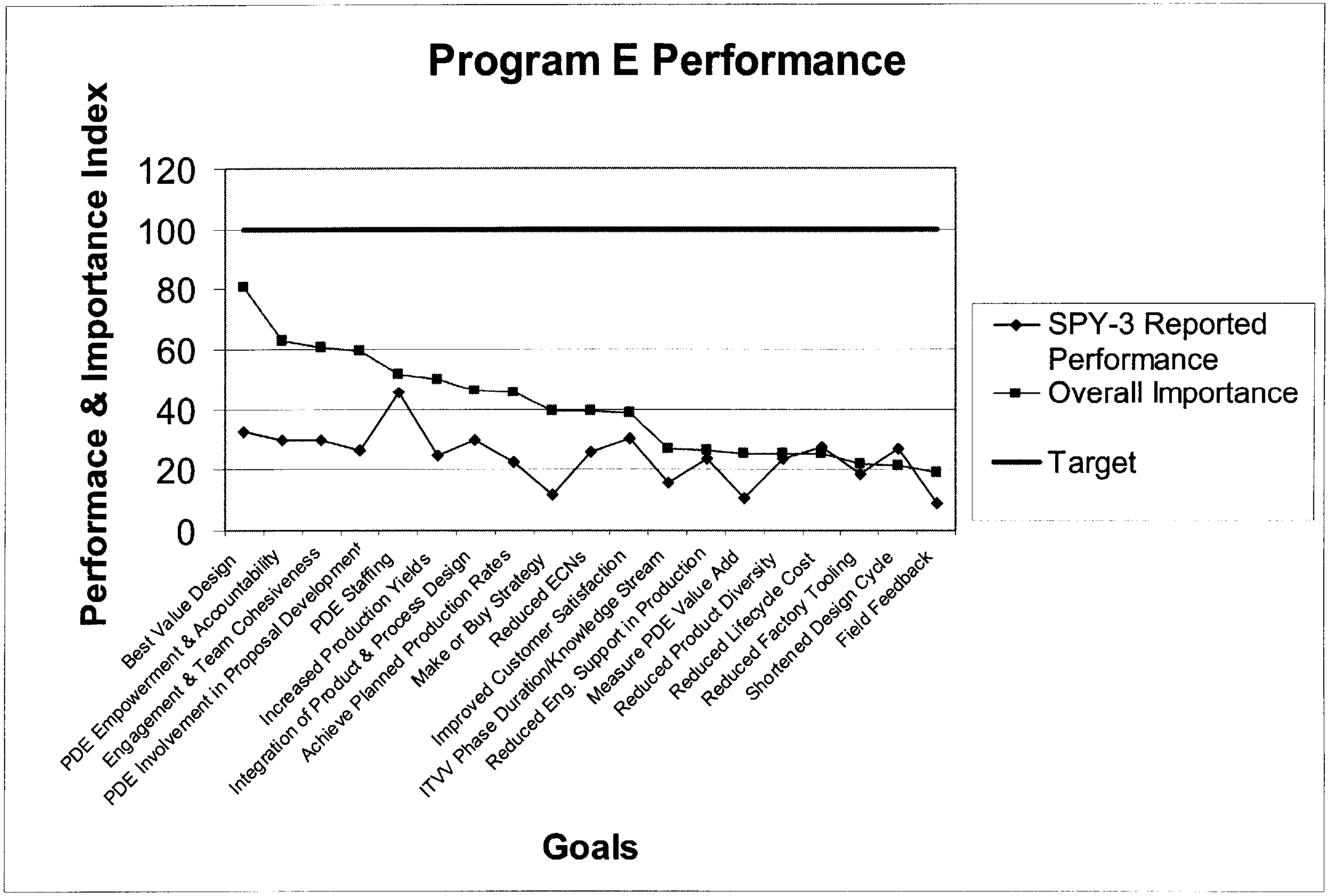


Appendix C

Team Member Preparedness Metric

Team Member Preparedness Metrics

Program:
Team:
Status (core/accessible):
Name:
Position:

PDE

Scoring:	
90 - 100%	green
75 - 90%	yellow
Below 75%	red

	Credit (Y = 1, N = 0	Status	PDE Threshold	Units	PDE Weightings	Core Team Threshold	Core Team Weightings	Accessible Team Threshold	Accessible Team Weightings
Goal 4 **Team Skills:**									
General Team Training	1	Y	Y	Y/N	10	Y	10	Y	10
Team Leader Training	0	N	Y	Y/N	8	Y	5	N	1
Facilitator Training	0	N	Y	Y/N	8	Y	5	N	1
360 evaluation	0	N	Y	Y/N	10	Y	8	Y	6
Communication for personality types training	0	N	Y	Y/N	8	Y	5	Y	5
Personal Myers-Briggs Evaluation	1	Y	Y	Y/N	10	Y	8	Y	5
Goal 2 **CE Skills:**									
Program Management Training	0	N	Y	Y/N	8	Y	5	N	1
Leadership Training	0	N	Y	Y/N	5	N	1	N	1
Negotiation/Conflict Resolution Training	0	N	Y	Y/N	5	N	1	N	1
CAIV [DTC] Training	0	N	Y	Y/N	10	Y	10	Y	6
ADAP Training	0	N	Y	Y/N	10	Y	10	Y	6
DFMA Training	1	Y	Y	Y/N	10	Y	10	Y	6
Voice of the Customer Training	0	N	Y	Y/N	8	Y	8	N	1
QFD Training	0	N	Y	Y/N	5	Y	5	N	1
Communication for Managers Training	0	N	Y	Y/N	5	N	1	N	1
Risk Management Training	0	N	Y	Y/N	8	Y	8	Y	4
Six Sigma Training (Awareness)	1	Y	Y	Y/N	8	N	1	N	1
Six Sigma Training (Specialist)	0	N	Y	Y/N	5	N	1	N	1

Team Member Preparedness Metrics

Program:
Team:
Status (core/accessible):
Name:
Position: PDE

Scoring:

90 - 100%	green
75 - 90%	yellow
Below 75%	red

	Credit (Y = 1, N = 0)	Status	PDE Threshold	Units	PDE Weightings	Core Team Threshold	Core Team Weightings	Accessible Team Threshold	Accessible Team Weightings
Software Training:									
PCAT Training (introduction)	1	Y	Y	Y/N	8	N	1	N	1
PCAT Training (user)	0	N	Y	Y/N	5	N	1	N	1
Pro-E Basic Training	0	N	Y	Y/N	8	N	1	N	1
Pro-Process Training (Pro E module)	1	Y	Y	Y/N	8	N	1	N	1
Product View Training	1	Y	Y	Y/N	8	N	1	N	1
Mentor Graphics Overview Training	0	N	Y	Y/N	5	N	1	N	1
IPDS Training (Overview)	1	Y	Y	Y/N	10	Y	10	Y	8
IPDS Training (Tailoring)	0	N	Y	Y/N	5	N	1	N	1
VISIO Training	1	Y	Y	Y/N	5	N	1	N	1
Microsoft Project Training	1	Y	Y	Y/N	8	Y	8	Y	6
Risk Manager Training	0	N	Y	Y/N	5	N	1	N	1
DOE/KISS Training	0	N	Y	Y/N	5	Y	3	N	1
Geometric Dimensioning & Tolerencing Training	0	N	Y	Y/N	4	Y	8	N	1
PRACS Training	0	N	Y	Y/N	5	N	1	N	1
Power Builder Standards Training	0	N	Y	Y/N	8	N	1	N	1
Basic Problem Solving Training:									
Brainstorming	1	Y	Y	Y/N	3	Y	3	Y	3
Root Cause Analysis	1	Y	Y	Y/N	3	Y	3	Y	3
Pareto Charts	1	Y	Y	Y/N	3	Y	3	Y	3
Flowcharting	1	Y	Y	Y/N	3	Y	3	Y	3
Statistical Process Control	1	Y	Y	Y/N	3	Y	3	Y	3

Team Member Preparedness Metrics

Program:
Team:
Status (core/accessible):
Name:
Position: PDE

Scoring:

90 - 100%	green
75 - 90%	yellow
Below 75%	red

		Credit (Y = 1, N = 0	Status	PDE Threshold	Units	PDE Weightings	Core Team Threshold	Core Team Weightings	Accessible Team Threshold	Accessible Team Weightings
	Independent Study in CE or Engineering Field:									
	Last SOCE conference/meeting/workshop	1	2	3	Months	8	3	5	3	3
	Last Engineering Society (ASME, etc.) meeting	0	4	3	Months	8	3	5	N/A	1
	Last Raytheon MRC Library or supervisor recommended text	1	2	3	Months	5	3	3	3	3
Goal 8	**Production Experience:**									
	Workcenter capability training	1	Y	Y	Y/N	10	Y	10	Y	6
	Production Work Experience	1	5	2	Years	10	0	1	0	1
Goal 15	Last Full-Time Rotation into Production	1	6	24	Months	10	0	1	0	1
	Last hands-on build week in:									
	CCA	0	Never	6	Months	10	12	6	N/A	1
	Cables	1	3	6	Months	10	12	6	N/A	1
	Metal Fab	0	Never	6	Months	10	12	6	N/A	1
	Microwave/RF	0	Never	6	Months	10	12	6	N/A	1
	Electrical Assembly	0	Never	6	Months	10	12	6	N/A	1
	Total Possible Points =	354				354		212		120
	Member Score =	153								
	Overall Preparedness Rating =	43%								

Appendix D

PDE Organization Performance Metrics

PDE Organization Performance Metrics

PDE Manager:

Goal 2

PDE Training:

Name	Preparedness Rating
Person 1	
Person 2	
Person 3	
etc.	

