A Comparison of Earned Value Management and Earned Schedule as Schedule Predictors on DoD ACAT I Programs

THESIS

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Abstract

Earned Schedule, since it was introduced by Walt Lipke in 2003, has been studied extensively in a variety of different fields and on programs of all sizes. However, Earned Schedule's viability as an extension of Earned Value Management (EVM) in Major Defense Acquisition Programs (MDAP) has yet to be effectively answered. The first aspect of this research explores the breadth of Earned Schedule's adoption by the System Program Offices (SPO) of the United States Air Force. The second phase of this research explores whether Earned Schedule is a more accurate and timely schedule predictor than the EVM technique currently employed by the United States Department of Defense (DoD). A series of five descriptive statistical tests were conducted on the Earned Value data for 64 Acquisition Category (ACAT) I MDAP's. This research finds Earned Schedule to be a more timely and accurate predictor than Earned Value Management.

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The completion of this thesis effort is dedicated to my loving wife and our beautiful daughter.

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Kevin T. Crumrine

Table of Contents

Page

List of Figures

Page

Page

Page

Page

Page

Page

Page

Page

List of Tables

List of Equations

Page

A Comparison of Earned Value Management and Earned Schedule as Schedule Predictors on DoD ACAT I Programs

I. Introduction

General Issue

One would be hard pressed to open the *Wall Street Journal* or the *New York Times* on any given day without encountering a number of articles related to the broad financial cuts the Department of Defense (DoD) will experience over the next decade. In the financially lean environment under which the DoD now operates, effective management of a program's cost and schedule performance has never been more vital. However, the DoD has long struggled with cost overruns and schedule delays on major acquisition projects. Earned Value Management (EVM) has been the premier method of program management and program cost forecasting within the DoD since its inception in the 1960s. EVM has long been hailed for its ability to identify to the decision-maker whether a program is going to be over cost or over schedule. However, EVMS's merit of forecasting schedule overages has been questioned in recent years (Lipke, 2003: 1). The predominant shortcoming of EVM is how it measures schedule performance: it quantifies schedule overages in terms of dollars ($), rather than in terms of time. This means of measurement is ambiguous and potentially confusing to program managers. To overcome this problem, a new schedule measurement technique, Earned Schedule (ES) was developed (Lipke, 2003: 1). Earned Schedule rectifies the ambiguities of traditional EVMS schedule analysis by expressing schedule measurements in terms of time. It has been argued that the critical development of ES provides program managers the predictive tool needed to determine project completion dates using EVM data.

Background

While the origins of Earned Value Management can be traced to the factory floor during the industrial revolution of the 1800s, it was introduced in its current form to the agencies of the U.S. government in 1967 as the Cost/Schedule Control Systems Criteria (C/SCSC). EVM has been predominantly used in program management within the federal government, but its use in the private sector has grown exponentially in the last 20 years. EVM has been widely lauded for its ability to improve cost, schedule and technical performance of a project; however, its limitations in its ability to predict schedule overruns are widely recognized. Use of EVM in commercial industry under the C/SCSC was nearly non-existent due to the overheads imposed by stiff regulations, but its use increased when the C/SCSC regulations were dropped in favor of the more flexible Earned Value Management System (EVMS) (Anbari, 2003: 12).

There are three parameters that are the basis upon which traditional earned value analysis is built. The first of these parameters is the Budgeted Cost of Work Scheduled (BCWS), also known as the Planned Value (PV) in commercial industry. BCWS is a "time-phased budget baseline . . . that can be viewed as the value to be earned as a function of project work accomplishments up to a given point in time" (Anbari, 2003: 13). More informally, it is the amount of work, measured in dollars, planned for completion during a measured period of time. The second parameter is the Budgeted Cost of Work Performed (BCWP), also known as the Earned Value (EV) in commercial industry. BCWP is the "amount budgeted for performing the work that was accomplished by a given point in time" (Anbari, 2003: 13). More simply, BCWP is the value of the work that has been completed. The final EVMS parameter is the Actual Cost of Work Performed (ACWP), known simply as Actual Cost (AC) in industry. ACWP is the cost in dollars of all the work that has been performed on a project (Anbari, 2003: 13). To more clearly illustrate these EVMS concepts, Table 1 gives an example of two lines of a standard Work Breakdown Structure (WBS). For WBS Package 1.1, the BCWS is $100K, while only $85K worth of work has actually been completed. Since the ACWP is $95K, costs have overrun. Additionally, because the value of work performed is less than the amount of work that has been scheduled for completion, this project is also behind schedule. For WBS Package 1.2, the BCWS is equal to the BCWP, indicating that all work has been completed on time. With the ACWP coming in below the value of the work performed, this project has been completed not only on time, but also under budget.

Table 1. EVMS Parameter Example

	BCWS ($K)	BCWP ($K)	ACWP ($K)
WBS Package 1.1	100	85	95
WBS Package 1.2	50	50	48

Program managers utilize two metrics in the traditional EVMS system to ascertain the status of a project's schedule. These traditional schedule specific metrics used under the umbrella of EVMS are Schedule Variance (SV($)) and the Schedule Performance Index in terms of dollars (SPI[$]). Schedule variance tells us how late our project is, but does so in terms of dollars. If a project is $100K late, how late is it in terms of days, months, or years? SV($) can't give us this answer, and for this reason, proponents of Earned Schedule have been sharply critical of it. The second metric used to measure schedule under EVMS is the Schedule Performance Index ($). SPI($), according to Corovic, is "a ratio between [BCWP] and [BCWS] at the end of the project, if the project has delivered all what was planned, [BCWP] and [BCWS] must be equal" (Corovic, 2006-2007: 2) Since this ratio always regresses to 1.0, there is little value in this ratio after a project reaches a certain point. Analysis has shown that this point is at about 2/3 completion of the project (Lipke, 2003: 1).

Earned Schedule was developed in 2003 by Walt Lipke in direct response to the aforementioned EVMS schedule calculation shortcomings. Earned Schedule uses the same data collected for the earned value calculations, but focuses on giving the program manager more useful information: schedule analysis metrics delivered in terms of time, rather than dollars, as well as the ability to predict if, and when, a project may go over schedule.

Problem Statement

The current EVMS metrics used for schedule are not effective predictors over the life of a program (Lipke, 2003: 1). Earned Schedule (ES) has been developed, and consequently studied significantly over the last decade, but a thorough and conclusive application to Acquisition Category I (ACAT I) Major Defense Acquisition Programs (MDAP) has yet to be accomplished. This paper will research whether ES is a more accurate predictor of schedule overruns than the current metrics used, whether it can predict schedule overruns earlier in the life of a program than the current schedule metrics, and how accurately ES can predict the final completion of a project on ACAT I DoD acquisition programs.

Methodology

This research will include a comprehensive literature review of all relevant works in the fields of earned value management, earned schedule, and their application to program management. Quantitatively, a comparison of means (paired t-test) will be conducted on the contracts for 64 different ACAT I acquisition programs to determine if there is a statistical difference between Earned Schedule and Earned Value Management. If there is a conclusive difference between the two techniques, a series of tests will be conducted on the data to determine which schedule analysis method offers more valuable information to the program manager. This analysis will include the current metrics used under the umbrella of Earned Value Management compared to the new metrics derived under Earned Schedule.

Research Questions

The following research questions will be investigated:

1.) To what extent is Earned Schedule currently utilized in Air Force ACAT I acquisition programs?

2.) Does Earned Schedule provide more accurate schedule predictions than traditional DoD methods?

3.) Does Earned Schedule provide more timely schedule predictions than traditional DoD methods?

Scope/Limitations

The scope of this research is limited to Acquisition Category I (ACAT I) programs from the former Aeronautical Systems Center (ASC) located at Wright-Patterson AFB, OH. The proximity of this product center allowed for interaction with the specific system program offices (SPO).

One limitation to this research is that only ACAT I programs from a single product center are studied. Another potential limitation of this research is its applicability: the data come from exclusively DoD sources, rendering the possibility that the results are germane only to DoD projects.

Preview

With the crippling fiscal environment the DoD is currently experiencing, coupled with austere budget projections for the foreseeable future, acquisition program managers need to vastly improve on delivering an on-time product. However, as decision makers, program managers are only as good as the information they are given by their analysts. The overall objective of this research is to identify the inadequacies of the current metrics used to provide schedule analysis to program managers, as well as to establish the value of earned schedule metrics as a more reliable toolset for the decision maker, through a comparison of 64 contracts. With their analysts able to provide more reliable predictions of schedule overages, as well as more accurate forecasts of project completion dates, program managers will be far more informed when making decisions in a financially lean DoD environment.

Chapter 2 of this thesis provides a review of relevant literature and previous research in the fields of earned value management and earned schedule. Chapter 3 discusses the methodology used to conduct this research. Chapter 4 discusses the results of this research. Chapter 5 wraps up the research through discussion of the potential impact the results will have on DoD program management, and offers ideas of further research to explore in the future.

II. Literature Review

Introduction

This literature review evaluates and discusses the pertinent theory and previous research conducted in the fields of Earned Value Management and Earned Schedule. It first examines broadly the importance of program management within the Department of Defense. It then overviews the Earned Value Management System (EVMS) by offering a historical perspective, defining the key terms and components, explaining how EVMS is used in the DoD today, and outlining the inherent flaws of using EVMS for schedule management. Next, it introduces Earned Schedule (ES), explains the basic theory, discusses its current use in program offices, and outlines the suggested advantages of using ES over EVMS for schedule analysis using EVM data. The chapter concludes with a discussion of previous research efforts related to ES application.

Importance of Program Management & Implementation in the DoD

In the DoD's Quadrennial Defense Review Report published in February 2010, one of the highlighted topics was "Reforming How we do Business." The pressing need to improve how we acquire defense systems was summarized by the following: "Another pressing institutional challenge facing the Department is acquisitions—broadly speaking, how we acquire goods and services and manage the taxpayers' money. Today, the Department's obligation to defend and advance America's national interests by, in part, exercising prudent financial stewardship continues to be encumbered by a small set of expensive weapons programs with unrealistic requirements, cost and schedule overruns, and unacceptable performance" (Department of Defense, 2010: 75-76). Of special interest to this research, the report goes on to say that, "to prepare the Department for the complex threats that will surely emerge in the future, we need to make our 'deliberate' processes more agile and capable of responding to urgent needs. During periods of conflict, in the traditional risk areas of cost, schedule and performance, 'schedule' often becomes the least acceptable risk" (Department of Defense, 2010: 81). Undoubtedly, the need for effective program management for both cost and schedule has never been more vital. According to a March 2011 GAO study, "half of the DoD's major defense acquisition programs do not meet cost performance goals" (GAO, 2011: 3). Further, "GAO continues to find that newer programs are demonstrating higher levels of knowledge at key decision points, but most are still not fully adhering to a knowledge-based acquisition approach, putting them at higher risk for cost growth and schedule delays" (GAO, 2011: 3). This same study noted that "programs that modified key performance requirements after development start experienced higher levels of cost growth and longer delays in delivering capabilities" (GAO, 2011: 14). Specifically for schedule, programs who changed key performance requirements experienced "three to five times greater schedule delays compared to programs with unchanged requirements" (GAO, 2011: 14-15).

These studies demonstrate the importance of sound program management in major defense acquisition programs. Program management is important because the DoD operates with American taxpayer money: there are no built-in incentives to trim costs for profit, which puts the DoD at a competitive disadvantage. Program management can help the DoD manage all the cost, schedule and technical performance aspects of large DoD acquisition programs (Langhals interview). Cost overruns and schedule delays are inevitable in its absence. The question then becomes what management technique(s) are best suited for DoD acquisition programs.

There are literally dozens of potential approaches to program management. The most common approaches are outlined below. In addition to the brief summary of the techniques, arguments are made for why the DoD chose the technique(s) they did, and how each approach adds value in the DoD context.

Cost Engineering - The American Association of Cost Engineers (AACE) defines cost engineering as "that area of engineering practice where engineering judgment and experience are utilized in the application of scientific principles and techniques to the problems of cost estimation, cost control and profitability" (Clark and Lorenzoni, 1997: 1). Projects that can be managed through cost engineering "can cover anything from a 2-day engineering effort to resolve a minor technical problem to the present day 'super projects'" (Clark and Lorenzoni, 1997: 2). Cost engineering has "application regardless of industry . . . and size" (Clark and Lorenzoni, 1997: 1). Cost Engineering is an extremely effective management technique, but is not specifically used for major defense acquisition programs. Cost engineering primarily focuses on profitability of a project, but this focus is not consistent with DoD priorities. Additionally, cost engineering is an effective tool for managing cost but doesn't address schedule and technical performance needed for management of DoD programs.

Critical Path Method - The Critical Path Method (CPM) is a program management tool that was originally developed in the 1950's by the United States Navy. The CPM is "a mathematically based algorithm for scheduling a set of project activities" (Santiago & Magallon, 2009). It is most effective for a project with "interdependent activities" and is "commonly used with all forms of projects, including construction, software development, research projects, product development, engineering, and plant maintenance, among others" (Santiago & Magallon, 2009). To effectively utilize the CPM, it is essential to provide a Work Breakdown Structure (WBS), the "list of all activities required to complete the project" (Santiago & Magallon, 2009), as well as to outline the amount of time required to complete each task of the WBS. CPM calculates "the longest path of planned activities to the end of the project" and "determines the critical activities on the longest path" (Santiago & Magallon, 2009). The benefits to using CPM is that it provides a "clear picture of the scope of a project that can be easily read and understood, it provides a vehicle for evaluating alternative strategies and objectives, [shows] the interconnections among the job and pinpoints the responsibilities of the various operating departments involved" (Kelley & Walker, 2009: 162). Current DoD practice in schedule analysis relies heavily on the critical path method and the integrated master schedule (IMS). Any schedule analysis tool used for DoD major acquisition programs in the future must address the critical path.

Critical Chain Project Management – Critical Chain Project Management (CCPM) "emphasizes focusing on the project schedule . . . [and] reduces project changes and the major course of project cost overruns by improving schedule performance"

(Leach, 1999: 39). CCPM specifies the critical chain, rather than the critical path, as the project constraint . . . [it] includes resource dependencies, and does not change during project execution" (Leach, 1999: 39). CCPM "seeks to change project team behavior, encouraging reporting early completion of activities and elimination of multitasking" (Leach, 1999: 39). The CCPM project planning and control process "directly addresses uncertainty and variation in project activity duration. It helps eliminate desirable behaviors fostered by using schedule dates and milestones within a project plan. It focuses on developing and managing project performance to meet or exceed reduced activity times, thereby reducing overall project duration" (Leach, 1999: 39). While CCPM doesn't directly address cost performance, it is an effective project management technique for schedule planning. Accurately predicting schedule overages in a timely manner gives the program manager the tools s/he needs to achieve long term project cost savings. (Leach, 1999: 44-45).

Earned Value Management – Earned Value Management is "the process of defining and controlling the project so that defined objectives are met. The controlling aspect includes scope control, schedule control, and budget control" (Humphreys, 2011: 32). Earned Value is "a management technique that relates resource planning to schedule and technical performance requirements" (Rose, 9). Earned Value Management is "an industry standard method of measuring a project's progress at any given point of time, forecasting its completion date and final cost, and analyzing variances in the schedule and budget as the project proceeds. It compares the planned amount of work with what has actually been completed, to determine if the cost, schedule and work accomplished are progressing in accordance with the plan" (Lessard and Lessard, 2007: 45).

Earned Value Management has shown its merit as an effective management technique, especially for cost performance. A study of over 700 DoD acquisition programs shows that EVM, when applied early in a programs life, can be very effective at predicting cost overruns over the life of a program. Additional benefits attributed to EVM are that "it imposes discipline on the resource planning process through the development of work and planning packages, provides a disciplined, standardized approach to measurement and terminology, ties cost and schedule performance to technical accomplishment of work, and provides and objective analysis of performance" (Rose, 11). As the primary tool for DoD program management, EVM is a proven method to accurately capture a snapshot in time, and delivers very understandable measurements. There is not a lot of interpretation needed, and is applicable to any kind of program (Langhals Interview).