Scoring:	
90 - 100%	green
75 - 90%	yellow
Below 75%	red

Average =
Standard Deviation =

Creation of CE Tools:

		Actual	Target	Last Update	Duration	Target	
Goal 8/16	Facility Books:						
	CCA	1	1	Date	3	6	months
	Cables	1	1	Date	4	6	months
	Metal Fab	0	1	Date	8	6	months
	Microwave/RF	0	1	Date	12	6	months
	Electrical Assembly	1	1	Date	1	6	months
	Facility Books Score =	60%					
	Design Checklists:						
Goal 16	*Tooling Checklists*						
	CCA	0	1	Date	10	6	months
	Cables	1	1	Date	3	6	months
	Metal Fab	0	1	Date	N/A	6	months
	Microwave/RF	1	1	Date	1	6	months
	Electrical Assembly	0.5	1	Date	6	6	months

PDE Organization Performance Metrics

	PDE Manager:						
Goal 8	*Design Guideline Checklists*						
	CCA	1	1	Date	3	6	months
	Cables	1	1	Date	4	6	months
	Metal Fab	1	1	Date	1	6	months
	Microwave/RF	0.5	1	Date	6	6	months
	Electrical Assembly	0.5	1	Date	6	6	months
Goal 17	*Error rate data for Design Details*						
	CCA	1	1	Date	3	6	months
	Cables	1	1	Date	4	6	months
	Metal Fab	1	1	Date	1	6	months
	Microwave/RF	0.5	1	Date	6	6	months
	Electrical Assembly	0.5	1	Date	6	6	months
	Design Checklist Score =	70%					
	<u>Production Simulation Tools:</u>						
Goal 18	*Cycle Time*						
	CCA	1	1	Date	3	6	months
	Cables	0	1	Date	N/A	6	months
	Metal Fab	0	1	Date	N/A	6	months
	Microwave/RF	0	1	Date	N/A	6	months
	Electrical Assembly	0	1	Date	N/A	6	months
Goal 17	*Assembly Processes*						
	CCA	1	1	Date	3	6	months
	Cables	0	1	Date	N/A	6	months
	Metal Fab	0	1	Date	N/A	6	months
	Microwave/RF	0	1	Date	N/A	6	months
	Electrical Assembly	0	1	Date	N/A	6	months
	Production Simulation Score =	20%					

PDE Organization Performance Metrics

	PDE Manager:	

	Standard Manufacturing Plans:	Actual Qty	Target Qty
Goal 15	T/RIMM	1	1
	Foundations	2	3
	Other Standard Building Blocks	5	10

Manufacturing Plan Score = 57%

	Lessons Learned Documentation:	Actual	Target
Goal 14	*General*		
	Program 1	1	1
	Program 2	1	1
	Program 3	0	1
	etc.	1	1

Lessons Learned Score = 75%

Note: Unless otherwise noted 1 = Complete, 0 = not complete/expired, 0.5 = about to expire

Goal 14 ECN Cause & Impact Database:

	Actual	Target	Last Update	Duration	Target	
Central ECN Database is maintained =	1	1	Date	1	2	months
Root Cause analysis is conducted =	0	1	Date	N/A	6	months
Findings are incorporated into checklists =	0	1	Date	N/A	6	months
Cost of an ECN is known =	0	1	Date	N/A	6	months

ECN Feedback Score = 25%

First Article Assembly Review Form Database:

	Actual	Target	Last Update	Duration	Target	
Central FAARF Database is maintained =	1	1	Date	1	2	months
Root Cause analysis is conducted =	0	1	Date	N/A	6	months
Findings are incorporated into checklists =	0	1	Date	N/A	6	months
FAARF Feedback Score =	33%					

Appendix E

Engineering Organization Performance Metrics

Engineering Organization Performance Metrics

Engineering Manager:

Goal 2 **Engineer Training for CE:**

Name	Preparedness Rating
Person 1	
Person 2	
Person 3	
etc.	

Scoring:	
90 - 100%	green
75 - 90%	yellow
Below 75%	red

Average =
Standard Deviation =

Goal 14 **Designer Feedback (errors found in the review process):**

	Check Sheet Posted		Pareto of Root Causes		Run chart of accuracy	
Name	Actual	Target (2 wks)	Actual	Target (2 wks)	Actual	Target (2 wks)
Person 1	1	1	0	1	1	1
Person 2	1	1	1	1	1	1
Person 3	1	1	0	1	1	1
etc.	1	1	1	1	1	1

Designer Feedback Score = 75%

Yes = 1, No = 0

Assumptions:
-- Posted Checksheet is worth 25%
-- Posted Pareto analysis is worth 50%
-- Posted Accuracy improvement is worth 25%

Note: Improvement targets will be set by designers & their managers on an individual basis

Engineering Organization Performance Metrics

Engineering Manager:

Goal 14

Change Management Plans:

	Actual	Target	Last Update	Duration	Target	
Plan for customer initiated changes =	1	1	Date	3	9	months
Plan for cost reduction changes =	1	1	Date	4	9	months
Plan for error correcting changes =	1	1	Date	8	9	months
Plan for performance improvement changes =	0	1	Date	12	9	months

Change management score = 75%

Field Lessons Learned Documentation:

		Actual	Target
Goal 19	*Field Feedback Database/Analysis*		
	Program 1	1	1
	Program 2	1	1
	Program 3	1	1
	etc.	1	1
Goal 19	*Field Feedback Interviews*		
	Program 1	1	1
	Program 2	0	1
	Program 3	0	1
	etc.	1	1

Field Lessons Learned Score = 75%

Appendix F

Production Organization Performance Metrics

Production Performance Metrics

Production Manager: [redacted]

Goal 13 **ITVV Phase Duration/Knowledge Stream:**

	Actual	Target		Target/Actual
Number of Prototypes constructed to date =	16	N/A		
% of prototypes with exact status/location which could be tracked online =	0%	100%		
% of prototypes where IPT/Cognizant Engineer was notified of construction schedule 24 hours in advance =	75%	100%		
Average cycle time for prototypes =	100	20	days	20%
Standard deviation of prototype delivery =	12	1	days	8%

ITVV production support score = 31%

Assumptions:	Scoring:	
-- Online tracking worth 10%	90 - 100%	green
-- Notification of design team worth 30%	75 - 90%	yellow
-- Prototype cycle time (target/actual) worth 30%	Below 75%	red
-- Delivery standard deviation (target/actual) worth 30%		

Goal 15 **Reduced Engineering Support in Production:**

% of production areas with dedicated liaison engineer =	85%
% of production areas with electronic viewing capability for engineering information =	60%

Production empowerment score = 73%

Production Performance Metrics

Production Manager:

Goal 18 **Control of Production Processes**

Work Areas:	Number of Typical Production Paths	% tracked & in control
CCA	50	75%
Cables	10	80%
Metal Fab	20	60%
Microwave/RF	15	50%
Electrical Assembly	15	40%

Control of Production Processes Score = 65%

Goal 16

Flexible Tooling:	Actual	Target	Last Updat	Duration	Target	
Database of Tooling Spending by area =	1	1	Date	1	2	months
Pareto analysis of tooling spending (past 3 years) =	1	1	Date	5	6	months
Brainstorm solutions	1	1	Date	5	6	months
Cost reduction proposals	$ 70,000	$ 75,000				
Total implemented savings to date =	$ 25,000	$ 50,000				

Yes = 1, No = 0

Flexible Tooling Score = 74%

Assumptions:
-- Database is worth 10%
-- Pareto analysis is worth 10%
-- Brainstorm solutions is worth 10%
-- Cost reduction proposals are worth 20%
-- Implementation is worth 50%

Scoring:	
90 - 100%	green
75 - 90%	yellow
Below 75%	red

Appendix G

Proposal Team Performance Metrics

Proposal Team Performance Metrics

Program:
Program Manager:

Goal 1/4

Lead Systems PDE Involvement:

	Actual:	Target:	Yes = 1, No = 0
Lead Systems PDE is included on proposal team =	1	1	
Lead systems PDE participates on selection & pricing of baseline design =	0	1	
Lead Systems PDE participates in the IPDS tailoring session =	1	1	
Lead Systems PDE Involvement Score =	67%		

Goal 1

BSEP PDE Services Plan and Funding:

PDE Services Plan:

Steps/Tools:	Negotiated Funding (hrs):	Actual Funding (hrs):	Scoring:	
Service 1	100	75	90 - 100%	green
Service 2	250	250	75 - 90%	yellow
Service 3	100	50	Below 75%	red
Service 4	80	40		
	Funding Score =	78%		

Design/Build Strategy:

Design/Build strategy addresses:	Actual:	Target:
Build locations	0	1
Technology	1	1
One time investments (e.g. new machinery)	1	1
Other Major estimate assumptions	0	1
Design/Build strategy score =	50%	

Proposal Team Performance Metrics

Program:
Program Manager:

Goal 11

Identification of Customer Needs:

	Actual:	Target:
Customer surveys received =	39	50
Customer observation sessions =	3	10
One-on-one interviews conducted =	5	15
Database of all requests maintained & ranked =	1	1

Customer needs identification score = 70%

Assumptions:
-- Customer surveys are worth 10%
-- Customer observation is worth 20%
-- Customer interviews are worth 20%
-- Database is worth 50%

Integration of Customer Needs:

	High	Medium	Low
Number of items in the customer needs database =	10	50	150
Number of items incorporated into the design =	1	40	50
Percentage compliance =	10%	80%	33%

Customer satisfaction score = 46%

Assumptions:
-- A high value item is 9 x more valuable than a low value item
-- A medium value item is 3 x more valuable than a low value item

Proposal Team Performance Metrics

Goal 1 **Cost Targets Established:**

<u>Procurement Cost:</u>	
Integration =	50
Opportunity 1	2
Opportunity 2	3
Opportunity 3	1
Integration Target Cost =	**44**
Assembly A =	600
Opportunity 1	20
Opportunity 2	15
Opportunity 3	3
Assembly A Target Cost =	**562**
Assembly B =	45
Opportunity 1	1
Opportunity 2	5
Opportunity 3	2
Assembly B Target Cost =	**37**
Assembly C =	750
Opportunity 1	100
Opportunity 2	20
Opportunity 3	10
Assembly C Target Cost =	**620**
Other Cost 1 Target =	20
Other Cost 2 Target =	60
Other Cost 3 Target =	5
Other Cost 4 Target =	10
Total Acquisition Cost Target =	**1,358**
<u>Operating Cost:</u>	
Operating Cost =	1000
Opportunity 1	100
Opportunity 2	20
Opportunity 3	10
Operating Cost Target =	**870**
<u>Support Cost:</u>	
Support Cost =	500
Opportunity 1	50
Opportunity 2	3
Opportunity 3	10
Support Cost Target =	**437**
Total Project Cost Target =	**2,665**

Proposal Team Performance Metrics

	Actual:	Target:
Procurement Cost Baseline is identified by area =	1	1
Procurement Cost opportunities are identified by area =	0	1
Procurement Cost targets are identified by area =	1	1
Other procurement cost baselines & targets are identified =	1	1
Baseline Operating costs are identified =	0	1
Operating costs opportunities are identified =	0	1
Operating cost targets are identified =	1	1
Baseline Support costs are identified =	0	1
Support cost opportunities are identified =	0	1
Support cost targets are identified =	1	1
Cost Target Score =	50%	

Appendix H

Program Management Performance Metrics

Program Management Performance Metrics

Program:
Program Manager:

Goal 3

Improvement Plan and Funding:

Design Improvement Plan:

Steps/Tools:	Negotiated Funding (hrs):	Scheduled Funding Released (hrs):	Actual Funding (hrs):
Step/Tool 1	1,000	200	160
Step/Tool 2	500	100	0
Step/Tool 3	100	20	20
Step/Tool 4	2,500	500	500
Step/Tool 5	1,000	200	100
Step/Tool 6	800	100	0

Funding Score = 70%

Scoring:

90 - 100%	green
75 - 90%	yellow
Below 75%	red

Goals 2/4/13/14

Team Staffing:

Integration Team (unique):

Core Disciplines:	Core Members:	Accessible Disciplines:	Accessible Members:
Lead Systems PDE		SCM	
Lead Electrical Systems		Finance	
Lead Mechanical Systems		Testing	
etc.		etc.	