EVM has demonstrated its utility as a program management tool through a long history of DoD acquisition programs. However, because it is time-consuming and costly to implement, it is only useful for certain types of programs. Programs where EVM is most useful are those with defined deliverables and products, programs with longer durations, programs with strict budget limits (or Firm Fixed Price contracts), and programs with a single contract encompassing all or most of the effort (Rose, 15). Currently, EVM is a required tool for all DoD programs that exceed $20 million (Rose, 15).

While there are numerous benefits to using EVM, there are also drawbacks to the technique: a predominant shortcoming to EVM is that it can easily be manipulated. EVM is good for monitoring a program, but it's not very useful for planning. There are techniques that are better for certain aspects of a program, but they aren't as easily traceable over time as is EVM (Langhals Interview).

Weighing the benefits and drawbacks of each of the different program management techniques, the DoD chose to use Earned Value Management as its preferred approach for managing major defense acquisition programs. Given its prominence in the DoD, a more detailed history of EVM, as well as an introduction to EVM's application to DoD programs follows.

Earned Value Management System

In 1967, the DoD issued a directive that "imposed 35 Cost/Schedule Control Systems Criteria (C/SCSC) on all private industrial firms that wished to participate in future major government systems" acquisition programs. The effect of this mandate was the formalization of the "earned value concept of cost and schedule management" (Fleming and Koppelman, 1998: 19). The United States Department of Defense has been the standard bearer for other countries to implement earned value management techniques into their major government acquisitions. Earned Value Management can give the program manager "an early warning signal that the project is headed for a cost overrun unless immediate steps are taken to change the spending plan" (Fleming and Koppelman, 1998: 19-20). While most organizations feel they have a cost management system in place, "more than 99% of projects in the world do not employ the earned value management concept. Instead, to monitor costs, they merely compare their spend plan to their actual costs" (Fleming and Koppelman, 1998: 20). In recent years, C/SCSC has evolved into the Earned Value Management System (EVMS). EVMS has reduced the number of criteria from 35 to 32, but is still a complex, and heavily regulated governing approach with substantial bureaucracy and far too many non value-added requirements (Fleming and Koppelman, 1998: 20).

Earned Value Management is "a technique that can be applied, at least in part, to the management of all capital projects, in any industry, while employing any contracting approach" (Fleming and Koppelman, 2002: 91). EVMS is a performance management tool that integrates cost, schedule and technical performance (Lipke, 2003: 1), and has shown to be a reliable tool for measurement as early as the 15% completion point of a project (Fleming and Koppelman, 2002: 91). While Earned Value Management has a proven record as an effective tool for estimating a program's cost performance, its ability to predict schedule overruns has come into question.

Under EVMS, there are three measurements taken and two major metrics tracked to perform a schedule analysis on a project. The three measurements are the Budgeted Cost of Work Scheduled (BCWS), the Budgeted Cost of Work Performed (BCWP) and the Actual Cost of Work Performed (ACWP). A graphical display of the Earned Value measurements, along with other valuable EVM data, is illustrated in Figure 1.

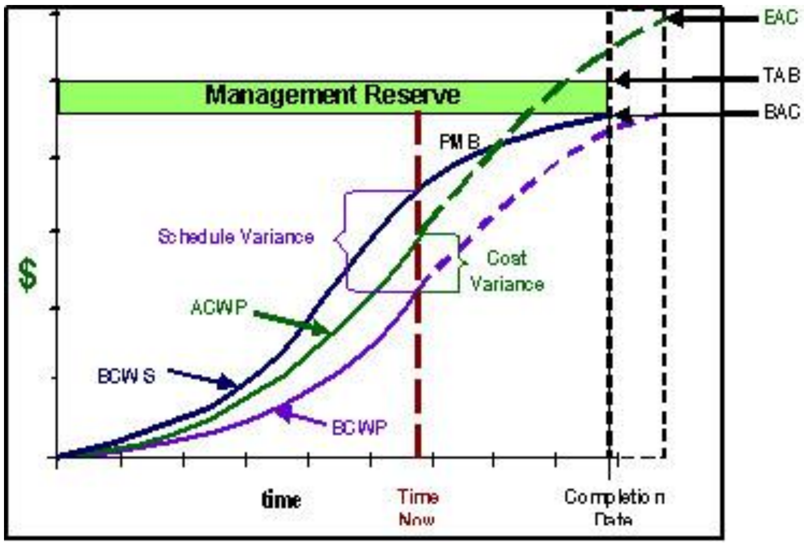

Figure 1: EVM Measurements (Defense Acquisition University, 2012)

BCWS is a "time-phased budget baseline . . . that can be viewed as the value to be earned as a function of project work accomplishments up to a given point in time" (Anbari, 2003: 13). In Figure 1 above, the BCWS is also shown as the Performance Management Baseline (PMB). The PMB is "a time-phased budget plan for accomplishing work against which contract performance is measured" (EVMIG, 2006: 103). BCWP is the "amount budgeted for performing the work that was accomplished by a given point in time" (Anbari, 2003: 13). The BCWP is the earned value of the completed work scheduled by the PMB. ACWP is the cost in dollars of all the work that has been performed on a project (Anbari, 2003: 13). There are three other values illustrated in Figure 1: the Estimate at Complete (EAC), the Total Allocated Budget (TAB) and the Budget at Complete (BAC). The EAC is defined as "the estimated total cost for all authorized work. [It is] equal to the sum of actual costs to date (including all allocable indirect costs), plus the estimated costs to completion" (EVMIG, 2006: 102). The TAB is defined as “the sum of all budgets allocated to the contract. TAB consists of the PMB and all management reserve. [It] reconciles directly to the contract budget base” (EVMIG, 2006: 104). The BAC is described as “ the sum of all performance budgets established for the contract. BAC is a term that may also be applied to lower levels, such as the PMB or at the control level account” (EVMIG, 2006: 100).

Using these measurements, two schedule indicators are tracked to measure project performance. Schedule Variance ($) (SV ($)) is the computed cost difference of BCWP – BCWS, as seen in Figure 1. SV($) is “a measure of the conformance of actual progress to the schedule” (Anbari, 2003: 14). Schedule Variance can be defined more simply as “what got done minus what was planned” (Handshuh, 2006). An SV($) value greater than zero indicates that the program is ahead of schedule. Conversely, an SV($) value less than zero designates that a program is behind schedule. In addition to SV($), the Schedule Performance Index (SPI($)) is a ratio that measures efficiency for how well the project progresses relative to planning” (Anbari, 2003: 15). The ratio is calculated by dividing the BCWP by the BCWS (BCWP/BCWS), and details to the user how much work has been done, divided by how much work was planned (Handshuh 2006). An SPI of greater than 1 indicates that the amount of work performed is greater than was originally planned: therefore, the program is ahead of schedule. Conversely, an SPI of less than 1 indicates that the amount of work performed is less than the amount of work scheduled to be performed, indicating that the program is behind schedule. The Actual Cost of Work Performed (ACWP) is not used directly in schedule analysis, but is an integral measurement when performing an assessment on a program’s cost performance.

Measuring BCWS and BCWP, and tracking the SV and SPI indicators is how program managers using EVMS have traditionally performed schedule analysis.

In the last decade, the validity of these EVMS indicators and their ability to predict schedule performance has been called into question, most notably by Walt Lipke. Predominantly, "it is known that [schedule] indicators of EVM fail to provide good information, nominally, over the final third of the project; they absolutely break down if the project is executing past its planned completion date (Lipke, 2003: 1). Further, the "root cause of the peculiarities associated with Earned Value and the EVM Schedule Variance" is that "Earned Value is algebraically constrained by its 'budgeted costs' calculation reference" (Henderson, 2003: 2). The reason for this is that, as a program moves towards its end date, the schedule variance (BCWP-BCWS) approaches zero, when the amount of work performed closes in on the amount of work scheduled. This stands to reason, as the amount of work accomplished towards the end of a program gradually gets closer to the amount of work scheduled for completion. Additionally, the Schedule Performance Index (BCWP/BCWS) approaches one, as the amount of work performed will eventually equal the amount of work scheduled (Lipke, 2003: 2). Thus, the traditional EVM schedule indicators fail to show that a program is behind schedule, even when we know definitively that a program is not completed on-time. Beyond this, the means of measuring schedule with EVMS is inherently flawed: schedule indicators are measured in terms of dollars, rather than in terms of time. This is a mental obstacle that is difficult for many program managers to overcome (Lipke, 2003: 1).

In order to illustrate the practical usage of the EVMS schedule analysis tools, a hypothetical program has been developed, with earned value data for the program shown in Table 1. This program, which begins on January 1st, is scheduled to take five months to complete (End of Month, May). The value of the work planned, known as the Budgeted Cost of Work Scheduled, was $200 per month. Data for the Budgeted Cost of Work Performed and the Actual Cost of Work Performed is also included. The metrics derived from this data, the Schedule Variance and the Schedule Performance Index are also provided in the table. The final result is a program that was scheduled to only take five months, in fact took seven months to complete.

Table 2. Earned Value Data for a Typical Program

	January	February	March	April	May	June	July
BCWS ($)	200	400	600	800	1000	1000	1000
BCWP ($)	192	367	561	747	902	977	1000
ACWP ($)	203	391	599	804	986	1045	1112
SV($)	-8	-33	-39	-53	-98	-23	0
SPI($)	.96	.92	.94	.93	.90	.98	1

Some of the problems described by Lipke are evident in this example. First, we know the program is scheduled to be completed in five months, but in fact took seven months. However, as the program gets closer to completion, the SV and SPI metrics become far less valuable when conducting a traditional EVMS schedule analysis. As was previously discussed, a SV of zero is notionally indicative of a program that is on schedule. In our example above, the SV in June is -$23, and regresses to $0 by the end of month, July. This would indicate improvement, but we know that the program is two months over schedule. Second, it was discussed that an SPI of one is indicative of a program that is on schedule. In our example, between May and July the SPI starts increasing as it approaches 1. This leads the program manager to believe that schedule performance is actually improving. Again, this assumption is misleading, because not only is the program already over schedule, only $75 worth of scheduled work was completed during June. Because no further work was scheduled during June, the SPI rose to .98. While this is a small example with limited EVM data, it demonstrates the well-known inadequacies of traditional schedule analysis techniques.

There is, within Earned Value Management, an indicator that has been primarily applied to cost metrics, but has begun to gain traction as a useful tool for schedule analysis as well. Under EVM, the Cost Performance Index (CPI), is "the ratio of the earned value accrued divided by the actual cost" (Lipke, 2009: 18). The new "companion cost indicator" (Lipke, 2009: 18) is the To Complete Performance Index (TCPI), defined as "the work remaining to be accomplished divided by the amount of unspent funding" (Lipke, 2009: 18). Effectively, the TCPI tells us the "cost performance efficiency required for the remainder of the project to achieve the desired final cost" (Lipke, 2009: 18). When the TCPI is "equal to or less than 1.00, there is confidence" that the project can meet its final cost (Lipke, 2009: 18). Further, if the TCPI is greater than 1.10, the project is considered to be "out of control" and meeting cost goals is likely unachievable (Lipke, 2009: 18-19). The literature focuses most on TCPI for cost, but it also addresses the TSPI for schedule analysis. TSPI is "equal to the planned duration for the work remaining divided by the duration available" (Lipke, 2009: 21). All applications and metrics for TCPI "can be made analogously to TSPI" (Lipke, 2009: 21). Thus, a TSPI less than or equal to 1.00 is on track to meet the project's schedule objectives, while a program with a TSPI of greater than 1.10 is very unlikely to be delivered on time.

Earned Schedule

Earned Schedule is a concept similar to Earned Value, but it measures schedule performance in *terms of time*, rather than in *terms of cost*. Earned Schedule is "determined by comparing the cumulative BCWP earned to the performance baseline, BCWS" (Lipke, 2003: 5). Earned Schedule was introduced in 2003 by Walt Lipke, in his seminal paper titled "Schedule is Different." Since then, analysis has been done in several areas, to include software programs (Lipke, 2008), construction projects (Rujirayanyong, 2009), and small acquisition projects (Lipke, 2011).

The first metric computed is Earned Schedule, which is "determined by comparing the cumulative BCWP earned to the performance baseline, BCWS. . .The cumulative value of ES is found by using BCWP to identify which time increment of BCWS the cost value occurs" (Lipke, 2003: 5). The value of ES is "equal to the cumulative time to the beginning of that increment, plus a fraction of it. The fractional amount is equal to the portion of the BCWP extending into the incomplete increment divided by the total BCWS planned for that same time period" (Lipke, 2003: 5). As an example from Lipke's 2003 paper "Schedule is Different," the June ES metric for a project that began in January is:

Equation 1: Earned Schedule Equation Example

$$Earned\ Schedule = Cumulative\ to\ May + Portion\ of\ June$$

$$ES = 5 + (BCWP(\$) - BCWS(May)/BCWS(June) - BCWS(May)$$

With the ES value determined, other metrics of interest to the program manager can be calculated. The first of these two additional metrics is the Schedule Variance in time (SV(t)), which is simply the ES value minus by the actual amount of time spent on the project:

Equation 2: SV(t) Equation

$$SV(t) = ES - AT$$

The second metric is the Schedule Performance Index in terms of time (SPI(t)), a ratio defined as the ES value divided by the actual amount of time spent on the project:

Equation 3: SPI(t) Equation

$$SPI(t) = ES/AT$$

There is significant information gained from these metrics that can be of value to the program manager in comparison to their EV counterparts. First, as previously discussed, the problem with SV($) is that it naturally regresses to zero as the program gets closer to completion. With SV(t), the variance does not regress to any value and is therefore useful throughout the life of the program. Additionally, unlike the traditional EVM SPI($), the SPI(t) metric does not regress to one, offering further insight as the program approaches its conclusion. This new metric gives the program manager a far more useful schedule performance index. This new SPI is useful in making predictions of estimated program completion dates.

The measurements taken when performing a traditional earned value schedule analysis (BCWS, BCWP, and ACWP) are also used to calculate Earned Schedule metrics. However, the metrics are computed in a different way, in an effort to put these metrics in terms of time, rather than in terms of dollars. The new metrics calculated are Earned Schedule, Schedule Variance in terms of time, and Schedule Performance Index in terms of time. The graphic below illustrates this difference:

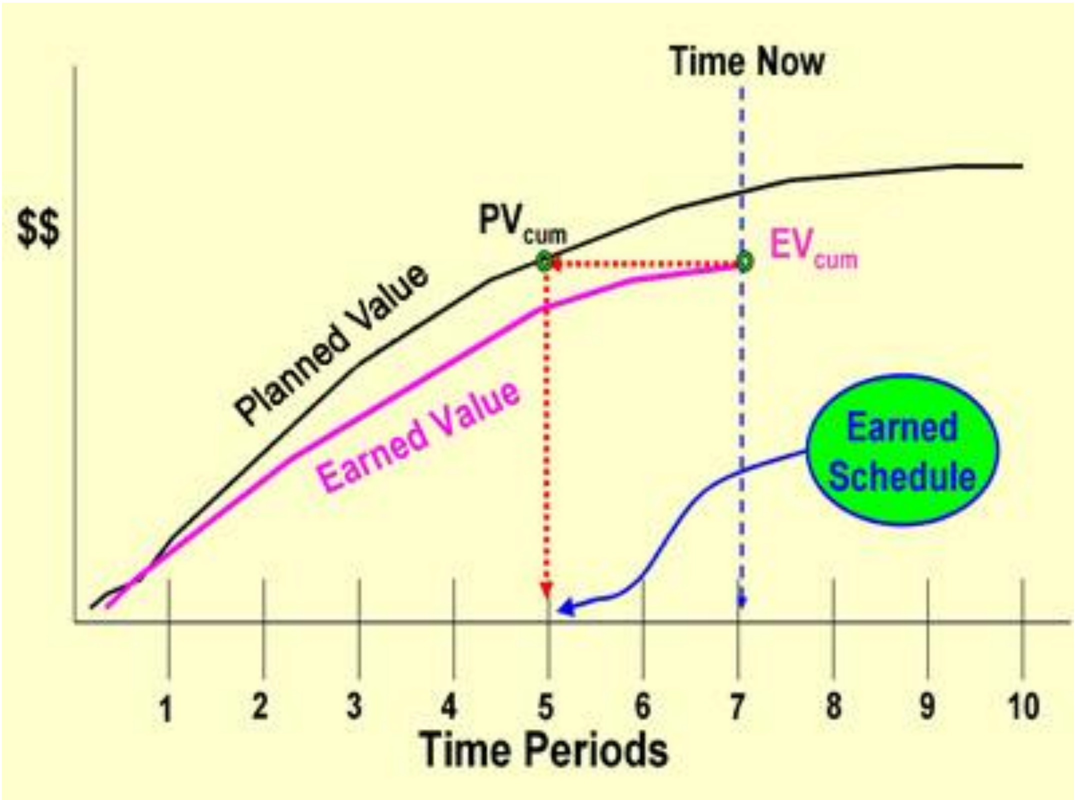

Figure 2: Schedule Variance (time) vs. Schedule Variance (Dollar) (Lipke, 2006)

To interpret this graph, the starting place is indicated as "Time Now" on the x-axis. Under EVMS, the SV($) is calculated by going vertically, and subtracting the earned value from the planned value (BCWP-BCWS). Looking at the Y-axis, this difference gives us a dollar value. In contrast to EVMS, Earned Schedule initiates at the actual time. To calculate the SV(t), the horizontal difference on the X-axis between the Earned Schedule and "Time Now" values capture the deviation in time. Regardless of whether the program in Figure 2 is analyzed in monetary terms or in terms of time, the results indicate that it is behind schedule. The earned value is less than the planned value for SV($), indicating the program is behind schedule in monetary terms. For ES, the earned schedule is behind the actual time for the value of SV(t), indicating that the program is behind schedule in terms of time.

There are significant differences in both the theory and application of earned value management and earned schedule, and with that difference comes two very singular sets of terminology. While there are some similarities across the two techniques, the differences are clearly outlined in Table 3 below (Lipke & Henderson, 2006: 6).

Table 3: Nomenclature for EVM and ES (Lipke & Henderson, 2003)

	Earned Value Management	**Earned Schedule**
Status	Earned Value (EV)	Earned Schedule (ES)
	Actual Costs (AC)	Actual Time (AT)
	Schedule Variance (SV)	SV(t)
	Schedule Performance Index (SPI)	SPI(t)
Future Work	Budgeted Cost for Work Remaining (BCWR)	Planned Duration for Work Remaining (PDWR)
	Estimate to Complete (ETC)	Estimate to Complete (time) ETC(t)
Prediction	Variance at Complete (VAC)	Variance at Completion (time) VAC(t)
	Estimate at Completion (EAC) (supplier)	Estimate at Completion (time) EAC(t) (supplier)
	Independent EAC (IEAC) (customer)	Independent EAC (time) IEAC(t) (customer)
	To Complete Performance Index (TCPI)	To Complete Schedule Performance Index (TSPI)

One of the main drawbacks to Earned Schedule noted both in academia and in the program offices is its inability to address the critical path of a project. In a 2006 paper, Walt Lipke tackles this concern and dispels the notion that ES isn't capable of addressing the critical path: "The Earned Schedule analysis method is demonstrated . . . to be applicable to more than the total project. Segregating and grouping EVM data for a specific portion of the project is the technique by which ES is made applicable to the total project and any sub-level desired. Specifically, the technique is shown to be capable of analyzing the schedule performance for the critical path. By employing the same techniques to analyze critical path, schedule performance by individual tasks can be evaluated, which then allows identification of the longest duration path for the project (actual critical path) along with schedule float" (Lipke, 2006: 7). Kym Henderson, the Vice President of Research and Standards with the College of Performance Management, hypothesized as to why ES has been thought to inadequately address the critical path: "We have long argued that 'drill down' on the ES data is required as part of a detailed analysis. The issue from a practice perspective . . . is that the mainstream EVM tool vendors have not yet incorporated ES into their products to do this, which forces many/most practitioners to use add-on toolsets." (Henderson 2012). Earned Schedule application to the critical path will be applied to an Acquisition Category I Defense Acquisition Program in chapter four.

Earned Schedule in Practice

To gain an understanding of how Earned Schedule is perceived by DoD practitioners in the field, and to determine the extent of its use, interviews were scheduled with the earned value points of contact and/or the lead cost analyst on all ACAT I programs at Aeronautical Systems Center, located at Wright Patterson AFB, OH.

Interviewees reported a wide range of Earned Schedule usage in the program offices: some program offices had never heard of Earned Schedule, while others used it frequently in their schedule analysis. The first question posed to the SPO was an inquiry as to how schedule analysis was presently accomplished. Generally speaking, each office has an Earned Value "guru" who accomplishes a full analysis on a monthly basis. This analysis is conducted with the earned value metrics, and is presented to the cost chief and/or the program manager. When asked about how earned schedule is used in their program office, the responses ranged from, "What is earned schedule?" to "I've heard of it, and I like to use it as a cross-check." A more detailed presentation of how Earned Schedule is presently used in MDAP program offices appears in Chapter 4 of this research.

While quantitative data was not utilized from Electronic Systems Center or Space and Missiles Center, qualitative data was made available. EVM analysts at each SPO were asked what they perceived as the value of ES, how widely it was used in their SPO, and what they felt ES failed to deliver that kept them from using ES. Of the five analysts who responded, each said they used ES in some capacity: some used it as a primary form of schedule analysis, while others used it primarily as an "indicator." ESC analysts who use ES in their schedule analysis stated that the primary reason they used it was because it's trustworthiness in identifying the actual duration of a project, as well as defining the schedule in terms of time. While the EVM analysts saw the value in using ES, they admitted that it has not been widely adopted by other personnel in the SPO. One analyst noted that ES's predictive ability for large DoD programs has not been studied, which should be alleviated by this research. Most analysts noted that ES is not used because the program management community is unfamiliar with it and it is not being actively included in the DAU curriculum.

To demonstrate the practical value of Earned Schedule compared to EVMS, the earlier example is revisited. When looking at Table 3 below, there are several observations about the usefulness of ES. The first observation concerns the new schedule variance calculation. When using EVM, the schedule variance metric from table 1 showed that, at the end of May, the project was $-98, or $98 behind schedule. This characterization of schedule variance in dollars is of little value to the program manager. In contrast, the ES schedule variance data from Table 2 shows the program manager that the project has an SV of -.49, or is .49 months behind schedule. The characterization of SV in time is very useful to the program manager. To further illustrate the use of these metrics, it is important to look at the program's completion at the end of July.   Table 1 shows us that the schedule variance has regressed back to zero, leading the program manager to believe that the project was delivered on time. It is clear, however, from the SV data in Table 3 and the information previously given, that the project wasn't completed until the end of month July, when it was scheduled for completion at the end of month May.   This illustrates the two month delay in delivery, which wasn't shown in the EVM schedule variance calculations.

The SPI calculations for EVM and ES also paint two very different pictures. An SPI of greater than 1 indicates that the program is ahead of schedule, while an SPI of less than 1 shows that the program is behind schedule. For the first five months of the program (the estimated time until completion at the start), the SPI's when calculated using EVM were identical to the calculations with ES. However, a deeper look shows that at the end of July the SPI($) for using EVM has regressed back to 1, leading the program manager to believe that the project has been delivered on time. Again, from our information, we know that the program was delivered two months late, once again rendering the EVM schedule calculations misleading. The earned schedule SPI(t) shows a value of .9 at the projected completion date, indicating that the program is behind schedule.

Table 4: Earned Schedule Data for a Typical Program

	January	February	March	April	May	June	July
BCWS ($)	200	400	600	800	1000	1000	1000
BCWP ($)	192	367	561	747	902	977	1000
ACWP ($)	203	391	599	804	986	1045	1112
ES	.96	1.835	2.805	3.735	4.51	4.885	7.00
SV(t)	-.04	-.125	-.03	-.07	-.225	-.625	1.115
SPI(t)	.96	.9175	.935	.934	.902	.8142	1.00

Previous Research

Since its inception in 2003, a number of studies have been conducted on a variety of different portfolios to establish the validity of Earned Schedule. The studies, conducted by Henderson (2003), Rujirayanyong (2009), Lipke (2011), Tzaveas, Katsavounis & Kalfakakou (2010), and Vanhoucke & Vandevoorde (2007) have focused predominantly on portfolios of small programs and construction projects. No such conclusive studies have studied the validity of ES when applied to DoD ACAT I programs. In 2005, Earned Schedule was studied by an AFIT student, 1st Lt Scott Smith. While Smith's conclusions did not support the use of ES as the proper methodology for schedule analysis, it was because "the DAES historical database does not contain the necessary data to test a hypothesis under the context proposed by Lipke" (Smith, 2005: 43). This research builds upon Lt Smith's findings with the assistance of an enhanced data set.

Kym Henderson - "Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data" (2003)

After Walt Lipke, in his seminal article "Schedule is Different," identified the shortcomings of Earned Value Management's schedule performance analysis, and proposed the concept of Earned Schedule, Kym Henderson of the College of Performance Management "retrospectively applied the ES measures proposed by Lipke to [a] small portfolio of six projects and subprojects managed using a 'simplified' EVM approach" (Henderson, 2003: 1). Henderson concluded that "ES based schedule metrics more accurately portray a project's schedule performance compared to the EVM equivalents. It is concluded that the ES measures and metrics are expected to have utility similar to their cost based counterparts, the recognized strength of EVM, and a greater utility than their historic EVM based equivalents" (Henderson, 2003: 1). An important conclusion from Henderson's study confirms Lipke's contention that "the application of Earned Schedule provides a set of schedule indicators, which behave correctly over the entire period of project performance" (Henderson, 2003: 10). This thesis intends to fulfill Henderson's recommendation that "these conclusions should be validated with a large scale follow on study in which ES is retrospectively applied to a broad portfolio" (Henderson, 2003: 11) to Acquisition Category I (ACAT I) Major Defense Acquisition Programs (MDAP). An ACAT I program is, according to DoD Instruction 5000.02, a program with a "dollar value estimated by the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) to require an eventual total expenditure for research, development, test and evaluation (RDT&E) of more than $365 million in fiscal year (FY) 2000 constant dollars or, for procurement, of more than $2.190 billion in FY 2000 constant dollars" (USD(AT&L), 2008).

Thammasak Rujirayanyong – "A comparison of Three Completion Date Predicting Methods for Construction Projects" (2009)

In this paper, Rujirayanyong "compares three different methods to predict completion date of construction project during construction stage" (Rujirayanyong, 2009: 305). The three methods compared are: the proposed method based on neutral networks, earned schedule, and earned value management. Neutral Network (NN) has "been widely used as a tool in different aspects of construction such as estimating, planning, and productivity forecasting . . . [and] developed a model [that considers] project physical conditions" (Rujirayanyong, 2009: 307). Rujirayanyong's research validates Lipke's assertion that "near the end of the project, when schedule performance is often the primary concern, the usefulness of traditional schedule metrics is demonstrably poor" (Rujirayanyong, 2009: 312). The results of this study showed the NN model as "more accurate and very stable for project completion date forecasting" (Rujirayanyong, 2009: 317). However, because NN is not a viable program management technique for major defense acquisition programs, Rujirayanyong's other results are far more relevant. He notes that "the ES method presented better results than those obtained from EVM method . . . It is also valuable in the last third of the project, when schedule performance is often a crucial concern . . . The EVM method, however, is still very helpful in managing construction projects, particularly in cost control" (Rujirayanyong, 2009: 317). Construction projects involve many different inputs coming together to form an output, no different than the many parts of an aircraft (avionics, propulsion, etc.) being assembled. The relevance of Earned Schedule for large construction projects, as shown in Rujirayanyong's study, lends credibility to the use of ES for major defense acquisition programs.

Walt Lipke- "Earned Schedule Application to Small Projects" (2011)

Lipke notes that the ES methods have proven to perform very well. However, "there are conditions during execution, generally for small, short duration projects, that can cause error in the calculated values for the ES indicators and duration forecasts . . . The conditions are "down time," defined as periods within the schedule where no work is scheduled, and "stop work," periods during execution where management has halted performance" (Lipke, 2011: 2). While these conditions can adversely affect the ES measurements, "the ES calculations converge to the correct duration forecast and the final schedule variance result" (Lipke, 2011: 2). One of the significant advantages of applying ES is that "the method provides the capability to forecast project duration and the expected completion date" (Lipke, 2011: 5). Lipke's paper concludes that, "For large projects, stop work and downtime conditions occurring for small portions of the project, in most instances, would not have much impact on the ES time based indicators or the duration and completion date forecasts. However, it is a different matter for small projects. The interrupting conditions will usually distort the ES indicators and forecasts, possibly enough to affect management decisions" (Lipke, 2011: 10).

Tzaveas, Katsavounis, Kalfakakou – "Analysis of Project Performance of a Real Case Study and Assessment of Earned Value and Earned Schedule Techniques for the Prediction of Project Completion Date" (2010)

A 680km highway stretching from one side of Greece to the other is one of 14 priority projects of the EU, and the first to be designed and built to modern international specifications (Tzaveas, Katsavounis & Kalfakakou, 2010: 754). For this study, a bridge carries the road over a deep river valley, and the schedule of the project was broken into 9 control periods that took into account the percentage completion of work and main events of the project (Tzaveas, Katsavounis & Kalfakakou, 2010: 755-756). The results support Lipke and Henderson's main takeaways: "It is apparent that Earned Schedule converges faster towards the actual duration without any remarkable results . . . The tendency of SPI($) to reach a value of 1.0 is clearly noted even though the project is late and exceeded the original contractual deadline, and that occurs at about 66% completion, that is when 2/3 of the project is effectively complete" (Tzaveas, Katsavounis & Kalfakakou, 2010: 756). Further, the authors noted that the "analyses carried out reveal the superiority of the ES method showing reliable results during the whole project duration . . . [and] provides value and reliable results along the project's lifespan" (Tzaveas, Katsavounis & Kalfakakou, 2010: 758). This study effectively illustrated not only the applicability of ES to large construction projects, but also the acceptance of earned schedule principles on an international scale.

Mario Vanhoucke and Stephan Vandevoorde – "Measuring the Accuracy of Earned Value/Earned Schedule Forecasting Predictors" (2007)

Because of the limited real-life data set, Vanhoucke and Vandevoorde aimed to validate "various earned value based forecasting methods on a very large and diverse set of fictive projects" (Vanhoucke & Vandevoorde, 2007: 27). They simulated the performance of three forecasting methods "by simulating a large dataset containing projects of moderate size and calculating the forecast accuracy of each method" (Vanhoucke & Vandevoorde, 2007: 27). The authors tested the Anbari's Planned Value method, Jacob's earned duration method, and Lipke's earned schedule method. The results of their simulation "clearly reveals that the earned schedule method outperforms, on average, the two other forecasting methods . . . both for projects that finish ahead of schedule and projects with a delay" (Vanhoucke & Vandevoorde, 2007: 28). A major drawback to the earned value method is the inaccuracy of SPI($) as an indicator over the final third of a project: Vanhoucke and Vandevoorde's research confirmed this, while also noting the "late stage forecast accuracy is much better for the ES method compared to the PV and ED methods . . . The SPI(t) indicator of the earned schedule method is developed to overcome [the EV method's] quirky behavior, leading to an improved forecast accuracy at the end of the project" (Vanhoucke & Vandevoorde, 2007: 28).

This study successfully simulated the effectiveness of ES compared to other forecasting methods for a large portfolio of fictitious programs.

The above mentioned papers have extensively studied the application of Earned Schedule in a variety of different program sizes and applications. However, a study of Earned Schedule's value to major defense acquisition programs within the Department of Defense has never been adequately conducted. This research intends to fill that void in the literature.

Summary

This chapter identified the importance of program management, introduced popular management techniques, established how EVM is used within the DoD and discussed why it may not be the best method for schedule analysis. Further, this chapter introduced the theory of Earned Schedule, detailed the work pioneered by Lipke and Henderson, and introduced a new set of metrics that may improve the DoD's ability to manage schedule delays using EVM data. The next chapter seeks to take the literature reviewed here, introduce the data collected, and identify the methods used to analyze the data.

III. Methodology

Introduction

The purpose of this chapter is to outline the methodology used for the research. It will discuss the data source, the limitations of the data, hypothesis of the research, and the statistical process used to perform the analysis.