% filled at project kickoff =		% filled at project kickoff =	
% still the same =		% still the same =	
% of team co-located (w/in 20') =		% of team co-located (w/in 20') =	
Average training score =		Average training score =	

Program Management Performance Metrics

Program:
Program Manager:

<u>REX Team (shared):</u>

Core Disciplines:	Core Members:	Accessible Disciplines:	Accessible Members:
Systems PDE		SCM	
Electrical Systems		Finance	
Mechanical Systems		Testing	
etc.		etc.	

% filled at project kickoff =		% filled at project kickoff =	
% still the same =		% still the same =	
% of team co-located (w/in 20') =		% of team co-located (w/in 20') =	
Average training score =		Average training score =	

<u>CCA Team (shared):</u>

Core Disciplines:	Core Members:	Accessible Disciplines:	Accessible Members:
Component PDE		SCM	
Electrical Engineer		Finance	
Mechanical Engineer		Testing	
etc.		etc.	

% filled at project kickoff =		% filled at project kickoff =	
% still the same =		% still the same =	
% of team co-located (w/in 20') =		% of team co-located (w/in 20') =	
Average training score =		Average training score =	

<u>Overall Team (all of the above):</u>

% filled at project kickoff =	95%	% filled at project kickoff =	100%
% still the same =	80%	% still the same =	100%
% of team co-located (w/in 20') =	100%	% of team co-located (w/in 20') =	25%
Average training score =	65%	Average training score =	75%

Program Management Performance Metrics

Program: [redacted]
Program Manager:

Team staffing score:

	Core Team Weight	Accessible Team Weight
% filled at project kickoff =	7.50	5.00
% still the same =	15.00	10.00
% of team co-located (w/in 20') =	33.75	2.50
Average training score =	18.75	7.50
	75.00	25.00
Total Weight =	100.00	

Team staffing score = **86%**

Note 1: Co-location Distance of 20' based on quadrupling the probability that people will communicate at least once a week
Allen, Thomas J., Managing the Flow of Technology, MIT Press

Note 2: Average training score based on member preparation metrics

Program Management Performance Metrics

Program: [redacted]
Program Manager:

Goal 4

Facilitation of Cross-Team Communication:

	Actual:	Target:
An internal program webpage is established	1	1
An organization chart of all manned teams is included	1	1
Names, functions and contact information for all team members are linked to the org. chart	0	1
Links are included to other related program webpages	1	1
Links are included to counterparts on other related programs	0	1
Area is available to post major design decisions	1	1
E-mail notification is sent to counterparts when new posting is added	0	1

Facilitation of Cross-team communication score = 57%

Goal 5

Design Cost & Quality Summary:

	Number of items to be targeted	**% targeted**
Cost (ADAP)	80	94%
Quality (PCAT)	75	100%

Scoring:

90 - 100%	green
75 - 90%	yellow
Below 75%	red

Program Management Performance Metrics

Program:
Program Manager: [redacted]

Goal 6

Make or Buy Strategy:

	Total Parts	Parts w/ final sourcing	Parts w/ preliminary sourcing	Parts w/o sourcing defined
Number of Parts	125	20	50	55
% of Parts	N/A	16%	40%	44%

Sourcing Definition Score = 29%

Assumptions:
-- A part w/ final sourcing is 3 x more certain than a part w/ preliminary sourcing

Goal 18

Support for Pre-Production Testing:

Item	Duration Required (days)	Duration Allotted	Budget Required Hours	Dollars	Budget Allotted Hours	Dollars
High Risk A	25	10	300	5000	300	2000
High Risk B	10	10	150	2000	150	2000
High Risk C	50	0	500	10000	0	0
etc.						
Average	28.3	6.7	317	5,667	150	1,667

Pre-Production Testing Support = 34%

Assumptions:
-- One hour = $100
-- Duration is equally important to Budget

Appendix I

IPT Performance Metrics

IPT Performance Metrics

Program:
Team:

Goal 4

Team Building:

		Standard:
Duration of Team Building Training (days):	2.0	3 continuous days
% of team participating in TBT:	95%	100%
Team Building Rating =	63%	

Scoring:
- 90 - 100%
- 75 - 90%
- Below 75%

Goal 3

Improvement Plan and Cost Adherence:

Design Improvement Plan:

Steps/Tools:	Required Funding (hrs):	Actual Funding (hrs):	Percentage Complete:	Earned Hours (from req.):	Actual Hours:	Efficiency:
Step/Tool 1	1,000	750	50%	500	451	110.86%
Step/Tool 2	500	0	0%	0	5	0.00%
Step/Tool 3	100	100	75%	75	80	93.75%
Step/Tool 4	2,500	2,500	32%	800	950	84.21%
Step/Tool 5	1,000	500	60%	600	550	109.09%
Step/Tool 6	800	400	80%	640	645	99.22%
	% Funded =	72%			**CE Efficiency =**	97.54%

Scoring (% Funded):
- 90 - 100%
- 75 - 90%
- Below 75%

Scoring (CE Efficiency):
- 110% or greater
- 95 - 110%
- 85 - 95%
- Below 85%

IPT Performance Metrics

Program:
Team:

Goal 5

Design Cost & Quality Summary:

(supported by ADAP & PCAT detailed summaries)

	Number of items	% baselined	% 1st round estimates	Average % change	Overall change	**of those baselined % meeting target**
Cost (ADAP)	80	88%	81%	-7%	-5%	**86%**
Quality (PCAT)	75	67%	60%	-5%	N/A	**80%**

Scoring (% baselined, % 1st round estimates)	Scoring (Average % change, Overall change)	Scoring (of those baselined % meeting target)
90 - 100%	-15% or greater	90 - 100%
75 - 90%	-5 to - 15%	75 - 90%
Below 75%	-5 to 10%	Below 75%
	10% or greater	

Goal 5

Risk (Schedule, Cost, Quality, Technical, Production) Summary:

(supported by a risk monitoring database)

	High Risk Items	Medium	Low
Number of risks identified	100	50	200
% of risks actioned	85%	40%	25%
% neutralized	10%	4%	25%

Risk Readiness Score = 29%

Scoring:

Scoring:
90 - 100%
75 - 90%
Below 75%

Assumptions:

-- A high risk item is 9 x more risky than a low risk item
-- A medium risk item is 3 x more risky than a low risk item
-- Actioning a risk is 25% of the battle to neutralize it

IPT Performance Metrics

Goal 7 **Design Cycle Time:**

	Design Product A	Design Product B	Design Product C
Quantity	50	100	20
Average Cycle Time in Days	7.0	30.0	23.0
Target Cycle Time in Days	10.0	25.0	20.0
Target/Actual	143%	83%	87%
Overall Target	20.0		
Overall Actual	22.4		
Overall Target/Actual	89%		
Standard Deviation of Cycle Time in]	4.0	20.0	10.0
Target SD of Cycle Time in Days	1.0	1.0	1.0
Target/Actual	25%	5%	10%
Overall Target	1.0		
Overall Actual	14.1		
Overall Target/Actual	7%		
Design Cycle Time Score =	48%		

Scoring:

90 - 100%

75 - 90%

Below 75%

Assumptions:

-- Design cycle begins with the first charge to a design product & ends with the last charge to that product

-- Days based on business days

-- Average cycle time is weighted at 50%

-- Standard deviation is weighted at 50%

IPT Performance Metrics

Goal 8 **Product Design Integrated with Process Design:**

	Total Number	% Flowcharted	% of design guide checklists complete	% of items with both flowcharts & checklists complete	% of Flowcharted + Checked free of Non-Standard Processes	Average # of Non-Standard Processes for remaining P/A	# of P/A with more than 5 Non-Standard Processes
Parts	150	75%	79%	65%	85%	3.3	10
Assemblies	25	50%	55%	35%	60%	8.2	2

Product/Process Integration Score = 54%

Scoring:
- 90 - 100%
- 75 - 90%
- Below 75%

Assumptions:

-- A design with 5 or more non-standard processes is not integrated with process design

IPT Performance Metrics

Goal 9 **Design Commonality:**

	Total Number	Total # of different parts	% different parts	Standard Parts	% of Standard Parts
Parts	150	98	65%	57	38%
			(within the same item)		(across different products)

Product Commonality Score = 37%

Scoring (Product Commonality Score)	Scoring (% different parts)	Scoring (% of Standard Parts)
80 - 100%	0 - 20%	80 - 100%
50 - 80%	20 - 50%	50 - 80%
Below 50%	Above 50%	Below 50%

Assumptions:

-- The Total Number of different Parts refers to The number of part numbers used in an item
(e.g. an assembly with 3 A's + 5 B's would have 2 different parts)

-- A part is considered standard if it used across more than one product

-- A part shared across more than one product is twice as valuable as a part shared within a product

Goal 10 **Life Cycle Cost:**

(supported by detailed lifecycle cost models)

	Targeted value ($M)	Baseline Value	Current Estimate	% change (baseline to current)	**% Deviation from target**	Scoring:	
Procurement Cost	56	75	70	-7%	25%	-15% or greater	blue
Operating Cost	200	275	250	-9%	25%	-5 to - 15%	green
Support Cost	102	90	95	6%	-7%	-5 to 10%	yellow
						10% or greater	red
				Overall =	16%		

LCC score (Target/Actual) = 86%

Scoring:	
95% or over	green
90 - 95%	yellow
Below 90%	red

IPT Performance Metrics

Goal 12 **Measuring/Publicizing the Value of the CE Process:**

	Actual:	Targets:
LCC Dollar Value Saved by IPT (millions) =	$25.0	$82
LCC % cost saved by IPT (vs. baseline) =	5.7%	18.6%
Average % reduction in DPMO (from PCAT) =	5.0%	15.0%
Critical Path Cycle Time Reduction (days) = (supported by mapping of critical path and relevant calculations)	52	40
% of program reviews at which the above data are displayed =	85%	100%
Number of articles published about IPT's activities =	3	15
Measuring/Publicizing Score =	54%	

Assumptions:
-- LCC cost savings measurement over zero worth 20%
-- Reduction in DPMO measurement over zero worth 20%
-- Reduction in critical path cycle time over zero worth 20%
-- Presentation at program reviews is worth 20%
-- Articles published worth 20%

Scoring:
90 - 100%
75 - 90%
Below 75%

IPT Performance Metrics

Goal 13/17

ITVV Phase Duration/Knowledge Stream:

		Scoring:
Number of critical Design Interfaces Identified =	53	100%
% assigned to IPT members for monitoring =	93%	90 - 100%
% inter-connection diagrams current with design =	87%	Below 90%

Number of Prototypes constructed to date =	16	Scoring:
% of prototypes modeled/simulated prior to prototype construction =	50%	90 - 100%
% of prototypes visited by IPT members during construction =	75%	75 - 90%
% of prototypes with checklists available to production personnel =	85%	Below 75%
% of prototypes followed up with interview of construction personnel =	60%	

ITVV preparedness/proactiveness Score = 74%

Assumptions:
-- Assigning an IPT member to monitor an interconnect worth 20%
-- ICD current with design worth 20%
-- Model/simulating prototype worth 20%
-- Visiting prototype during construction worth 10%
-- Checklist provided to production personnel worth 10%
-- Follow up interview worth 20%

Scoring:
90 - 100%
75 - 90%
Below 75%

IPT Performance Metrics

Goal 8 **Test Requirements Development:**

Item Number/Description/Responsible Person	Design Review	FTE Design Review	Test Strategy	Testability Review	TRS Review	Average
Assembly A	3	3	2	2	1	2.20
Assembly B	4	3	1			2.67
Assembly C	2					2.00
Average =	3	3	1.5	2	1	2.29
		Test Requirements Development Score =				**76%**

Assumptions:
-- FTE = Factory Test Equipment
-- TRS = Test Requirements Specification
-- Items that are blank have not been completed
-- All five categories are equally weighted
-- Scoring:

1 = Completely unsatisfactory
2 = Needs Improvement
3 = Satisfactory
4 = Exceptional

Goal 11 **Integration of Customer Needs:**

	High	Medium	Low
Number of items in the customer needs database =	10	50	150
Number of items incorporated into the design =	3	45	100
Percentage compliance =	30%	90%	67%

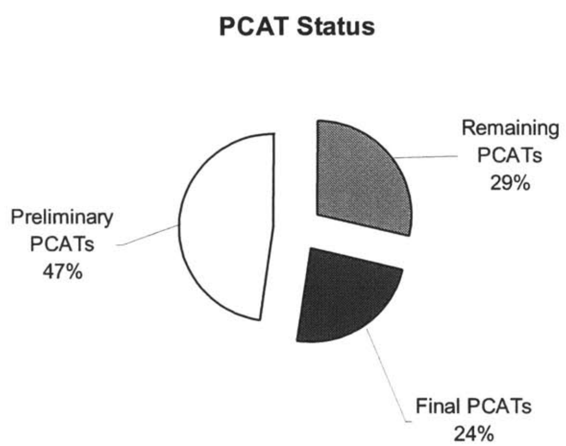
Customer satisfaction score = 67%

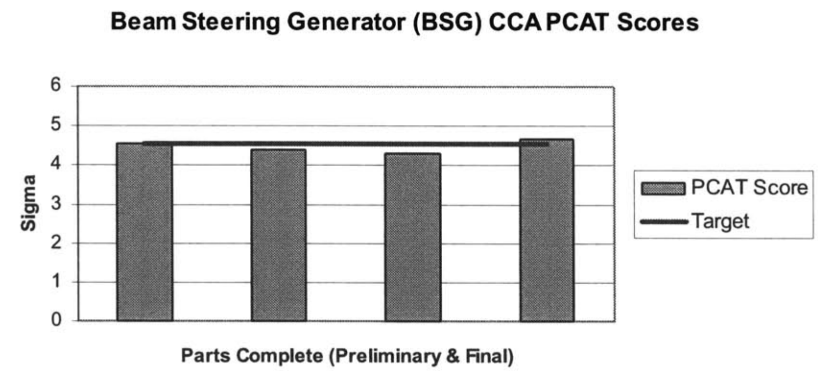
Assumptions:
-- A high value item is 9 x more valuable than a low value item
-- A medium value item is 3 x more valuable than a low value item

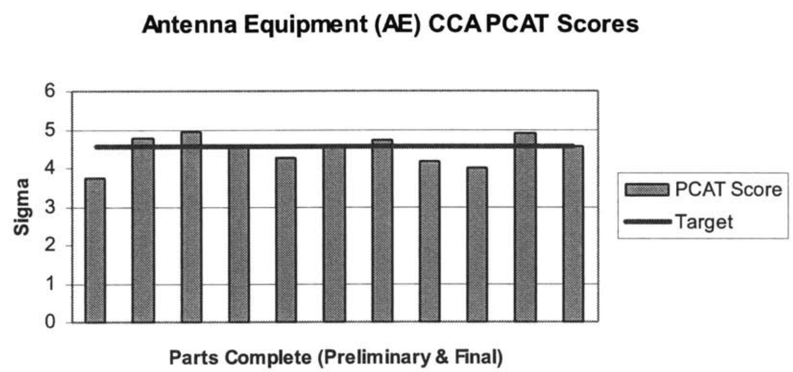
Appendix J

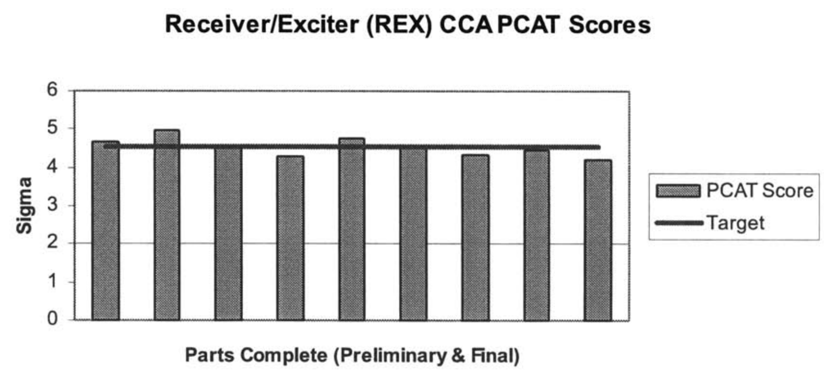
PCAT Based Performance Metrics

Appendix J: PCAT Based IPT Performance Metrics









Appendix K

ADAP Based IPT ROM Estimating Format and Graphical Performance Metrics

Material Worksheet

ADAP Submittal Format

Item	Quantity	Material Unit Cost	Source (examples)	Material Burden Fctr	Material Cost
TRIMM	1	N/A			
Cable Assy RF (part number if avail.)	1	$98.00	Current Cost Returns (date/reference part number)	1.2	$117.60
BF to T/R Connection	8	$10.11	Catalogue Pricing (date/catalogue)	1.2	$97.06
Beam Former 8:1	1	$595.00	Vendor A Quote (date)	1.2	$714.00
Cover Input	8	$11.50	Current Cost Returns (date/reference part number)	1.2	$110.40
T/R Connection Assy	8	N/A			
Input connection assy	8	$14.94	Estimator's Judgement	1.2	$143.42
Output connection assy	8	$19.64	Estimator's Judgement	1.2	$188.54
Transmit/receive	8	$875.47	Dallas Quote (date)	1	$7,003.76
PWR/Logic CCA	1	N/A			
Printer wire board	1	$486.41	Supporting Spreadsheet A	1.2	$583.69
IC	3	$10.52	Estimator's Judgement	1.2	$37.86
IC	4	$11.92	Current Cost Returns (date/reference part number)	1.2	$57.22
EMC	4	$38.02	Current Cost Returns (date/reference part number)	1.2	$182.52
IC	1	$13.18	Current Cost Returns (date/reference part number)	1.2	$15.82
Connection	1	$67.93	Vendor D Quote (date)	1.2	$81.51
PWR Input Flex	1	N/A			
Flex circuit	1	$72.50	Vendor E Quote (date)	1.2	$1,887.00
CCA connection	1	$65.51	Vendor F Quote (date)	1.2	$78.61
DC/DC connection	1	$302.11	Supporting Spreadsheet B	1.2	$362.53
Delta in NRE Cost	1	$0.00		1	$0.00

Subtotal Material Cost =	$12,502.70
Allowance for Material under $10 unit cost =	$625.14
Margin at 3% =	$393.84
Total Material Cost =	**$13,522**

Labor Worksheet

ADAP Submittal Format

Item	Quantity	Labor Unit Hours	Source (examples)	Labor Hours
TRIMM	1	N/A		
Assemble & Inspect TRIMM	1	2.70	Production Estimate	2.70
Test TRIMM	1	2.05	Current Cost Returns (date/reference function)	2.05
Cold Plate	1	N/A		
Fabricate Cold Plate	1	1.00	Estimator's Judgement	1.00
DC/DC Converter	2	N/A		
Circuit Card Assembly	2	1.29	Current Cost Returns (date/reference function)	2.58
Test DC/DC	2	0.05	Time Study	0.11
PWR/Logic CCA	1	N/A		
Circuit Card Assembly	1	1.18	Current Cost Returns (date/reference function)	1.18
Test DC/DC	1	0.57	Current Cost Returns (date/reference function)	0.57
PWR Input Flex	1	N/A		
Cable Assembly	1	0.50	Time Study	0.50
Inspection	1	0.33	Current Cost Returns (date/reference function)	0.33
			Subtotal Labor Hours =	11.02
			Margin at 3% =	0.33
			Total Labor Hours =	**11.35**