Data Source

The Office of the Under Secretary of Defense (OUSD) for Acquisition, Technology, and Logistics (AT&L) maintains the Defense Acquisition Management Information Retrieval (DAMIR) system. DAMIR is comprised of all contractor performance report (CPR) data for all Department of Defense (DoD) acquisition programs. The CPR "is a contractually required report, prepared by the contractor, containing performance information derived from the internal EVMS. [It] provides status of progress on the contract" (EVMIG 2006, 91). Within this CPR data are monthly and quarterly updates for all the Work Breakdown Structures (WBS) for a project. The CPR is broken down into "five formats containing data for measuring contractors' cost and schedule performance on Department of Defense acquisition contracts" (OUSD(AT&L), 2005: 1). Detailed explanations of each of the five formats follows: "Format 1 provides data to measure cost and schedule performance by product-oriented Work Breakdown Structure elements, the hardware, software, and services the Government is buying. Format 2 provides the same data by the contractor's organization (functional or Integrated Product Team (IPT) structure). Format 3 provides the budget baseline plan against which performance is measured. Format 4 provides staffing forecasts for correlation with the budget plan and cost estimates. Format 5 is a narrative report used to explain significant cost and schedule variances and other identified contract problems and topics" (OUSD(AT&L), 2005: 1). The CPR "is a management report [that] provides timely, reliable summary-level data with which to assess current and projected contract performance. The CPR's primary value to the Government is its ability to reflect current contract status and reasonably project future program performance" (OUSD(AT&L), 2005: 1). See appendix A for examples of Format's 1-5 of a contractor performance report.

For this research, several measurements will be gathered from the Format 1 of each month's CPR. All data was cumulative for the program:

Budgeted Cost of Work Scheduled (BCWS) → Planned Value

Budgeted Cost of Work Performed (BCWP) → Earned Value

Schedule Variance in terms of Dollars (SV($)) → Earned Value – Planned Value

Schedule Performance Index in terms of Dollars (SPI($)) → Earned Value/Planned Value

These figures are provided to the Systems Program Office (SPO) by the contractor every month, and are validated by SPO cost analysis personnel. The Defense Contract Management Agency (DMCA) is the "DoD Executive Agent for EVMS. [They] . . . ensure initial and ongoing compliance with EVMS guidelines in ANSI/EIA-748"

(EVMIG, 2006: 18). Such guidelines ensure the EVM data produced by the contractors allows program managers to make the most informed decision.

Data was collected from two sources. The first source is the Cost Library located at Aeronautical Systems Center (ASC), Wright-Patterson AFB, OH. The CPR data from the cost library was collected on microfiche. While it would have been ideal to use the pure CPR data from the program offices as the sole data source, it was determined over the course of the research that the data was incomplete: entire years of data were missing for many programs, and for some programs only data from a single contract existed. The data that was available from the program offices was monthly data, but the data as a whole was far less complete than the data gathered from DAMIR. There were some programs, however, that had usable data from the program office: of particular note, the A-10. The second source of data was DAMIR. The programs selected were: Rockwell B-1B Lancer, Northrop Grumman B-2 Spirit, General Dynamics F-16 Fighting Falcon, McDonnell Douglas F-15 Eagle, Fairchild Republic A-10 Thunderbolt, Fairchild T-46, Boeing E-3 Sentry Airborne Warning and Control System (AWACS), Boeing C-17 Globemaster III, General Dynamics/Grumman EF-111A Raven, AGM-131 Short Range Attack Missile (SRAM) II, AGM-86 Air Launch Cruise Missile (ALCM), AGM-65 Maverick, and Lockheed Martin C-130J Super Hercules Upgrade. Additionally, DAMIR was a focal point for lists of active and completed Air Force programs, provided program start dates, original Program Manager Estimated Completion Dates (PMECD), and final completion dates.

The programs comprising the dataset have been completed, and are either in their operational phase, or have been retired from the Air Force fleet. The preceding programs are all Acquisition Category I (ACAT 1) Major Defense Acquisition Programs (MDAP): An ACAT I program is, according to DoD Instruction 5000.02, a program with a "dollar value estimated by the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD(AT&L)) to require an eventual total expenditure for research, development, test and evaluation (RDT&E) of more than $365 million in fiscal year (FY) 2000 constant dollars or, for procurement, of more than $2.190 billion in FY 2000 constant dollars" (OUSD(AT&L), 2008).

In addition to the above mentioned programs, a "deep-dive" analysis will be completed on the C-130J. While the twelve programs mentioned above will be analyzed at the "program" level, the C-130J will be analyzed at the work breakdown structure (WBS) level. Table 5 illustrates the complete dataset.

Table 5: Platforms, Number of Contracts & Number of Data Points in Data Set

Platform Name	Number of Contracts	Number of Data Points
B-1	14	233
B-2	2	19
F-16	4	51
F-15	8	115
A-10	5	135
E-3	2	50
T-46	2	25
C-17	11	226
EF-111	2	36
AGM-131 (SRAM)	1	17
AGM-86 (ALCM)	8	74
AGM-65 (Maverick)	4	41
C-130J	1	65
Sum	64	1,087

Data & Limitations

There are some limitations to this data, predominantly in the breadth of the study. The study is limited to only projects with complete CPR data, as it is necessary to have complete and accurate figures for the budgeted cost of work scheduled (BCWS) and budgeted cost of work performed (BCWP). For this reason, no active acquisition programs can be studied, and no programs with incomplete and/or inaccurate data can be studied. A further limitation to some of the programs selected is that only "Cost Plus," and other similar types of contracts can be studied. Cost Plus contracts encapsulate the costs of the materials and labor, as well as an additional award fee or incentive fees. Several contracts, and even some entire programs, are Firm Fixed Price (FFP) contracts. In these contracts, the government and the contractor agree on a set of goods and services that need to be provided by the contractor for a flat fee paid by the government. For FFP contracts, EVM data is not collected: a firm fixed price contract outlines specific services to be accomplished for a pre-determined amount of money, negating the need for any earned value analysis.

Air Force acquisition is predominantly accomplished at three major product centers, each under the Air Force Life Cycle Management Center. A product center focuses on acquiring systems for a particular Air Force capability. For instance, Aeronautical Systems Center, the largest of the three product centers, "designs, develops and delivers dominant aerospace weapon systems and capabilities for the United States Air Force, other United States military, allied and coalition-partner war fighters, in support of Air Force leadership priorities" (WPAFB ASC factsheet). A limitation to this study is that the data comes only from one service, the United States Air Force, and from a single product center, ASC, at Wright-Patterson AFB, OH. This limits the results of this finding to aircraft acquisition, and it is possible that the results may not be extrapolated to other types of weapons systems.

Within the dataset of aeronautical systems, there were additional limitations. First, no data was available for rotary-wing aircraft (helicopters) in either the cost library or the DAMIR system. Additionally, no data was found for other programs, specifically the Lockheed Martin F-22 Raptor, the McDonnell Douglass KC-10 Extender, and the Boeing KC-135 Stratotanker.

Hypothesis

The hypotheses for this research explore two distinctive avenues of program performance: timeliness and accuracy. The first facet attempts to answer whether using Earned Schedule for a program's schedule analysis would identify schedule overages with greater accuracy than the current Earned Value Management schedule analysis techniques. The second facet attempts to answer whether using Earned Schedule for a program's schedule analysis would identify schedule overages earlier in the life cycle of a program than the current Earned Value Management schedule analysis techniques.

$\mathbf{H_o}$: Earned Schedule is not a more accurate and timely predictor of schedule overages than traditional Earned Value techniques.

$\mathbf{H_a}$: Earned Schedule is a more accurate and timely predictor of schedule overages than traditional Earned Value techniques.

In failing to reject the null, the results of this analysis would indicate that using Earned Schedule rather than EVM for schedule management offers no additional benefit. If, however, the null is rejected, Earned Schedule proves to be a more accurate and timely predictor of schedule overages than traditional EVM methods.

Assumptions

There was one major assumption made during this analysis, regarding what constitutes a program in "trouble." There is no specific SPI value agreed upon by earned value and earned schedule practitioners that signals that major changes must be made to a program in order to meet schedule milestones. There is, however, an agreed upon value for the To Complete Schedule Performance Index (TSPI). Practitioners agree, based on Lipke's (2009) analysis, that any TSPI greater than 1.1 signals a program must undergo significant changes in order to meet the scheduled completion date. In essence, a TSPI value of 1.1 tells us that 10% more work must be completed each month for the programs duration to have an SPI of 1 at the programs completion date. Because there is not a universally accepted SPI value, the 10% "behind" schedule logic was used. For this research, any program with an SPI less than .9 was considered to be "in trouble."

Statistical Process

Earned Value and Earned Schedule statistics are needed to test the hypotheses. Each contract's quarterly BCWS and BCWP figures are used to calculate the SV($), SV(t), SPI($) and SPI(t) for that respective month. While the formulas for SV($) and SPI($) have been previously defined, the formulas for the earned schedule metrics have not. Two key elements are needed for these calculations: the earned schedule value, and the actual time elapsed in the project. Earned schedule is "the cumulative earned value in time units identified on the BCWS curve, as established by the value of the BCWP [where} partial units of time are calculated" (Haupt, 2004: 5). ES accounts for the value of completed months, as well as partial months. The ES statistic is calculated using the formula below:

Equation 4: Earned Schedule Equation

$$ES = Monthx + (BCWPcum - BCWSx)/(BCWSy - BCWSx)$$

Once the ES statistic has been calculated it is used, along with the actual duration (abbreviated as AT) of the program, to determine the values of SV(t) and SPI(t):

Equation 5: Earned Schedule Metrics

$$SV(t) = ES - AT$$

$$SPI(t) = ES/AT$$

With the data collected and the Earned Value and Earned Schedule statistics calculated, the originally postulated hypothesis can be examined through a series of tests. First, a paired t-test is employed to determine whether there is a statistically significant difference between the EV and ES data. A paired t-test "is used to ascertain how likely the difference between two means that contain the same (or matched) observations is to occur by chance alone" (Bausell & Li, 2002: 57). The paired t-test is used when: "(1) there are two continuous sets of numbers, and (2) the hypothesis to be tested is expressed in terms of a mean difference between these two sets of numbers" (Bausell & Li, 2002: 57). For this research, the pair t-test takes the difference between the SPI(t) and SPI($) and analyzes whether the difference between the two is significantly different than zero. To test this significance, the SPI(t) value and SPI($) value for each data point is compared. Effectively, the SPI($) value is the pre-test variable, and the SPI(t) is the post-test variable. Once the comparison is completed on these variables, the t-statistic is tested for significance. If the significance is determined to be below an alpha level of .05 (Bausell & Li, 2002: 10), then it can be concluded that there is not a statistically significant difference between the Earned Value and Earned Schedule methods. If a statistical significance *is not* found, then it must be concluded that ES does not provide more timely or accurate schedule information than EV. If statistical significance *is* found, then further tests are conducted to determine whether ES provides more accurate and timely schedule information than EV.

Upon conclusion of the paired t-test, five additional tests are conducted on the data for each of the contracts. These five tests use descriptive statistics to help answer the original hypothesis questions.

Test 1: Analysis of SPI(t) and SPI($) below .90 Over Time

The first test analyzes the SPI(t) for Earned Schedule and the SPI($) for Earned Value, and determines which method detects that the program is "in trouble" earlier in the program's life. A program was determined to "in trouble" when the SPI dropped below

.90. A definitive value for SPI signaling that a program is "in trouble" was not found during the literature review for this research, so an assumption was made. To analyze this, a scatter plot is utilized for each of the individual contracts, capturing the SPI(t) and SPI($) values at similar durations of the program's life. This scatter plot captures the activity of the SPI(t) and SPI($) values over the life of the contract.

Test 2: Analysis of Frequency of SPI(t) and SPI($) values below .90

The second test examines the percentage of time that the SPI(t) and SPI($) values for all of the contracts are below .90. Effectively, this test analyzes whether one method more consistently indicates that a program is "in trouble." In addition to the results of each individual contract, a summary histogram is utilized for both the Earned Value and Earned Schedule methods. The histogram shows the percentage distribution of SPI(t) and SPI($) values below .90, and also provides the mean and median values for each method.

Test 3: Analysis of Optimism and Accuracy in SPI(t) vs. SPI($) values

The third test is broken into two parts: both parts also use the SPI values for Earned Schedule and Earned Value Management. The first part of this test looks at each data point and determines which method is the more "optimistic" of the two, regardless of whether the SPI value was above or below .90. For instance, if SPI(t) was .95 and SPI($) was .90, it was determined that SPI(t) was more optimistic for this data point. Conversely, if SPI(t) was .82 and SPI($) was .97, it was determined that SPI($) was more optimistic. The total number of "optimistic" data points for each method was calculated at the end. Historically, major acquisition programs have failed to meet schedule objectives because of optimistic planning: this test determines which method more accurately identifies the more optimistic scheduling. The second part of the test looks at which method is more accurate. For each data point, the SPI values are compared to the final schedule result, and whichever method is determined to be closer to the final contract over/under run is deemed to be the more “accurate” method. The total number of more accurate points for each method is totaled at the end, and displayed as a percentage.

Test 4: Analysis of TSPI Values

The fourth test looked at a different metric: the To Complete Schedule Performance Index (TSPI). The TSPI is the SPI efficiency that must be achieved from the current month until the estimated project completion date in order to come in on time. Any program with a TSPI value greater than 1.1, which implies that 10% more work needs to be completed every month than is scheduled, is considered to be unrecoverable. This research investigates whether a program that had a TSPI reach a value of 1.1 ever recovered to come in on schedule. The same test is done for programs where the TSPI’s reached 1.05 and 1.01. Once analysis on all programs is completed, a histogram is utilized to show the distribution of program completion percentages. Further, the mean and median completion percentage for each TSPI value is calculated. This test aims to determine which TSPI value the DoD should use to indicate a program is unrecoverable unless changes are made.

Test 5: Analysis of SV(t) vs. SV($) Divergence Point

The final test uses SV(t) and SV($) data for all of the contracts studied. As discussed in chapter two, one of the advantages of ES is that it puts schedule in terms of time, rather than dollars. The schedule variance under EVM (SV($)) is a dollar figure, the difference between Earned Value and Planned Value. At the end of a program, all work that was scheduled will be performed. Thus, the SV($) will always regress to zero. However, ES puts schedule in terms of time: the value tells us how far ahead or behind, in terms of our unit of measure (in this case, quarters), our program is. A negative SV(t) indicates that the program is behind schedule, while a positive SV(t) indicates that a program is ahead of schedule. For example, an SV(t) of -1.45 indicates that the program is 1.45 quarters behind schedule. To analyze how the two schedule variances react, a scatter plot with two y-axes is utilized. One y-axis is measured in dollars to accommodate the EV calculation. The other y-axis is measured in time to accommodate the ES calculation.

The purpose of this test is to graphically show how the SV's for a program compare when measured using the two different methodologies. Because the behavior of the two schedule variance methodologies had already been identified in the ES literature, this research also results in an analysis of at which percentage completion point in a contract the divergence between the two methods occurs. To study this, the schedule variance scatter plot was used to subjectively determine at which point in the programs completion the SV(t) began to decrease at an increasing rate while the SV($) began to regress towards zero.

Chapter Summary

The purpose of this chapter is to outline the methodology used for the research. It discusses the data source, the limitations of the data, hypothesis of the research, and the statistical process used to perform the analysis. Chapter Four will discuss and describe the results of this analysis.

IV. Analysis and Results

Chapter Overview

The purpose of this chapter is to document the results of the research. We first looked back to the research questions submitted in Chapter 1.

1.) To what extent is Earned Schedule currently utilized in Air Force ACAT I acquisition programs?

2.) Does Earned Schedule provide more accurate schedule predictions than traditional DoD methods?

3.) Does Earned Schedule provide more timely schedule predictions than traditional DoD methods?

The first question looks to qualitatively answer how extensively ES is used in Air Force acquisition programs, as well as to gain a deeper understanding of how schedule analysis is conducted and of what value it is to the program manager. The two final questions are quantitative in nature. Once it is determined that there is a statistical difference between Earned Value Management and Earned Schedule, a series of tests is conducted to answer the questions of which method is more accurate and more timely as a predictor of schedule performance.

Extent of Earned Schedule in Air Force Acquisition Category I Programs

Before statistically analyzing the difference between Earned Value Management and Earned Schedule, we investigate our first research question to gain an understanding of to what extent, and how, schedule analysis is currently conducted in Air Force System Program Offices (SPO), as well as the SPO's familiarities with the concept of Earned

Schedule. Interviews with SPO's at Aeronautical Systems Center at Wright Patterson AFB, OH were conducted in person, as well as through e-mail and phone conversation as required. Due to funding limitations, interviews with program offices at Electronic Systems Center at Hanscom AFB, MA and Space and Missile Center at Los Angeles AFB, CA were conducted exclusively through e-mail communication.

Most programs, especially ACAT I programs, have an Earned Value analyst. These Earned Value analysts were the focal point for the interviews and data collection. In the absence of an EV analyst, we worked with the programs Finance chief. We first explored how the program conducted their schedule analysis, and how frequently the analysis was done. We ascertained where they got their schedule data, what EVM calculations were done, and how the results were presented to the program manager. We then determined how familiar the SPO was with the concepts of Earned Schedule, and whether ES was used in their analysis. If the SPO did not use ES, we asked what they felt it lacked to make it a valuable tool. We asked the SPO if they were satisfied with their results using EVM as their schedule analysis tool, and if they felt there were any drawbacks to its use. Finally, we asked the analysts' opinion as to why they felt Earned Schedule had not gained popularity as a schedule analysis tool for defense acquisition programs.

Earned Value Management in Practice

Most of the programs surveyed conduct their schedule analysis on a monthly basis. Some stated that they have experimented with conducting the analysis on a weekly basis, but that it offered no further insight and thus was not worth the additional effort.

Programs, almost exclusively, receive their data from the Integrated Master Schedule (IMS), which is also the basis for the Contractor Performance Reports (CPR). The SPO's briefed their EVM results to the Program Manager on a monthly basis: most did so in face-to-face meetings, while others provided the results in an e-mail and discussed any areas of concern on a teleconference.

One area of disparity between the programs was how much value they felt the Program Manager placed in the EVM results. One EV analyst stated that "The program manager is proficient in understanding how the schedule status influences the Estimate at Complete (EAC) projections, and I think the program manager understands the value of EVM" (Tatum). Another EVM analyst agreed with this sentiment, by stating that "The program manager sees the value of Earned Value Management. Maybe not as much the numbers, but they find the analysis to be valuable." (King). The EVM analyst for another program stated that "Our program manager was very fluent and interested in every detail of the EVM analysis . . . well beyond the standard reporting" (Winterhalter). One other analyst supported these thoughts: "Our program manager is very fluent in the different schedule metrics and takes necessary action to improve the IMS on the contract. They also use the lessons learned to ensure the IMS on the follow-on contract will be a better tool to manage their program." (Suchland) However, one analyst disagreed with these statements: they felt that "the program manager is only really interested in the schedule when it starts to overrun." (Kapaku). While there were some dissenting opinions, EVM analysts largely felt their program managers understood their work and saw its value in the scheme of their program.

Earned Schedule in Practice

The responses from each Product Center were varied. Generally, Earned Schedule has not been broadly accepted by government acquisition programs. We asked each of the SPO's if they were familiar with Earned Schedule. We asked those who were familiar with ES to expound upon how they use ES in their analysis and how they feel it compares to the results obtained using EVM. The results of the inquiry are displayed in Table 6 below:

Table 6: Results of Earned Schedule Usage Qualitative Study

Product Center	Total Number of Program Offices in Product Center	Total Number of Program Offices Contacted	Number of Program Office's Responded	Number of Program Offices Using ES
ASC	16	14	12	3
ESC	30	30*	5	3
SMC	12	1**	1	0

* - Includes ACAT II and ACAT III programs located at Hanscom AFB

** - Response from SAF/FMC staff on behalf of all programs within the product center

* - Includes ACAT II and ACAT III programs

As Table 6 illustrates, Earned Schedule has not broadly been accepted by Air Force program offices. At Aeronautical Systems Center (ASC) and Electronic Systems Center, Earned Schedule has been introduced to, and is understood by, several of the program offices, but all were adamant that they did not use ES as their primary schedule analysis tool.   Space and Missile Center, contrarily, has not implemented ES in any capacity, and it is not currently used by any of their programs.

For those programs that replied, the responses ranged from “I have never heard of Earned Schedule,” to “I am very familiar with Earned Schedule, and I use it extensively in my analysis.” Of the seventeen responses, fourteen of the programs have heard of Earned Schedule. Of those fourteen programs, six of the programs actively use Earned Schedule in their analysis. None of the programs queried felt there were significant limitations to using EVM exclusively: rather, they all endorsed EVM, and feel that it provides more than enough valuable information to the program manager. The strongest endorsement for the implementation of Earned Schedule comes from the KC-46 program, who noted “We have implemented Earned Schedule analysis on our program. We include the SPI(t) calculation on our performance charts. So far, the ES numbers have not been much different than the EV numbers, but SPI(t) becomes a more useful index later in the program.” (Pierri). Another program, the C130J, also uses Earned Schedule in their analysis: “We find Earned Schedule to be useful because its puts into perspective how far behind we are. We use ES as a crosscheck for EVM.” Further, the C-130J stated that they find ES to be “more useful at the WBS level because it helps identify where delays occur.” (King).   One analyst from ESC noted that ES is “fairly trustworthy as far as identifying an actual duration for the schedule variance – SV(t). The SV(t) usually would be close to what was pulled out of the Integrated Master Schedule (IMS).” Another ESC analyst responded, “ES adds another element of understanding as a snapshot of past vs. potential contract performance. It bridges the gap between a schedule metric being described in a time component as opposed to a monetary component." However, that same analyst responded that "ES is not used in any capacity that I am aware of on my contracts." Of the eighteen programs who responded, only six use Earned Schedule in their analysis, and none use it as their primary schedule analysis technique.

Based on our findings, it is clear that the use of ES within DoD acquisition programs is very scarce. We surveyed the programs as to why they felt ES had not gained any popularity since its introduction in 2003. One common response was obtained when asked why ES is not used as the primary tool for schedule analysis in the program offices: unfamiliarity. Several analysts stated that while they felt that ES added value, it is not given the same support from program leadership as is EVMS. Several hypothesized that because it is not included in the curriculum at the Defense Acquisition University (DAU), it is not widely understood, and therefore not utilized in the field.

Revisiting the original research question, we have determined the extent of Earned Schedule usage in Air Force ACAT I programs. Rather than utilize Earned Schedule, programs use the IMS to complete their monthly EVM analysis. In general, program managers are content with these EVM metrics. Thus, the extent of ES usage is minimal. The integration of Earned Schedule as the *primary* schedule analysis tool has yet to happen for any programs, but it is used as a secondary/crosscheck tool for about one-third of the programs surveyed.

Accuracy & Timeliness of Earned Schedule vs. Earned Value Management

Prior to examining the accuracy and timeliness of Earned Schedule versus Earned Value Management, we must first determine if there is a difference between the two methods. If there is a statistical difference between the two methods, we reject the null hypothesis, and further compare the two methods.

Results of Significance Test

To determine if the results of the Earned Value Management and Earned Schedule techniques were statistically significantly different from zero, a paired t-test is used. The paired t-test measures the mean difference between two sets of numbers. For this analysis, a comparison of 13 programs, comprised of 64 contracts, resulting in 1,087 data points was used. The resulting t-statistic of the paired t-test is -8.6231, with a resulting p-value of 2.27467E-17 and a rejection of the null hypothesis. Therefore, it is determined that the difference between Earned Value Management and Earned Schedule is statistically significant. The output of the paired t-test is found in Figure 3 below.

t-Test: Paired Two Sample for Means		
	Variable 1	*Variable 2*
Mean	0.939165476	0.95750293
Variance	0.008831643	0.006653895
Observations	1087	1087
Pearson Correlation	0.689419981	
Hypothesized Mean Difference	0	
df	1086	
t Stat	-8.623145392	
P(T<=t) one-tail	1.13734E-17	
t Critical one-tail	1.646257934	
P(T<=t) two-tail	2.27467E-17	
t Critical two-tail	1.962150792	

Figure 3: Results of Paired t-test

The result of the significance test demonstrates that there is a statistical difference between Earned Value Management and Earned Schedule. With this fundamental difference established, we revisit our original hypothesis questions, and analyze whether Earned Schedule or Earned Value Management is more accurate and timely in predicting schedule overages. The questions are examined through a series of five tests.

Test 1: Analysis of SPI(t) and SPI($) below .90 Over Time

The first test conducted shows how the SPI(t) and SPI($) acted over the course of the program. The literature suggests that Earned Value Management and the SPI($) is relatively useless over the final third of a program because the SPI($) value regresses towards zero. For this research, the earned value and planned value data for each point were used to calculate the SPI(t) and SPI($), and a scatter plot is used to illustrate how the SPI(t) and SPI($) changed over the course of a program. Figure 4 exhibits the scatter plot for a typical program, in this case the B1B Propulsion Lot 1 contract. See Appendix B for SPI(t) vs. SPI($) scatter plots for all programs.

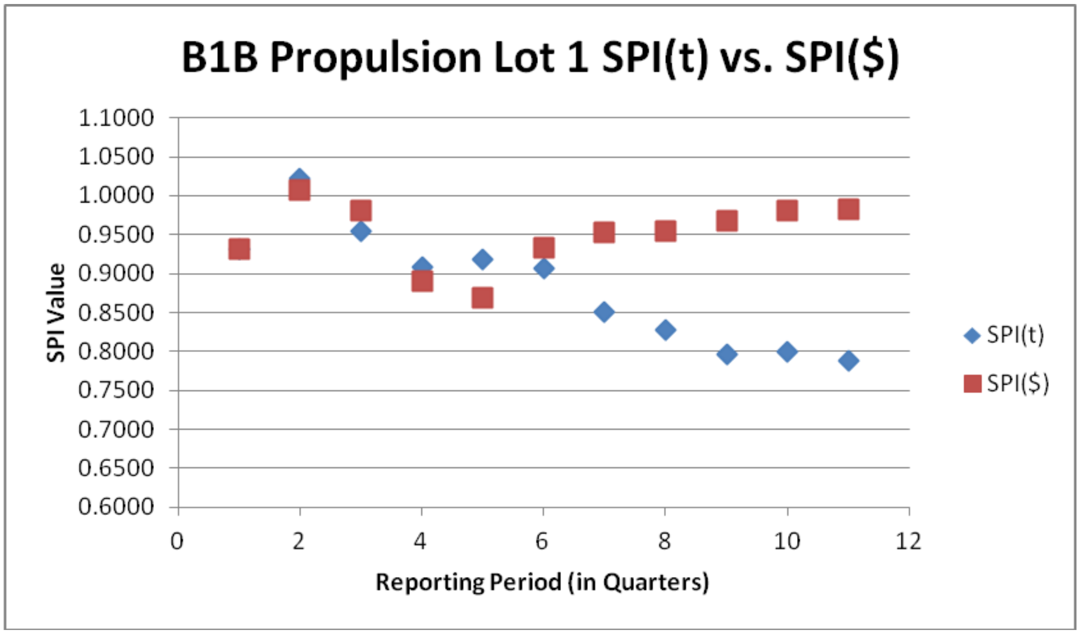

Figure 4: B1B Propulsion Lot 1 SPI(t) vs. SPI($)

While graphs such as that seen in Figure 4 are helpful to see how the SPI(t) and SPI($) values react over the course of each individual program, not all programs reacted the same way. To get a more broad understanding of how the SPI(t) and SPI($) values for defense acquisition programs reacted over time, the SPI(t) and SPI($) values for each program were calculator at the 20%, 40%, 50%, 60%, 80%, and 90% program completion points. From there, the average for each completion point was graphed to show the reaction of the broader portfolio. That graph is seen in Figure 5.

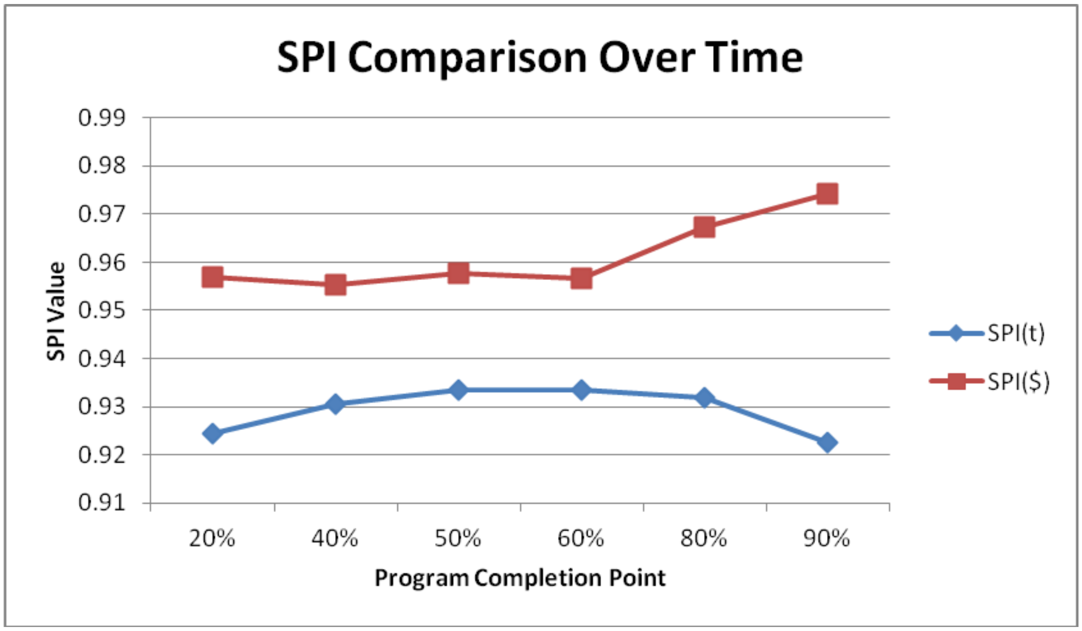

Figure 5: SPI Comparison Over Time

The SPI comparison in Figure 5 shows, at the portfolio level, what we expected from the SPI values. The SPI(t) and SPI($) values react with general consistency over the first two-thirds of the program, with the SPI values separated by only hundredths of a point. However, at the two-thirds completion point, the SPI values go in different directions: the SPI(t) value begins to decrease at a more rapid pace, while the SPI($) value regresses back towards a value of 1.0. We know that an SPI value of 1.0 indicates that a program is on schedule, but also that all of the programs studied were delivered after their estimated completion dates. This validated our belief that as a program progresses past the two-thirds completion point, SPI($) becomes an unreliable measure of program schedule. While the first test shows how the SPI(t) and SPI($) values react over the life of a program at both the individual and enterprise level, we wanted to determine which method of schedule analysis was more accurate in detecting schedule overages.