Total Product Cost

Labor Unit Cost ($/hr) =	$200.00
Labor Cost =	$2,270
Material Cost =	$13,522
Total Cost =	$15,791

Use this page to create support spreadsheets in the standard format presented on the previous page for parts built in house

	Material Dollars	Labor Hours	Total Dollars	Date	Intiator
Baseline ADAP					
List of changes from Baseline to next revision					
First Round ADAP					
List of changes from first round to next revision					
Second Round ADAP					
Continued to current design					

List of Assumptions for Surface Radar ADAP Estimates:

1) All parts over $10 unit cost should be identified and prices assigned (with supporting rationale).
   A 5% margin should be added to material cost to account for small part that are not identified.
2) The estimator should add in parts that he knows will be required even if they are not yet depicted on the drawings
3) The estimator should use supporting spreadsheets to calculate the cost of small component parts that are built in house
   This cost should be entered in as a material unit cost.
4) The estimator should identify the rationale behind each line item (unit cost or unit labor)
5) Estimator's judgement in unit costs should not account for more than 10% (target) of the subtotal product cost (labor & material)
6) A ten percent margin should be added to the estimate when the design is in transition
7) A three percent margin should be added to the estimate when the design is ready for release
8) Material lot sizes should be assumed based on the quantity Raytheon currently has under contract
9) Burden should be added to all material at 20% except for quotes from other Raytheon facilities or COEs
10) Costs should roll up to the Manufacturing Cost Level (similar to PCL)
11) Labor unit rates should be incorporated as specified in the following table:

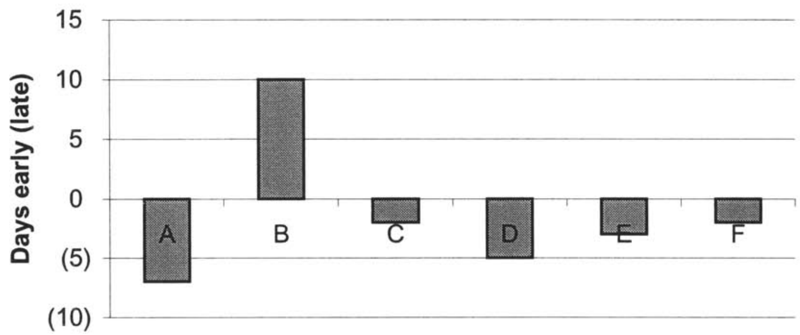
Assembly Quantity	Cost per standard labor hour
1 -- 10	$500.00
11 -- 100	$350.00
101 -- 1000	$250.00
1001 +	$200.00

These costs include a K factor, a factor for direct charge support, an average wage rate, fringe benefits, overhead, and other direct charges

12) The estimates using these processes should be considered as rough order of magnitude (ROM) estimates accurate +/- 10%
13) The estimates and design information should be reviewed by production management in relevant areas

ADAP Schedule Update

Schedule Compliance for ADAP Submittals

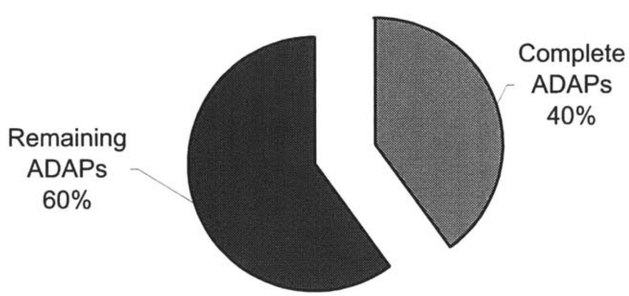


Mean = (2) days
Standard Deviation = 5.96 days

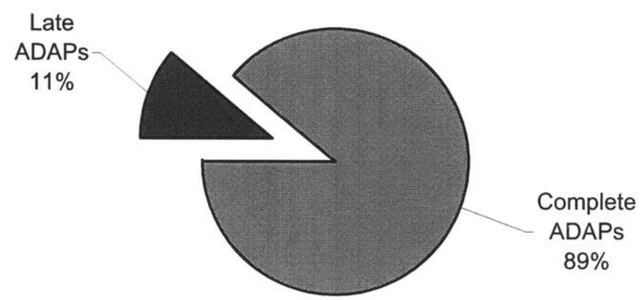
The Top 10:

Item	Planned	Outlook	Responsibility
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			

% of ADAP's Complete vs. Total ADAP's



% of ADAP's Complete vs. Planned Complete



ADAP Cost Performance

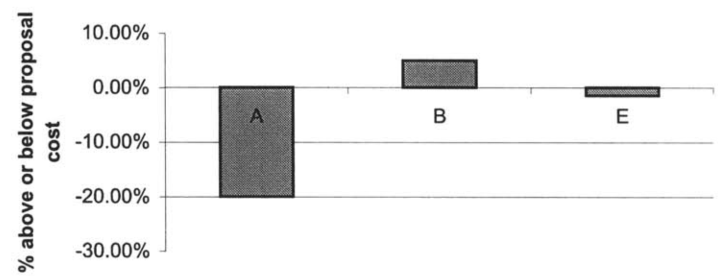
<u>Color Coding:</u>

Blue =	over 15% reduced from proposal
Green =	within +/- 5% of proposal to 15% reduced from proposal
Yellow =	between 5 - 15% increased from proposal
Red =	Unbuildable or greater than 15% increase from proposal

Category A Performance

Item	Proposal Cost	ADAP Estimate	Delta	% Change
A	1,000	800	(200)	-20.00%
B	500	525	25	5.00%
E	350	345	(5)	-1.43%
			Mean =	-5.48%
			Std Dev =	12.98%

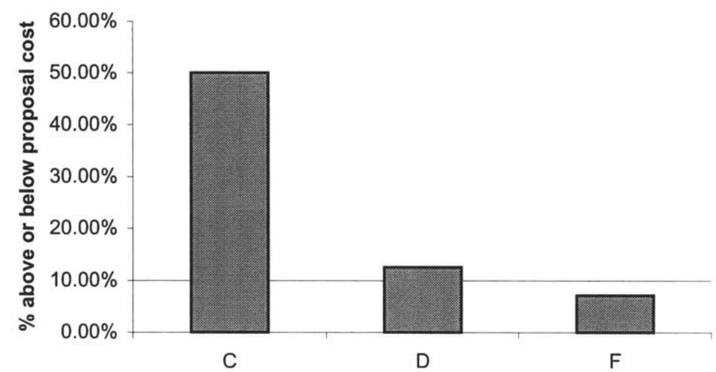
Category A ADAP Performance



Category B Performance

Item	Proposal Cost	ADAP Estimate	Delta	% Change
C	2,000	3,000	1,000	50.00%
D	200	225	25	12.50%
F	700	750	50	7.14%
			Mean =	23.21%
			Std Dev =	23.35%

Category B ADAP Performance



Appendix L

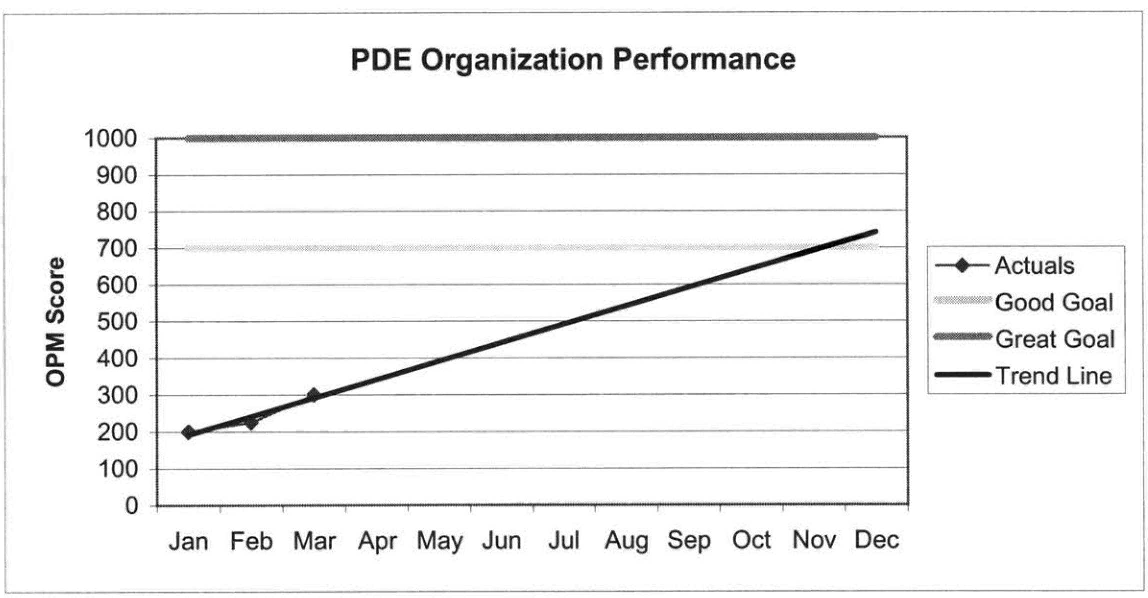
OPM Summaries

PDE Organization OPM

Measurements taken monthly

PDE Training score	PDE Training standard deviation	Facility Books score	Design Checklist score	Production Simulation score	Manufacturing Plan score	Lessons Learned score	ECN Feedback score	FAARF Feedback score	Score	Comments
98%	0%	100%	100%	100%	100%	100%	100%	100%	10	
95%	0%	100%	100%	100%	100%	98%	100%	100%	9	
93%	5%	100%	95%	89%	98%	94%	100%	100%	8	
90%	10%	95%	90%	75%	90%	90%	90%	90%	7	
88%	15%	86%	85%	61%	82%	86%	74%	76%	6	
85%	20%	78%	80%	48%	74%	83%	58%	62%	5	
83%	25%	69%	75%	34%	65%	79%	41%	48%	4	
80%	30%	60%	70%	20%	57%	75%	25%	33%	3	
78%	35%	51%	65%	6%	49%	71%	9%	19%	2	
75%	40%	43%	60%	0%	41%	68%	0%	5%	1	
73%	45%	34%	55%	0%	33%	64%	0%	0%	0	
80%	30%	60%	70%	20%	57%	75%	25%	33%	**Performance**	
3	3	3	3	3	3	3	3	3	**Score**	
20	10	15	15	10	10	10	5	5	**Weight**	
60	30	45	45	30	30	30	15	15	**Value**	