Test 2: Analysis of Frequency of SPI(t) and SPI($) values below .90

The second test utilizes the graphs from test 1 to determine the point at which the initial indication came that there were issues with a program. The intent of this test is to determine whether Earned Value Management or Earned Schedule is an earlier detector of problems in meeting program schedule objectives. To perform this analysis, the point at which the SPI(t) and SPI($) for each program first dropped below .90 is determined. Because the literature lacked a conclusive threshold, the definition of a problem (SPI(t) or SPI($) < .90) is an interpretation for this research. That information is presented in Table 7 below:

Table 7: Comparison of First Data Points Below .90

	Percent Complete (Mean)	Programs with no SPI value below .90
Earned Schedule	29.89%	21
Earned Value Management	17.89%	30

From the results, we determined that, on average, Earned Value Management detected earlier in a program that there are problems. This was a notable result, but one that lost some significance when it was found that EVM failed to detect any problems 30 of the 64 programs studied, while Earned Schedule only failed to detect a problem on 21 of the programs. This told us that there were nine programs where Earned Schedule detected a problem where EVM never did. We also noticed that there were several programs where the SPI(t) and/or SPI($) value dipped below .90 early in a program (perhaps the first data point), but quickly recovered to an SPI value of greater than .90 for the remainder of the program. An example of this is shown in Figure 6 below:

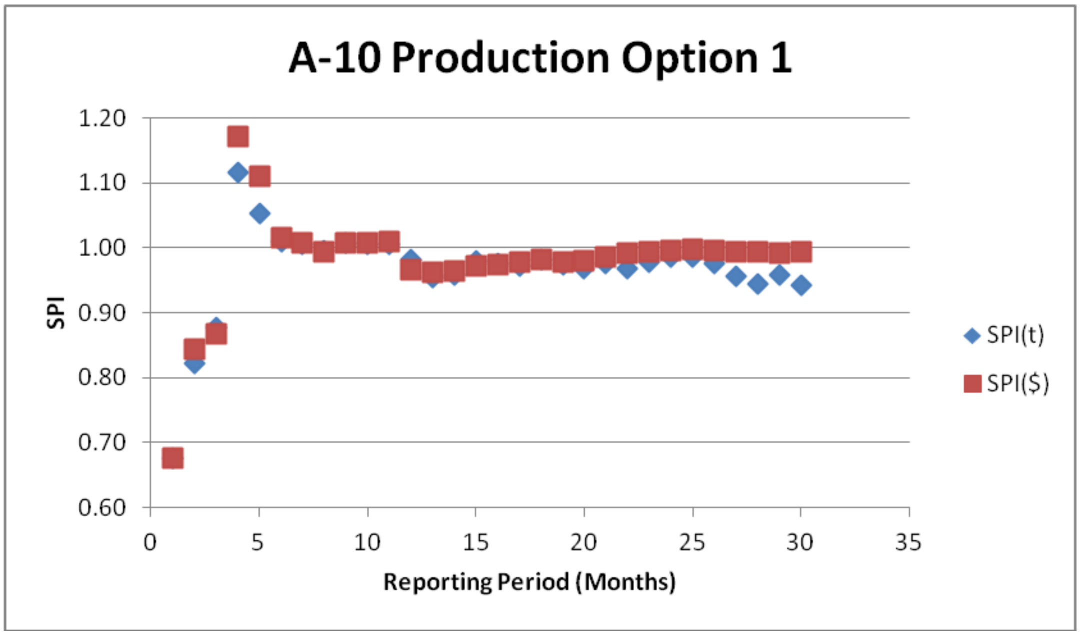

Figure 6: Example of Quickly Recovering SPI Value

We felt this first test failed to paint the full picture, necessitating a second test: determining which method more frequently indicates that there are problems with a program.

The second part of this test examines the amount of time that a program was deemed to be "in trouble" to determine if Earned Schedule or Earned Value Management is more consistent at identifying schedule delays. To study this, the SPI(t) and SPI($) values for each data point are calculated. From there, the total number of points with an

SPI value below .90 is counted for each method. Of the 1,087 data points, 12.42% (135 points) had an SPI($) of less than .90 under the Earned Value Management method, while 20.24% (220 points) had an SPI(t) of less than .90 under the Earned Schedule method. The results are shown in Table 8.

Table 8: Total Number of Data Points with SPI Less than .90

	Total Points < .90	Percentage of Overall Points
Earned Value Management	135	12.42
Earned Schedule	220	20.24

The total number of SPI(t) and SPI($) values below .90 were gathered at each of the following program completion points: 20%, 40%, 50%, 60%, 80%, and 90%. The results are found in Table 9 below.

Table 9: Number of SPI Values Below .90 Over Time

	20%	40%	50%	60%	80%	90%
SPI(t)	20	17	11	14	15	20
SPI($)	12	11	4	5	2	1

These values were calculated to show the differing reactions of the SPI values over time. While Earned Schedule is marginally more accurate in predicting schedule delays over the first half of a program, there was a considerable change over the second half of the programs that was consistent with the literature. As a program got closer to its completion point, the SPI($) metric indicated fewer programs were having problems. At the 60% completion point, SPI(t) found 14 programs to have SPI values below .90 while SPI($) found only 5 programs to have problems. At the 80% completion point, SPI(t) found 15 programs to have problems while SPI($) only found 2. Finally, at the 90% completion point, SPI(t) found 20 programs to be "in trouble," while SPI($) found only 1. This confirmed what was found in the literature and what we found in earlier tests: as a program approaches its completion point, Earned Value Management yields an SPI($) value that approaches 1.0, indicating that the program is on schedule. We also noticed that there were 20 points detected at both the 20% and 90% completion points for SPI(t). Deeper analysis revealed that seven data points which detected a problem at the 20% completion point also detected one at the 90% completion point. This test revealed that as a program nears its completion point, the use of Earned Schedule is a much more accurate schedule predictor than the current method employed by the Department of Defense.

The data from Table 9 is displayed graphically in Figure 7. Figure 7 compares the total number of SPI(t) and SPI($) values below .90 at six thresholds over time. It demonstrates how, especially over the final half of the program, the SPI(t) is a much more accurate predictor of schedule overages. At the 90% completion point, only one program is determined to be behind schedule using EVMS, while ES predicts schedule overages for 20 programs.

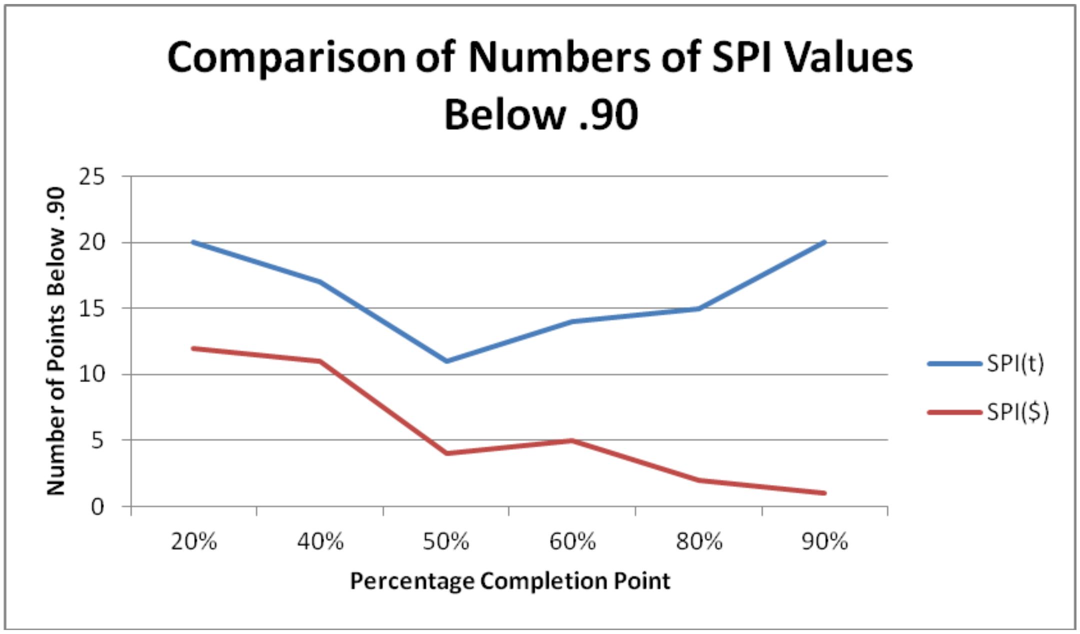

Figure 7: Comparison of Numbers of SPI Values Below .90

The raw data suggests that Earned Value Management is an earlier indicator of schedule overages than Earned Schedule, as it detects problems at the 17.89% program completion point as opposed to the 29.89% completion point. However, this singular statistic is misleading: overall, EVM fails to detect a problem on nine fewer programs than ES, and detects 85 fewer SPI values below .90 than ES. Ultimately, Earned Schedule is the better metric for schedule detection over the life of an acquisition program.

Test 3a: Analysis of Optimism and Accuracy in SPI(t) vs. SPI($) values

Historically, schedule metrics are often overly optimistic. Programs, especially those of the magnitude of an ACAT I defense acquisition program, are typically delivered later than the original estimate, but the numbers calculated on a monthly basis paint a much more positive picture. We conducted this test to determine which method was the more "optimistic of the two, regardless of whether the SPI value was above or below .90. Whichever SPI value is higher is determined to be the most optimistic. Of the 1,087 data points, the SPI($) value for Earned Value Management was more optimistic 59.43% (646 points) of the time, while the SPI(t) value for Earned Schedule was more optimistic 35.05% (381 points) of the time. There are 60 instances (5.52%) where the SPI($) and SPI(t) values are the same. Earned Value Management was 41.02% ((646-381)/646) more optimistic than Earned Schedule. The results of this test are reflected in Table 10.

Table 10: Points more Optimistic

	Number of Occurrences	Percentage of Overall
Earned Value Management	646	59.43
Earned Schedule	381	35.05
EVM = ES	60	5.52

As a way to show graphically the difference between the two methods, two histograms were used. The first, shown in Figure 8, depicts when EVM was the more optimistic of the two methods. On the X-axis is the percentage of points that were more optimistic in a program, with the frequency (in the number of programs) on the y-axis. Figure 8 illustrates, for example, that there are 14 programs where Earned Value Management is the more optimistic measure 100% of the time.   Further, Figure 8 demonstrates that 56 of the 64 total programs studied had over 50% of their data points where the SPI($) value was the more optimistic of the two measures.

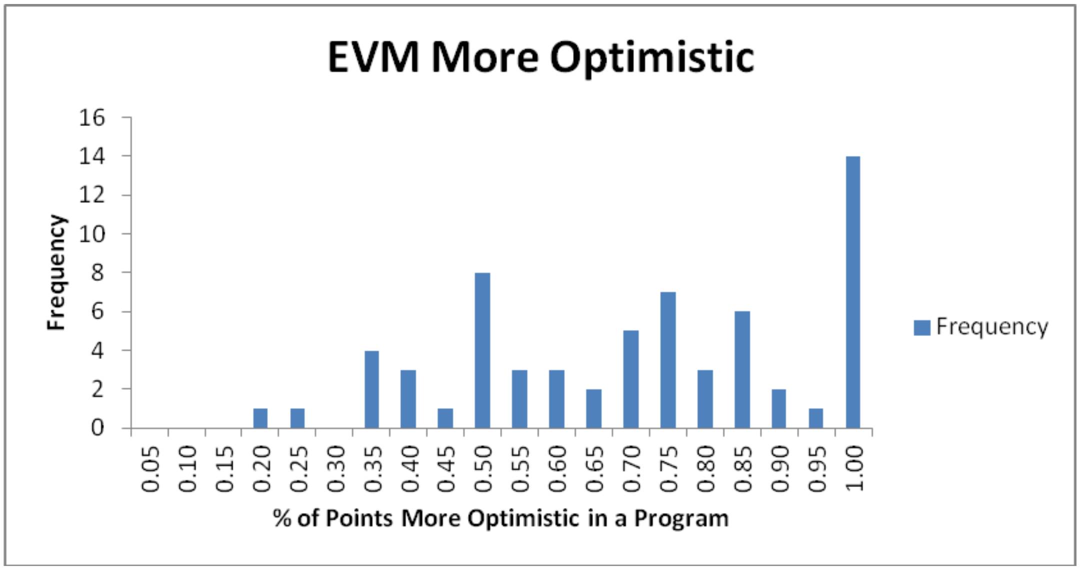

Figure 8: EVM More Optimistic

Figure 9 illustrate the percentage of points in a program where Earned Schedule was the more optimistic measure. There is a substantial skew to the left, indicating that most of the programs studied had less than 50% of their data points where Earned Schedule was the more optimistic measure. There were only two programs out of the 64 studied where Earned Schedule was the more optimistic measure on more than 75% of the data points.

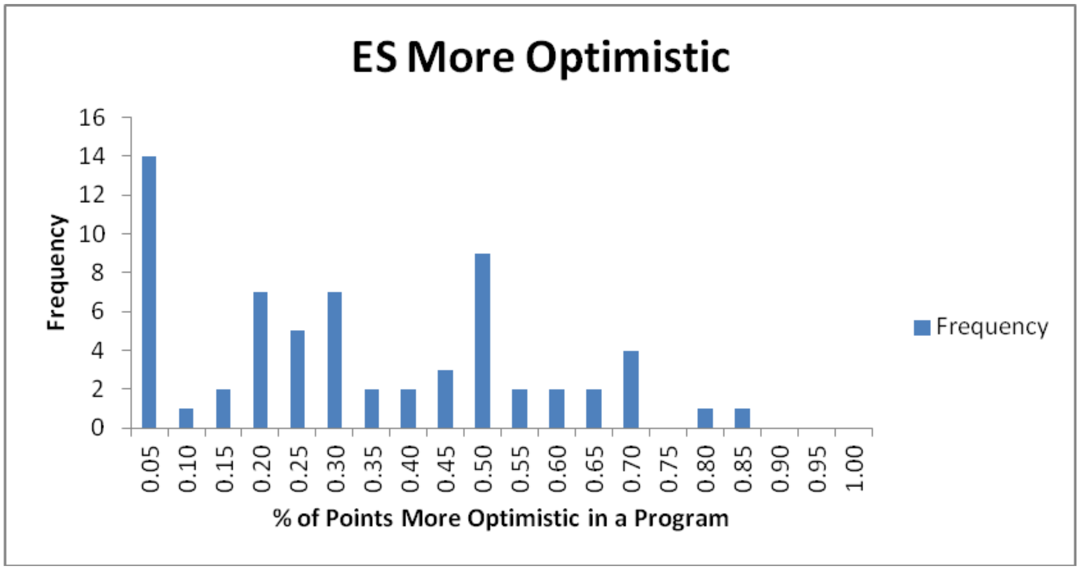

Figure 9: ES More Optimistic

One further illustration for this test is displayed in Figure 10, which compares the frequency with which each SPI value is more optimistic for each program. While there are some programs where the SPI(t) value is more frequently the optimistic measure, the overwhelming number of programs had more SPI($) values that were more optimistic.

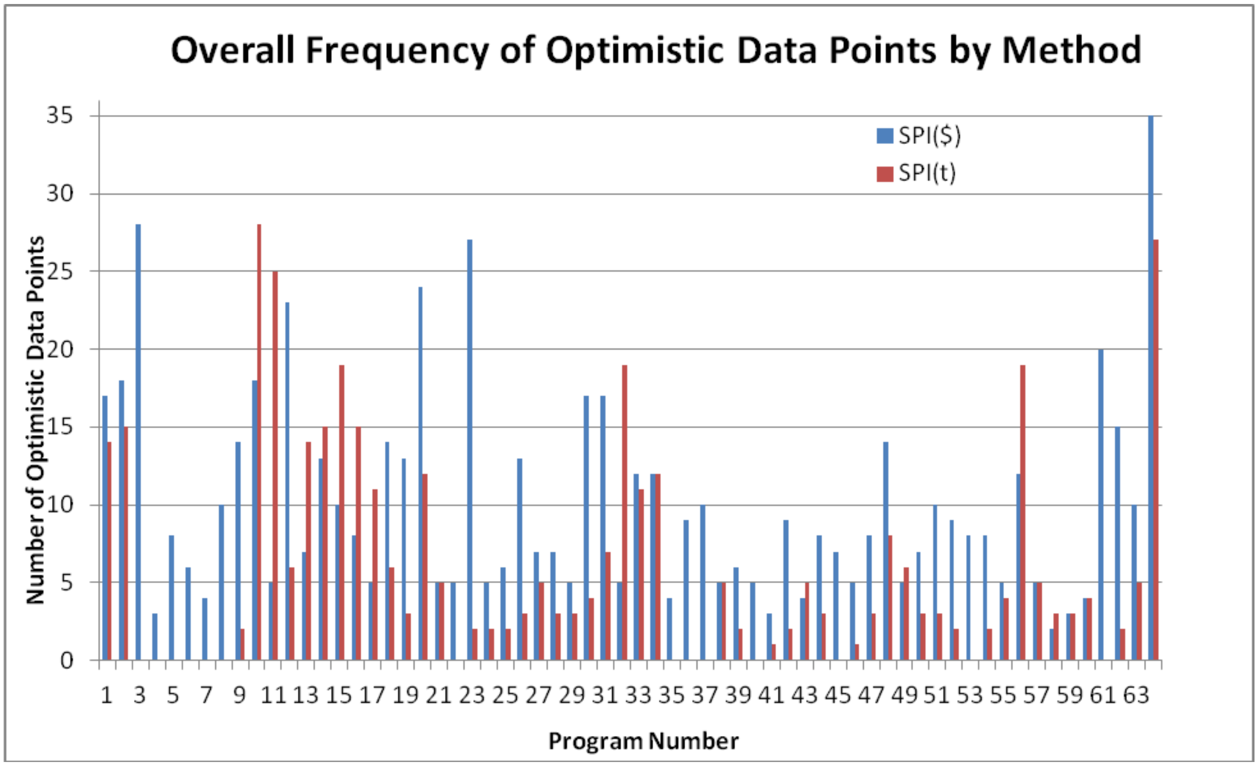

Figure 10: Overall Frequency of Optimistic Data Points by Method

A final demonstration for this test is illustrated in Figure 11. This graph shows which method was more optimistic as a schedule predictor at various points throughout the life of a program: 20%, 40%, 50%, 60%, 80%, and 90%. Because of the number of months in certain programs, there wasn't always an exact 90% completion point, so the closest possible point was used for that program. It should be noted that some completion points have greater than 64 points, the number of programs studied in this research. For instance, the 20% completion point has 72 points because 8 programs had idential SPI(t) and SPI($) values at that point. The results of this test revealed that there isn't much difference in the first 50% of a program: the SPI($) value is only slightly more optimistic than the SPI(t) value. However, there comes a staggering change over the second half of a program. At the 60% completion point, EVM was more optimistic for 46 programs, compared to ES which was more optimistic for only 22 programs. At the 80% completion point, the difference in these two values grows: SPI($) is more optimistic for 53 programs, whereas SPI(t) is more optimistic for only 11 programs. At the 90% completion point, Earned Value Management was more optimistic for 59 of the programs, while Earned Schedule was more optimistic for only 5 programs. We surmise that, had we had the final CPR reports as a part of our data set, that this trend would have continued and EVM would have been more optimistic for close to, if not all, of the programs studied in this research.