Total Month ending | 3/31 | **300**

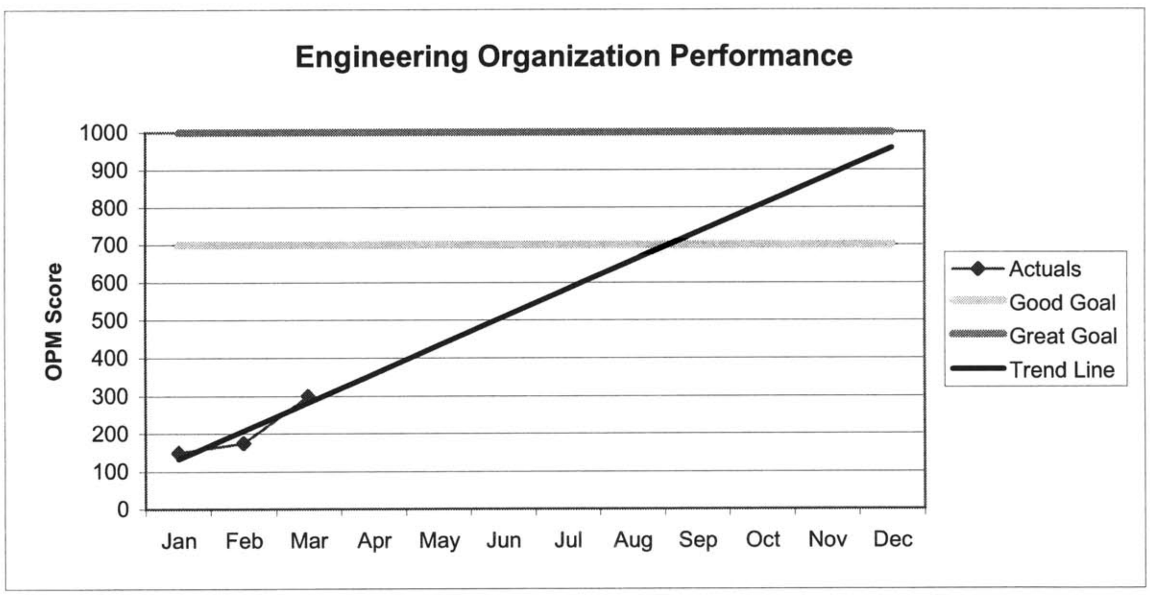


Engineering Organization OPM

Measurements taken monthly

Engineering Training score	Engineering training standard deviation	Designer Feedback score	Change management score	Field Lessons Learned Score	Score	Comments
98%	0%	100%	100%	100%	10	
95%	0%	98%	98%	98%	9	
93%	5%	94%	94%	94%	8	
90%	10%	90%	90%	90%	7	
88%	15%	86%	86%	86%	6	
85%	20%	83%	83%	83%	5	
83%	25%	79%	79%	79%	4	
80%	30%	75%	75%	75%	3	
78%	35%	71%	71%	71%	2	
75%	40%	68%	68%	68%	1	
73%	45%	64%	64%	64%	0	
80%	30%	75%	75%	75%	**Performance**	
3	3	3	3	3	**Score**	
25	15	30	20	10	**Weight**	
75	45	90	60	30	**Value**	

3/31	**300**

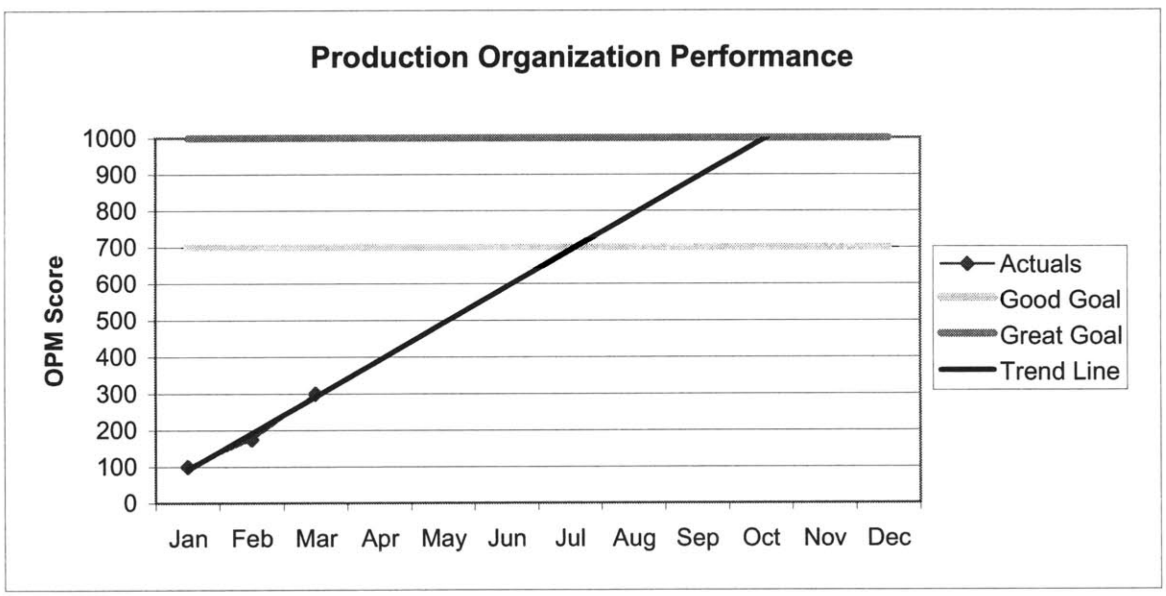


Production Organization OPM

Measurements taken monthly

ITVV production support score	Production empowerment score	Control of Production Processes score	Flexible Tooling score	Score	Comments
100%	100%	100%	100%	10	
100%	99%	100%	98%	9	
100%	94%	96%	94%	8	
90%	90%	90%	90%	7	
75%	86%	84%	86%	6	
61%	81%	77%	82%	5	
46%	77%	71%	78%	4	
31%	73%	65%	74%	3	
16%	68%	58%	70%	2	
2%	64%	52%	66%	1	
0%	59%	45%	61%	0	
31%	73%	65%	74%	**Performance**	
3	3	3	3	**Score**	
30	30	20	20	**Weight**	
90	90	60	60	**Value**	

3/31	**300**

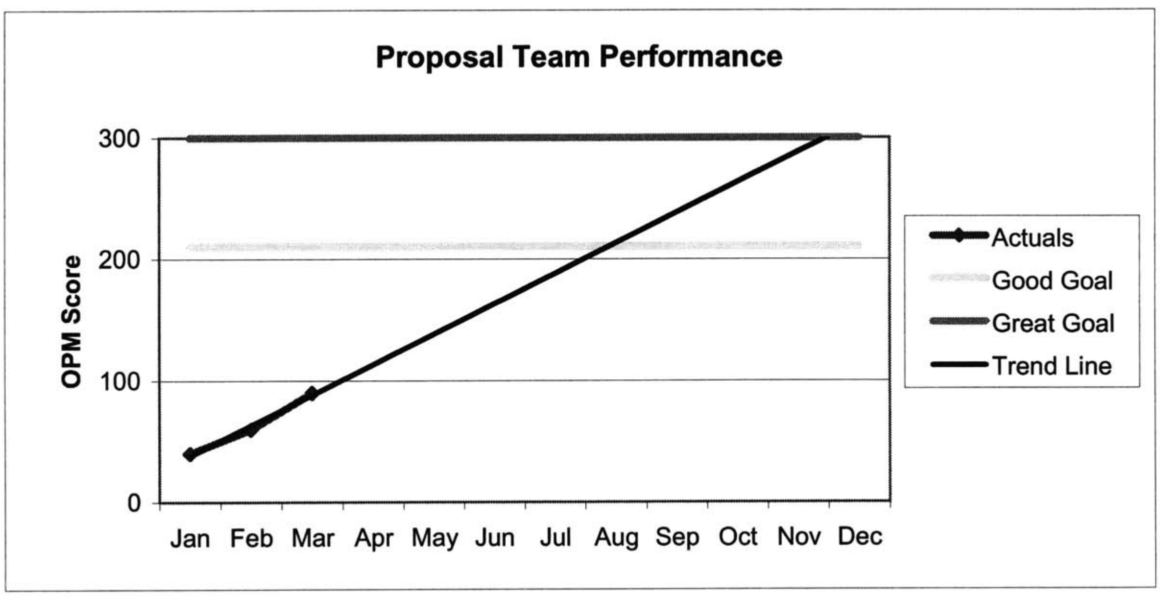


Proposal Team OPM (Naturally Stable Items)

Measurements taken monthly

Funding Score	Customer satisfaction score	Score	Comments
99%	100%	10	
96%	100%	9	
93%	100%	8	
90%	90%	7	
87%	79%	6	
84%	68%	5	
81%	57%	4	
78%	46%	3	
75%	35%	2	
72%	24%	1	
70%	13%	0	
78%	46%	**Performance**	
3	3	**Score**	
20	10	**Weight**	
60	30	**Value**	