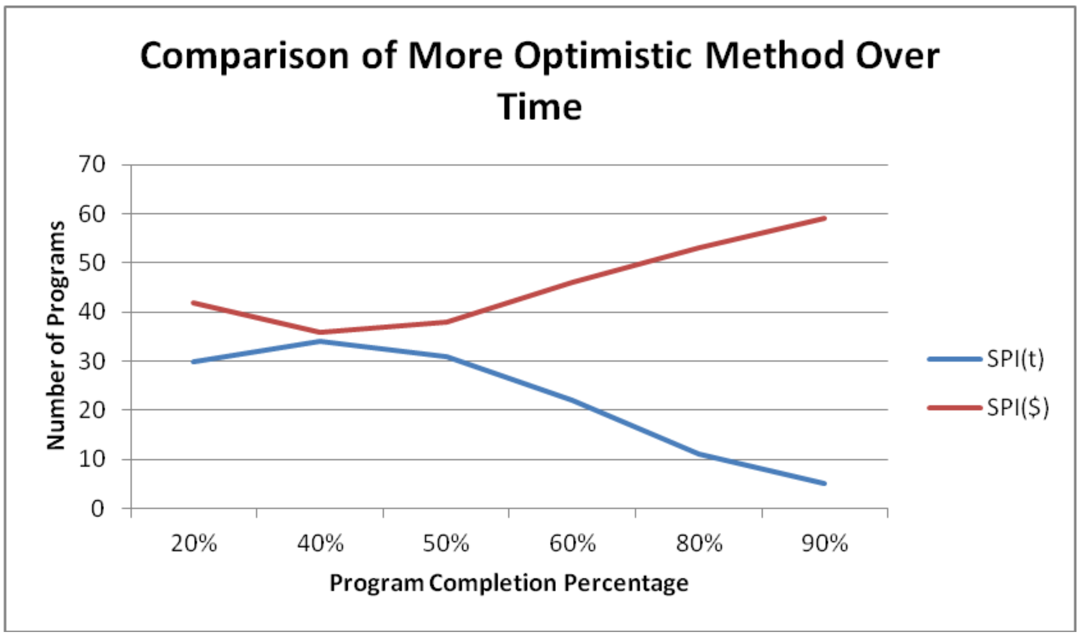

Figure 11: Comparison of More Optimistic Method Over Time

Upon examining the results of this test, we concluded that overall, the SPI($) metric and Earned Value Management system were 41.02% more optimistic as a measure of a program's schedule. While the difference between the two methods early in the program is not as noteworthy, there is significant difference in the two values over the final half of a program. This test helped us answer our second research question, and leads to the conclusion that Earned Schedule is a more accurate schedule predictor for Air Force ACAT I defense acquisition programs.

Test 3b: Analysis of SPI(t) vs. SPI($) Points Closer to the Final Schedule Result

The previous test was one technique to research whether Earned Value Management or Earned Schedule was a more accurate schedule predictor. As an additional means of measuring the accuracy of the EVM and ES methods, the SPI($) and SPI(t) values for each data point are compared to the final schedule result. Whichever method is closer to the final contract over/under run is deemed to be the more "accurate" technique. Of the 1,087 data points studied, Earned Value Management was closer to the final schedule result 37.07% (403 points) of the time, while Earned Schedule was the more accurate technique 57.41% (624 points) of the time. There are 60 instances (5.52%) where the SPI($) and SPI(t) values are the same. A summary of the data points closer to the final schedule result are outlined in Table 11 below:

Table 11: Points Closer to Final Schedule Result

	Number of Occurrences	Percentage of Overall Occurrences (%)
Earned Value Management	403	37.07
Earned Schedule	624	57.41
EVM = ES	60	5.52

The graphic in Figure 12 depicts the frequency of programs having a particular percentage of their data points closer to the final schedule result. For instance, the C130J Weapon System program had 14 points where the SPI($) was closer to the final schedule result than the SPI(t). There were 62 data points for this program, so EVM was closer to the final schedule result 22.58% of the time. According to Figure 12, this program was one of nine programs where the SPI($) value was closest to the final schedule result between 20% and 25% of the time. There is a definite skew to the right in this histogram, with 48 of the 64 programs having less than 50% of their data points closer to the final schedule result.

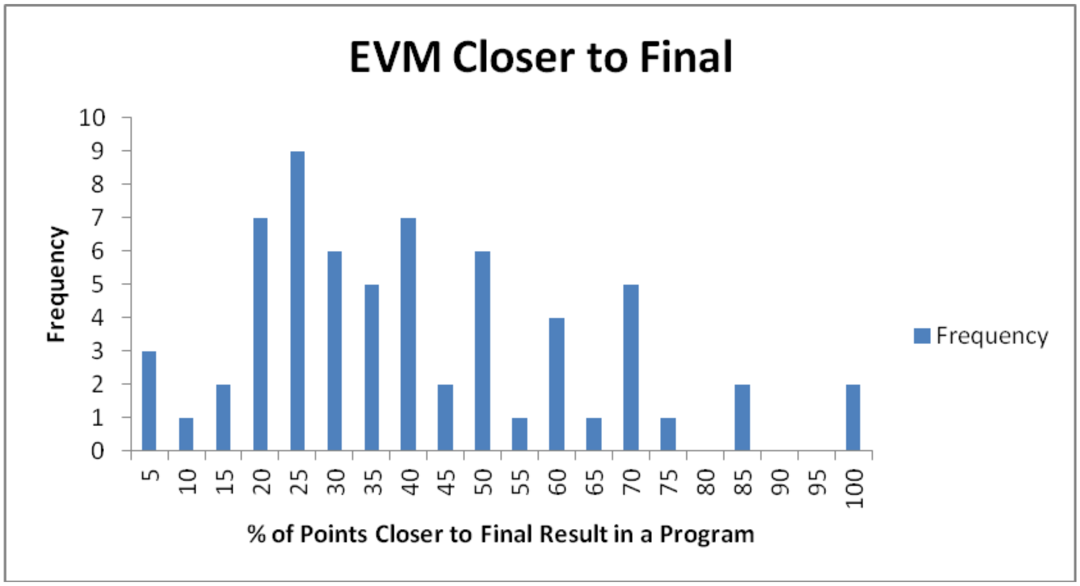

Figure 12: EVM Closer to Final

While Figure 12 shows the frequency of SPI($) values being closer to the final schedule result, Figure 13 shows the same information for the SPI(t) values. To use a different example, the SPI(t) value was closer to the final schedule result for 32 of the 46 (69.57%) data points for the C-17 Research, Development, Test & Evaluation and Lot 1 Production program. According to Figure 13, this program was one of seven programs to have between 65% and 70% of its data points with an SPI(t) value closer to the final schedule result. As this graphic mirrors the graphic in Figure 12 (above), there is a skew to the left. There are only four programs that have less than 30% of their data points with SPI(t) values closer to the final schedule result.

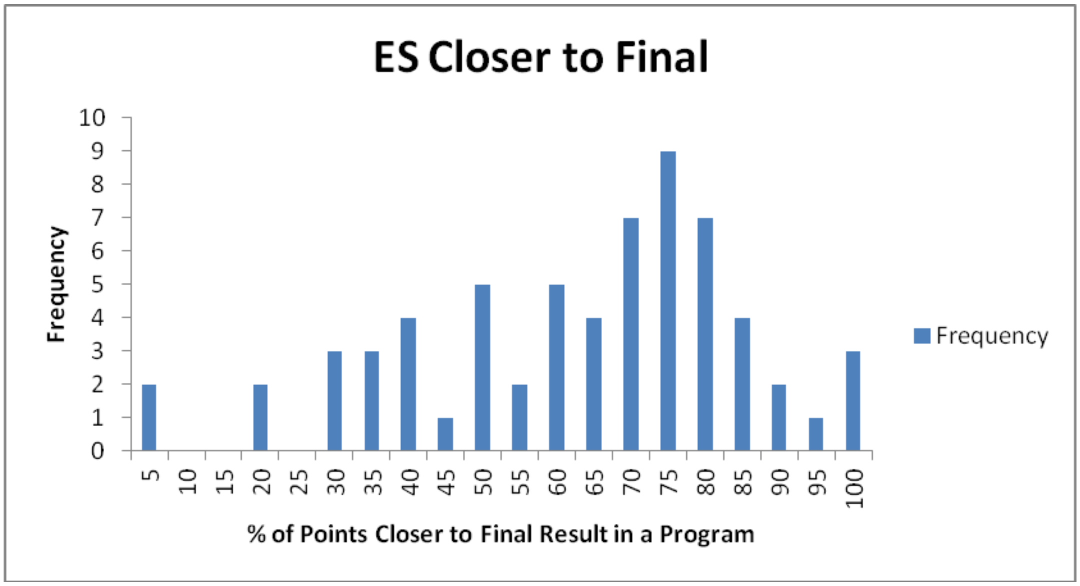

Figure 13: ES Closer to Final

In addition to analyzing the programs at an individual level, we also wanted to determine how the entire portfolio acted over a period of time. As evidenced in Figure 14, there was little difference over the first 40% of a program, the SPI(t) was closer to the final schedule result over the final 60% of the program. A small dip occurred at the 80% completion point, where SPI(t) was closer to the final schedule for only nine more programs than SPI($), after having been closer on fourteen programs at the 60% completion mark. This trend quickly reversed, as the SPI(t) value was closer to the final schedule result for seventeen more programs (39 vs. 22) than the SPI($) value at the 90% completion point.

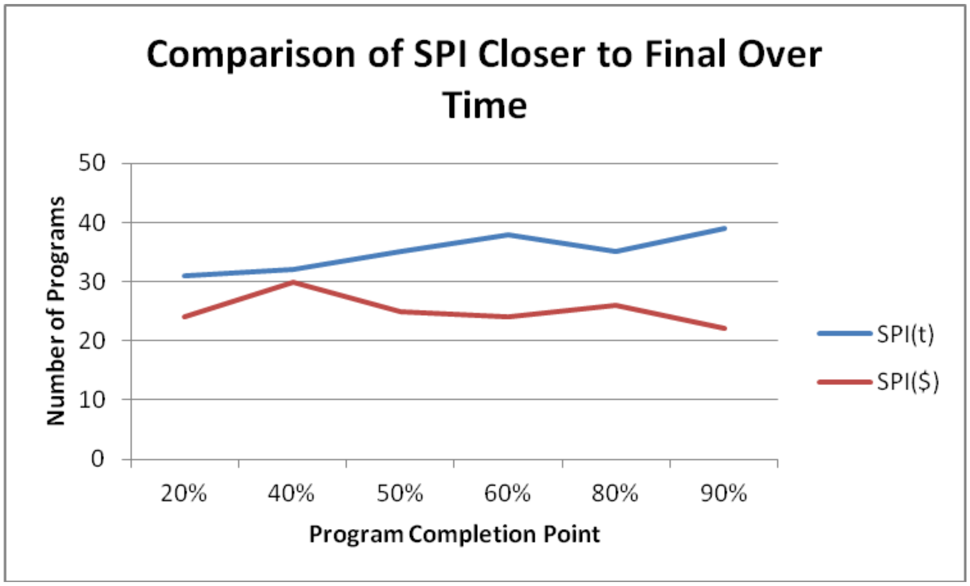

Figure 14: Comparison of SPI Closer to Final Over Time

In summary, the tests comparing the optimism in ES vs. EVM and which method is closer to the final schedule result help answer the original research questions regarding accuracy of the Earned Schedule and Earned Value Management methods. We previously determined that Earned Schedule more frequently determined problems with a program than Earned Value Management, and that EVM was substantially more optimistic with its schedule predictions than ES. This test illustrated that ES is a more accurate predictor of schedule over the course of a program. Earned Schedule gives more accurate signals of what the final SPI value will be over the entire life of a program, lending further to its credibility as a schedule analysis tool for defense acquisition programs.

Test 4: Analysis of TSPI Values

Test 4 analyzes different To Complete Schedule Performance Index (TSPI) values, and determines at which program completion point each contract achieves that value. The TSPI is the SPI efficiency that must be achieved from the current month until the estimated project completion date in order to come in on time. The literature suggests that any program where the TSPI reaches 1.1 in unrecoverable, and stands no chance of meeting its schedule objectives. Of the 64 programs studied in this research, zero met their initial estimated completion date. Of those 64 programs, there were three that never had a TSPI value greater than 1.10 despite not being delivered on time. Two of those three programs also never achieved a TSPI value of greater than 1.05: again, neither of these programs were delivered to the customer on their original estimated completion date. All 64 of the programs studied had a TSPI value greater than 1.01.

TSPI Greater Than 1.10

As the literature suggests, a TSPI value equal to 1.10 indicates that unless an SPI efficiency equal to, or greater than 10% more than the planned value of remaining work on a program is completed, the program will not be delivered on time. Figure 15 depicts the program completion percentages where a TSPI value greater than or equal to 1.10 is first achieved. The mean completion percentage at which a program first achieved a TSPI value of 1.10 or greater is 64.22%. The median percentage completion point is 65.52%. The earliest a program achieved a TSPI value greater than 1.10 is the 22.22% completion point, while the latest was 94.12%.