Total Month ending	3/31	**90**

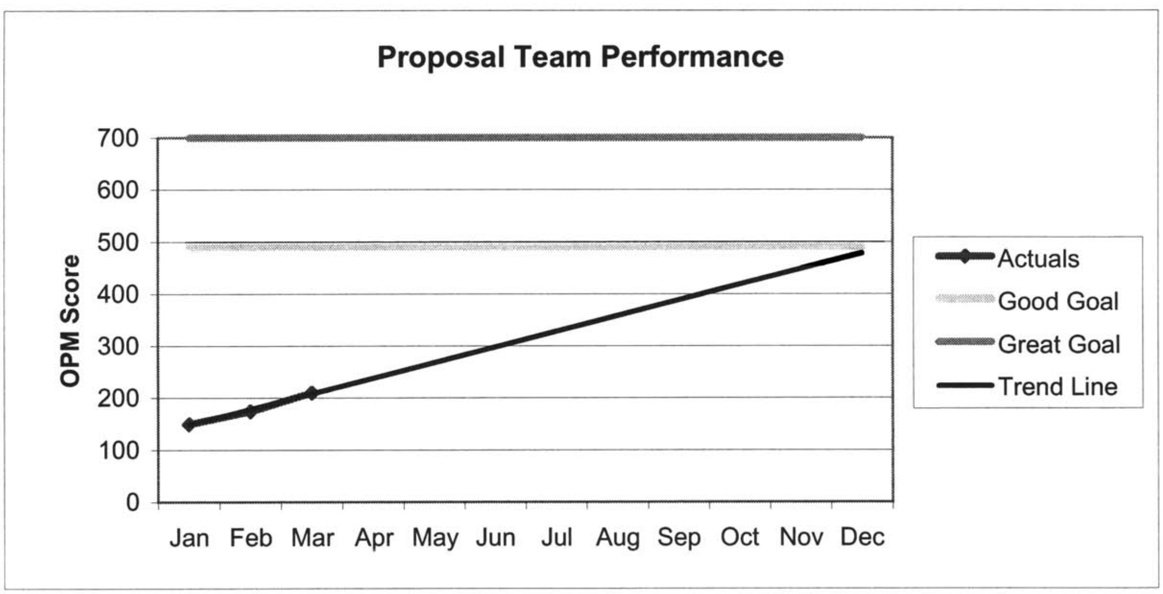


Proposal Team OPM (Naturally Growing Items)

Measurements taken monthly

Lead Systems PDE Involvement Score	Design/Build strategy score	Customer needs identification score	Cost Target Score	Score	Comments
100%	100%	100%	100%	10	
100%	100%	100%	100%	9	
96%	100%	95%	100%	8	
90%	90%	90%	90%	7	
84%	80%	85%	80%	6	
78%	70%	80%	70%	5	
73%	60%	75%	60%	4	
67%	50%	70%	50%	3	
61%	40%	66%	40%	2	
55%	30%	61%	30%	1	
49%	20%	56%	20%	0	
67%	50%	70%	50%	**Performance**	
3	3	3	3	**Score**	
20	10	10	30	**Weight**	
60	30	30	90	**Value**	

Total Month ending	3/31	**210**

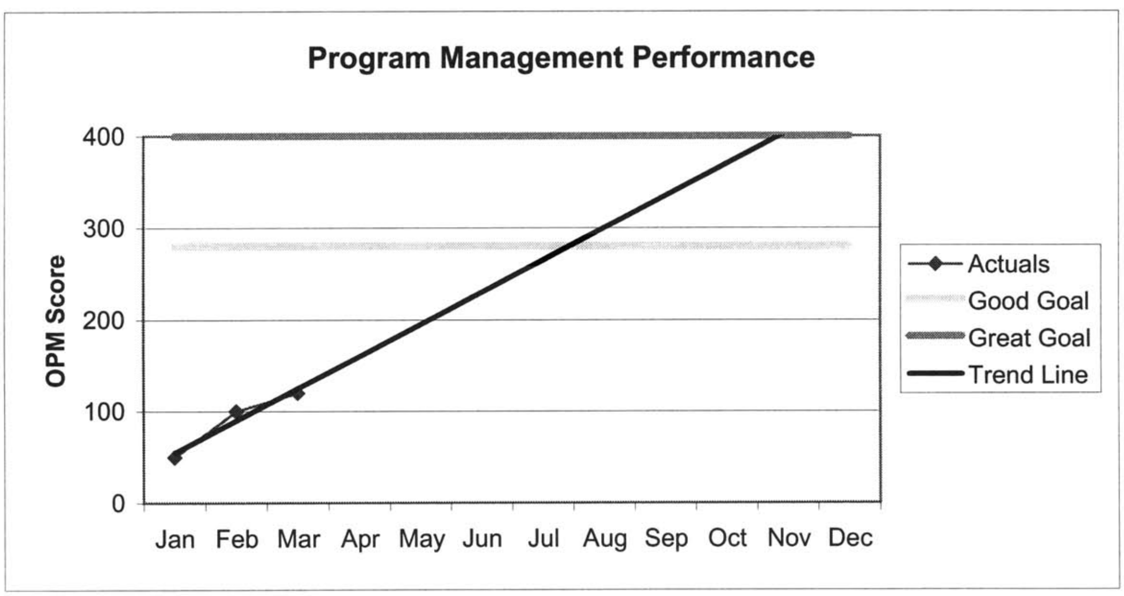


Program Management OPM (Naturally Stable Items)

Measurements taken monthly

Funding Score	Team staffing score	Pre-Production Testing Support	Score	Comments
100%	93%	100%	10	
99%	92%	100%	9	
94%	91%	100%	8	
90%	90%	90%	7	
86%	89%	76%	6	
81%	88%	62%	5	
77%	87%	48%	4	
72%	86%	34%	3	
68%	85%	20%	2	
63%	84%	6%	1	
59%	84%	0%	0	
72%	86%	34%	**Performance**	
3	3	3	**Score**	
15	15	10	**Weight**	
45	45	30	**Value**	

Total Month ending	3/31	**120**

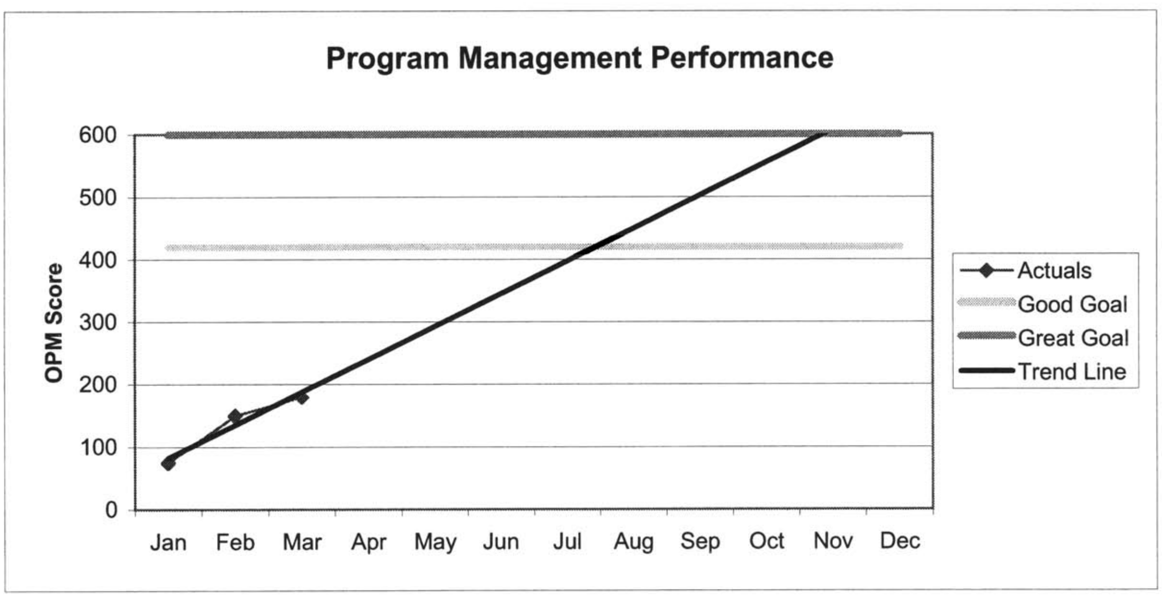


Program Management OPM (Naturally Growing Items)

Measurements taken monthly

Facilitation of cross-team communication score	Cost targetting score	Quality targeting score	Sourcing Definition Score	Score	Comments
100%	100%	100%	100%	10	
100%	100%	100%	100%	9	
100%	100%	100%	100%	8	
100%	100%	100%	90%	7	
89%	98%	100%	75%	6	
79%	97%	100%	60%	5	
68%	95%	100%	45%	4	
57%	94%	100%	29%	3	
46%	92%	100%	14%	2	
36%	91%	100%	0%	1	
25%	89%	100%	0%	0	
57%	94%	100%	29%	**Performance**	
3	3	3	3	**Score**	
10	20	20	10	**Weight**	
30	60	60	30	**Value**	

Total Month ending	3/31	**180**

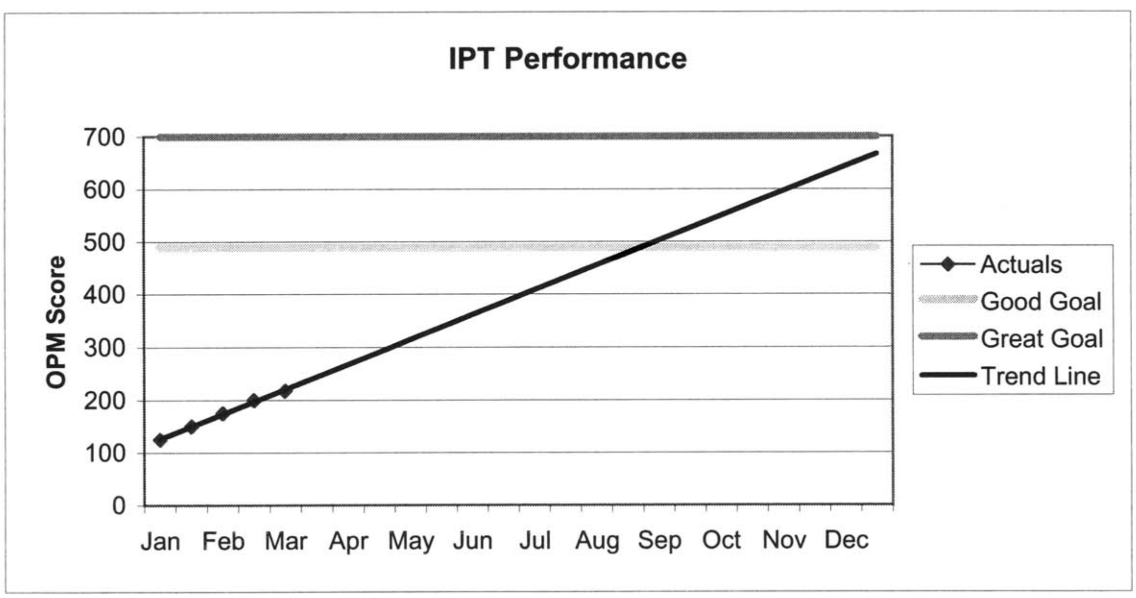


IPT OPM (Naturally Stable Items)

Measurements taken every two weeks

Team Building Rating	CE Efficiency	Cost target score	Quality target score	Design Cycle Time score	Product Commonality score	LCC score (Target/ Actual)	Test Requirements Development score	Customer satisfaction score	Score	Comments
100%	111%	100%	100%	100%	100%	93%	118%	100%	10	
100%	109%	100%	100%	100%	94%	92%	112%	100%	9	
97%	107%	100%	100%	100%	85%	91%	106%	96%	8	
90%	105%	100%	100%	90%	75%	90%	100%	90%	7	
83%	103%	96%	95%	80%	65%	89%	94%	84%	6	
77%	101%	93%	90%	69%	56%	88%	88%	79%	5	
70%	99%	89%	85%	59%	46%	87%	82%	73%	4	
63%	98%	86%	80%	48%	37%	86%	76%	67%	3	
57%	96%	82%	75%	38%	27%	85%	70%	61%	2	
50%	94%	79%	70%	27%	18%	84%	64%	56%	1	
43%	92%	75%	65%	17%	8%	83%	58%	50%	0	
63%	98%	86%	80%	48%	37%	86%	76%	67%	**Performance**	
3	3	3	3	3	3	3	3	3	**Score**	
10	5	10	10	10	5	10	2.5	10	**Weight**	
30	15	30	30	30	15	30	7.5	30	**Value**	

Two week period ending	3/31	**217.5**

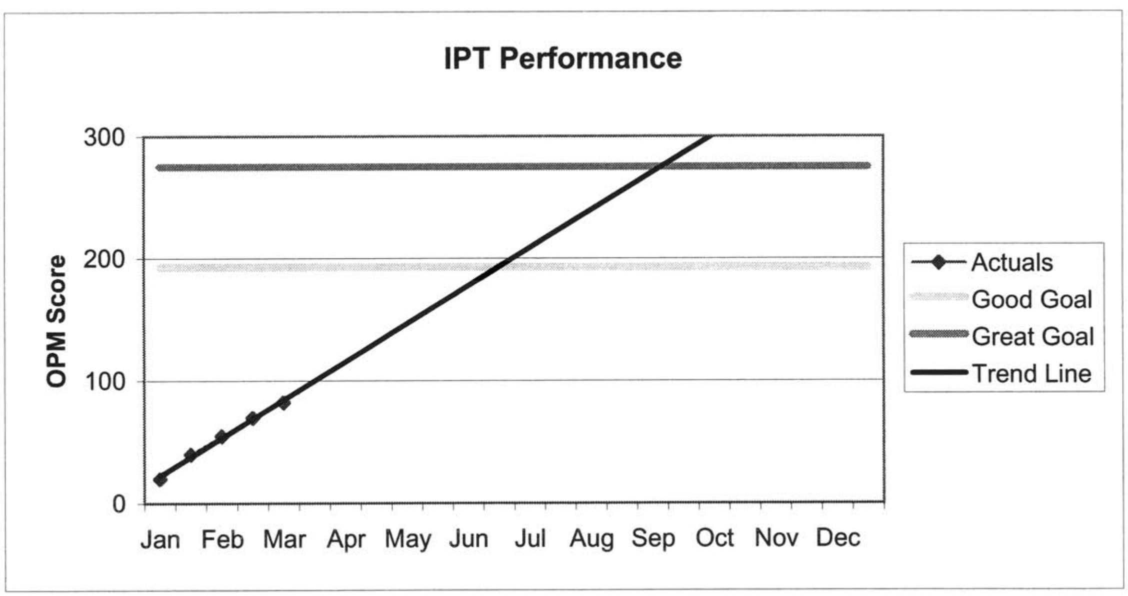


IPT OPM (Naturally Growing Items)

Measurements taken every two weeks

Risk Readiness score	Product/ Process Integration score	Measuring/Publicizing score	ITVV preparedness/ proactiveness score	Score	Comments
100%	100%	100%	100%	10	
100%	100%	100%	98%	9	
99%	99%	99%	94%	8	
85%	90%	90%	90%	7	
71%	81%	81%	86%	6	
57%	72%	72%	82%	5	
43%	63%	63%	78%	4	
29%	54%	54%	74%	3	
15%	45%	45%	70%	2	
1%	36%	36%	66%	1	
0%	27%	27%	62%	0	
29%	54%	54%	74%	**Performance**	
3	3	3	3	**Score**	
10	10	5	2.5	**Weight**	
30	30	15	7.5	**Value**	

week period ending	3/31	**82.5**



Appendix M

Matrix of Co-Sponsors

Matrix of Responsible Personnel for all Metrics Phases (Rev. K)

Category	Metric	Responsible Person (1)		Actionee (2)	Implementation Phase
		Primary	Secondary		
Ideal Processes Matrix	Ideal Processes vs. Actual Processes Comparison	R. Filosa	E. Verryt	G. Sannicandro	Phase 1
Team Member Preparedness Metrics	Overall Preparedness rating (PDEs)	R. Hayes	K. Johnson	PDE & Their Supervisor	Phase 1
	Overall Prep. rating (Engineers)	E. Aaronson	R. Filosa	Eng. & Their Supervisor	Phase 1
	Overall Preparedness rating (Accessible Team)	G. Beninati	J. O'Sullivan	Ind. & Their Supervisor	Phase 1
PDE Organization Performance Metrics	PDE Training Score	R. Hayes	K. Johnson	PDE Manager	Phase 1
	Design Checklists Score	G. Beninati	R. Hayes	Hardware PDEs	Phase 2
	Facility Books Score	G. Beninati	G. Sannicandro	PDE Staff	Phase 3
	Production Simulation Score	G. Beninati	G. Sannicandro	PDE Staff	Phase 3
	Manufacturing Plan Score	G. Beninati	J. Hofmann	PDE Staff	Phase 3
	Lessons Learned Score	K. Johnson	G. Sannicandro	Lead Systems PDE	Phase 3
	ECN Feedback Score	K. Johnson	G. Beninati	Lead Systems PDE	Phase 3
	FAARF Feedback Score	D. Martino	R. Hayes	PDE Staff	Phase 2
Engineering Organization Performance Metrics	Engineer Training Score	R. Filosa	E. Aaronson	Engineering Supervisor	Phase 1
	Designer Feedback Score	R. Filosa	E. Aaronson	Engineering Supervisor	Phase 2
	Change Management Score	R. Filosa	E. Aaronson	Engineering Manager	Phase 3
	Field Lessons Learned Score (new)	R. Filosa	E. Aaronson	Engineering Manager	Phase 3
Production Performance Metrics	ITVV Production Support Score	J. Elwood	G. Beninati	Prototype area manager	Phase 2
	Production Empowerment Score	J. Elwood	J. Wagner/ J. McReynolds	Prod. Staff Assistant	Phase 3
	Control of Production Processes Score	J. Elwood	J. Wagner/ J. McReynolds	Prod. Staff Assistant	Phase 3
	Flexible Tooling Score	J. Elwood	H. R. Schuler	Six Sigma Team	Phase 3
Proposal Team Performance Metrics	Lead Systems PDE Involvement Score	K. Johnson	M. Kizner	Lead Systems PDE	Phase 2
	Funding Score	K. Johnson	M. Kizner	Lead Systems PDE	Phase 2
	Design/Build Strategy Score	E. Aaronson	K. Johnson	Proposal Lead	Phase 2
	Customer Needs Identification Score	E. Aaronson	K. Johnson	Proposal Lead	Phase 2
	Customer Satisfaction Score	E. Aaronson	K. Johnson	Proposal Lead	Phase 2
	Cost Target Score	K. Johnson	R. Hinman	Lead Systems PDE	Phase 2

Matrix of Responsible Personnel for all Metrics Phases (Rev. K)

Category	Metric	Responsible Person (1) Primary	Responsible Person (1) Secondary	Actionee (2)	Implementation Phase
Program Management Performance Metrics	Funding Score	K. Johnson	G. Beninati	Lead Systems PDE	Phase 1
	Cost Targeting Score	K. Johnson	R. Hinman	Lead Systems PDE	Phase 1
	Quality Targeting Score	R. Hayes	K. Johnson	Lead Systems PDE	Phase 1
	Team Staffing Score	E. Aaronson/PMO	K. Johnson	Program Lead	Phase 2
	Facilitation of Cross-Team Communication Score	K. Johnson	G. Sannicandro	Program Lead	Phase 2
	Sourcing Definition Score	E. Aaronson	J. Passanisi/ K. Johnson	Lead Systems PDE	Phase 2
	Pre-production Testing Support Score	E. Verryt	E. Aaronson	Program Lead	Phase 2
IPT Performance Metrics	CE Efficiency	K. Johnson	G. Beninati	Team Leader	Phase 1
	Cost Target Score (ADAP)	K. Johnson/R. Hayes	D. Dagavarian	Hardware/Lead Sys. PDE	Phase 1
	Quality Target Score (PCAT)	R. Hayes	G. Beninati	Hardware PDE	Phase 1
	Design Cycle Time Score	R. Filosa	E. Aaronson	Team Leader	Phase 1
	Life Cycle Cost Score	E. Aaronson	K. Johnson	Team Leader	Phase 2
	Team Building Rating	E. Aaronson/PMO	K. Johnson	Team Leader	Phase 2
	Risk Readiness Score	E. Aaronson	K. Johnson	Team Leader	Phase 2
	Product/process integration score	J. Hofmann	R. Hayes	Hardware PDE	Phase 2
	Measuring/publicizing score	K. Johnson	G. Sannicandro	Team Leader	Phase 2
	ITVV Preparedness/Proactiveness Score	G. Beninati	R. Hayes	Hardware PDE	Phase 2
	Test Requirements Development Score (new)	J. Glover	E. Aaronson/ M. Segal	Manufacturing Test Staff	Phase 1
	Product Commonality Score	E. Aaronson	K. Johnson/ R. Hayes	Hardware PDE	Phase 3
	Customer Satisfaction Score	E. Aaronson	K. Johnson	Team Leader	Phase 3
OPM Summaries	Summaries by Category	K. Johnson	J. O'Sullivan	Automatic	As Available

(1) Process expert and/or person responsible for ensuring that recommended processes are used and metric is maintained
(2) Person responsible for maintaining metric

Accepted for Piloting Designated Not Designated

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