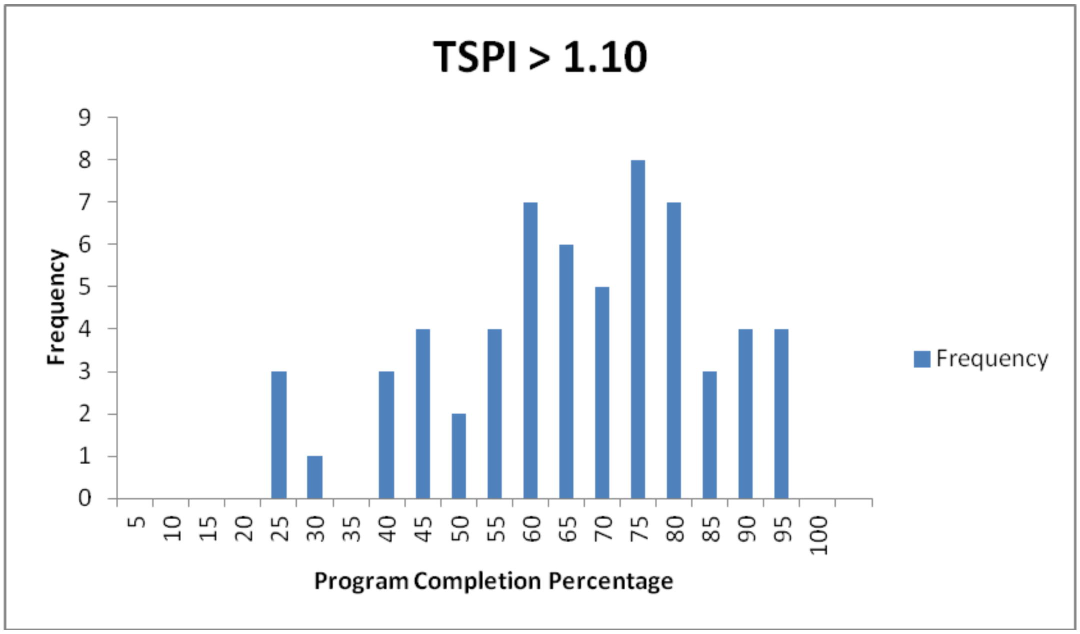

Figure 15: TSPI > 1.10

While it is helpful to have an understanding at the 64% completion point that an additional 10% efficiency is required, this is a point late in the program where many decisions have been made and many dollars expensed: with only one-third of the program remaining, it would be very difficult to operate with such efficiency. With that in mind, we explored if lowering that standard gave an earlier warning signal that a program was in trouble.

TSPI Greater Than 1.05

We chose a TSPI greater than 1.05 as the next threshold to test. A histogram, depicted in Figure 16, is used to visually depict the program completion percentages where a TSPI value greater than or equal to 1.05 is first achieved. The mean completion percentage at which a program first achieved a TSPI value of 1.05 or greater is 50.81%.

The median percentage completion point is 50.39%. The earliest a program achieved a TSPI value greater than 1.05 was the 10.00% completion point, while the latest was 88.24%.

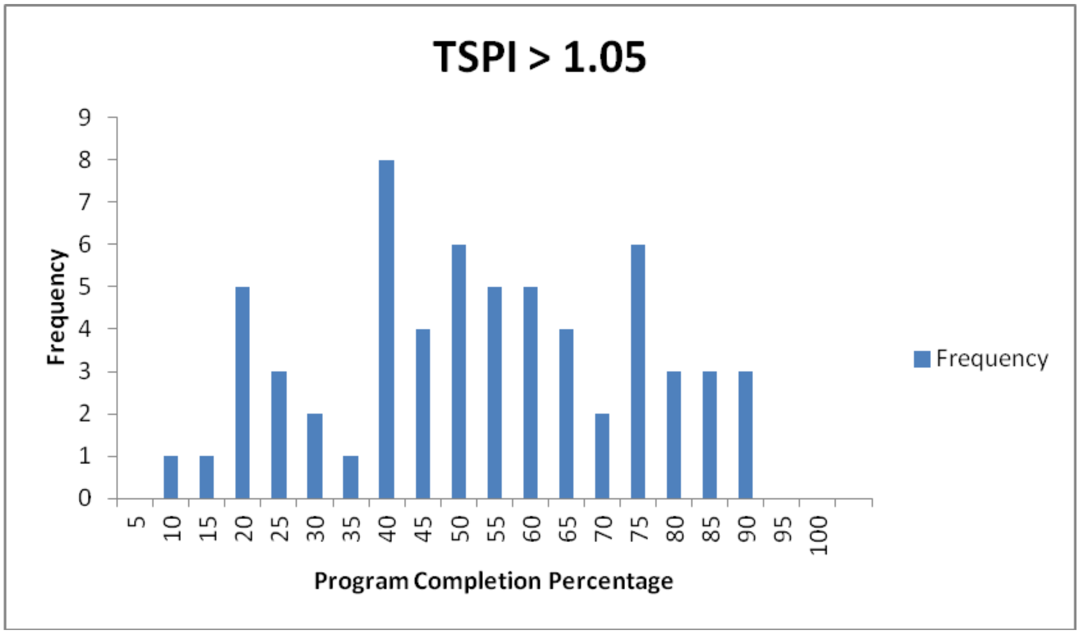

Figure 16: TSPI > 1.05

Of the 64 programs analyzed, the TSPI value reached 1.10 on 61 of the program, while the TSPI value reached 1.05 of 62 of the programs. This indicated that there is only one program where a program reaches the 1.05 threshold where it doesn't later reach the 1.10 threshold. Those programs are likely the meet the TSPI greater than 1.10 value that we argue is too high: using the TSPI greater than 1.05 as the threshold would give the program an earlier indication that action must be taken. There is enhanced value in using the TSPI greater than 1.05 metric in lieu of the currently accepted TSPI greater than

1.10 value, but it still fails to detect a problem until the program is halfway complete. Our final test observed the advantages gained by using a TSPI greater than 1.01.

TSPI Greater Than 1.01

The final threshold we tested measured the first time the TSPI value reached 1.01. A histogram, depicted in Figure 17, is used to visually depict the program completion percentages where a TSPI value greater than or equal to 1.01 is first achieved. The mean completion percentage at which a program first achieved a TSPI value of 1.01 or greater is 24.24%. The median percentage completion point is 18.18%. The earliest a program achieved a TSPI value greater than 1.01 was the 2.94% completion point, while the latest was 75.00%. Of all 64 programs studied, only 6 achieved a TSPI value greater than 1.01 later than the 50% completion point.

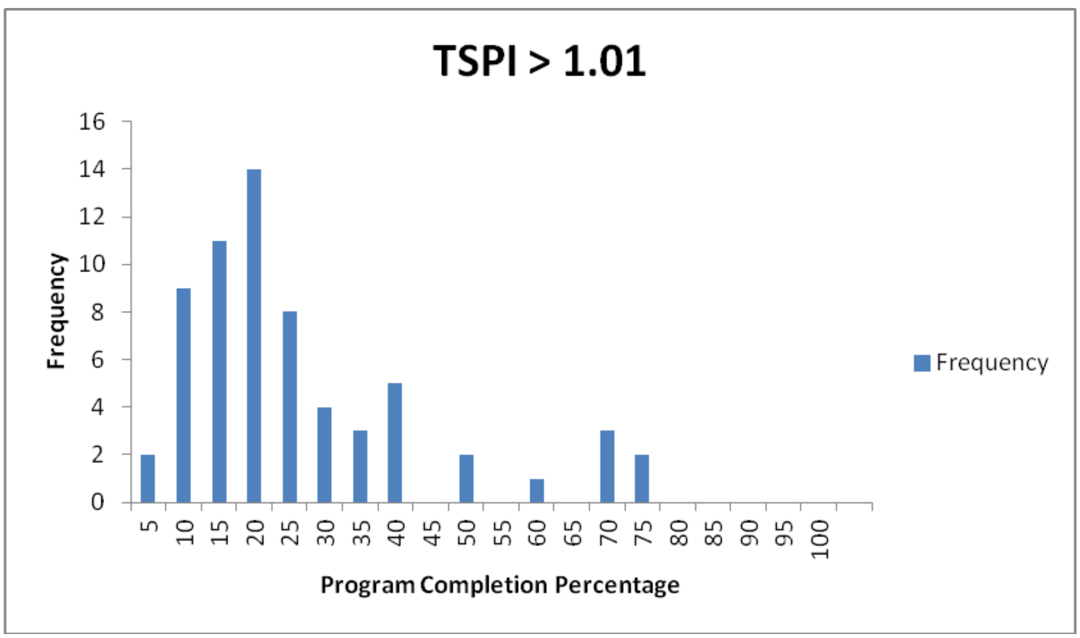

Figure 17: TSPI > 1.01

Of the 64 programs studied, each one reached a TSPI value of greater than 1.01. There were only three instances where the program didn't reach a TSPI value of 1.10. We see that on 61 of 64 occasions (95.31%), a program that reaches a TSPI value of 1.01 will eventually reach a TSPI value of 1.10. Using the TSPI value greater than 1.01 as the "indicator" that a program is in trouble will not falsely identify programs that are in trouble, but rather, will provide the program manager additional time (and resources) to make adjustments to the program to allow for an on-time delivery.

There was one drawback to this approach: there were several occasions where a TSPI would reach a certain threshold, often by only tenths or hundredths a point. The next reporting period would then reduce that TSPI value below the aforementioned threshold. To account for such circumstances, we studied the TSPI values at six thresholds throughout each of the programs: 20%, 40%, 50%, 60%, 80%, and 90%. The TSPI for each contract at each of these thresholds was examined, and if it was equal to, or greater than the TSPI value, it was counted. The results can be seen in Table 12 below:

Table 12: TSPI Comparison Over Time

	20%	40%	50%	60%	80%	90%
TSPI > 1.01	35	46	51	51	62	57
TSPI > 1.05	9	21	31	40	53	55
TSPI > 1.10	3	9	14	25	45	51

The data is also presented graphically in Figure 18 below:

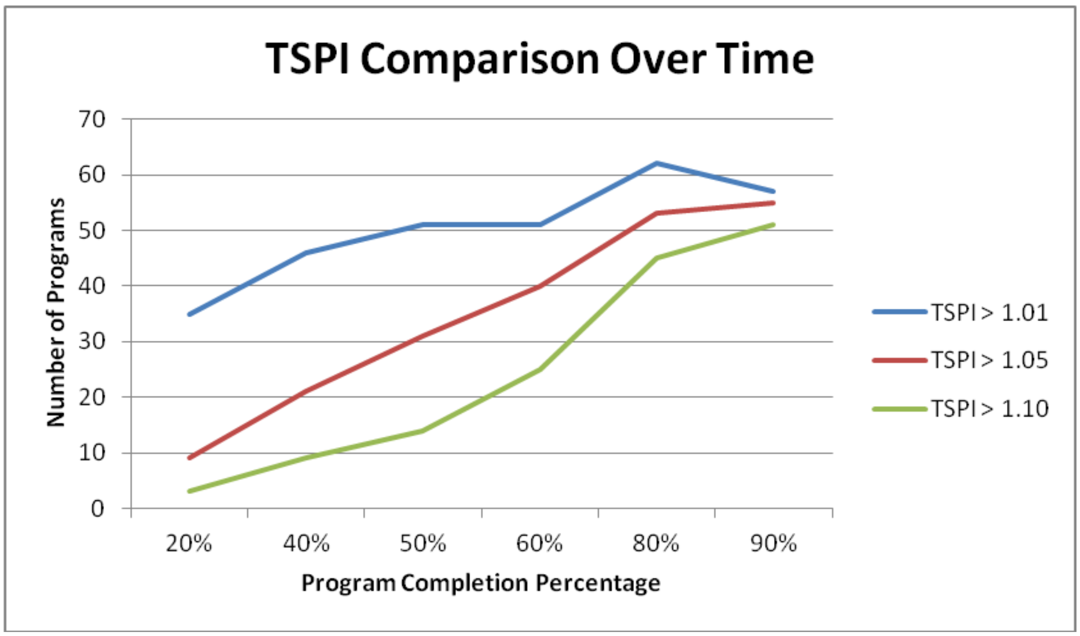

Figure 18: TSPI Comparison Over Time

From this analysis, we determined that there is a significant disparity in the detection capability when a TSPI greater than 1.10 is used rather than TSPI greater than 1.05 or TSPI greater than 1.01, especially over the first 50% of the program. As the program reaches the 60% completion point, the relative improvement of TSPI greater than 1.01 is somewhat reduced, but it is still significantly more accurate than the other thresholds. That margin declines further at the 80% program completion point, and the difference between using a TSPI greater than 1.01, 1.05 or 1.10 is negligible at the 90% program completion point.

One potential critique to using such a low value for the TSPI is that one poor month early in the program will result in a very early detection. That, however, is not necessarily the case: the TSPI takes into account the anticipated remaining duration of a program, and accounts for the program's ability to make up lost efficiency over that period. Using an earlier value for detection also prevents forcing the program manager to make drastic changes to the program.

Test 5: Analysis of SV(t) vs. SV($) Divergence Point

The final test conducted on the data set studied the schedule variance (SV(t) and SV($)) for each contract. For each contract, the SV(t) and SV($) were calculated and graphed on a scatter plot. The scatter plot had two vertical axes: one measured in dollars to accommodate the EV calculation and one measured in time to accommodate the ES calculation. The ES literature identified the behavior of the two schedule variance methodologies: this research attempted to identify at what percentage completion point in a program that the SV(t) and SV($) diverge. The scatter plots illustrated how the SV(t) and SV($) changed over the course of a program. Figure 19 exhibits the scatter plot for a typical program, in this case the B1B Propulsion Lot 1 contract. See Appendix C for SV(t) vs. SV($) scatter plots for all programs.

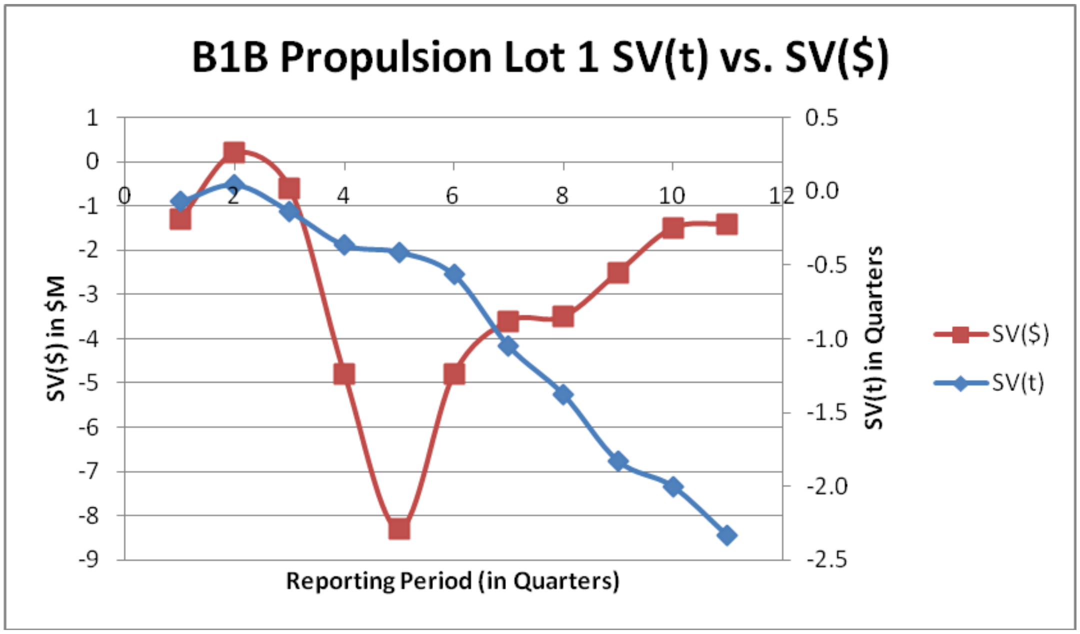

Figure 19: B1B Propulsion Lot 1 SV(t) vs. SV($)

For this analysis, the divergence point on each of the scatter plots is identified, and put in terms of program percentage completion. The divergence occurs when the SV($)is no longer growing and begins its regression towards zero. In Figure 19, the divergence is determined to occur during the 5th reporting period, which was the 45.45% completion point of the program. The final reporting period for this program specifies that the SV($) is -$1.4M, while the SV(t) is -2.33 quarters, or 7 months behind schedule. Were the final CPR data made available by the contractor, we surmise that the SV($) would have regressed closer to zero, while the SV(t) would have reamined constant or continued to decrease.

The divergence points, in terms of percentage, were calculated for each of the programs. Of the 64 programs studied for this research, there were three where there was no discernable divergence point: ALCM Interface, F-15 Airframe Development and F-15 Engine Lot 7 Production. For our analysis, these three data points were removed. The mean divergence point was 50.62% program completion, while the median divergence point was 50.00% completion. The divergence point occurred as early in the program as the 10.34% completion point (C-17 Performance Enhancement) and as late as the 86.67% completion point (F-15 ALQ Update 3). A histogram showing the distribution of the percentage completion points is presented in Figure 20 below:

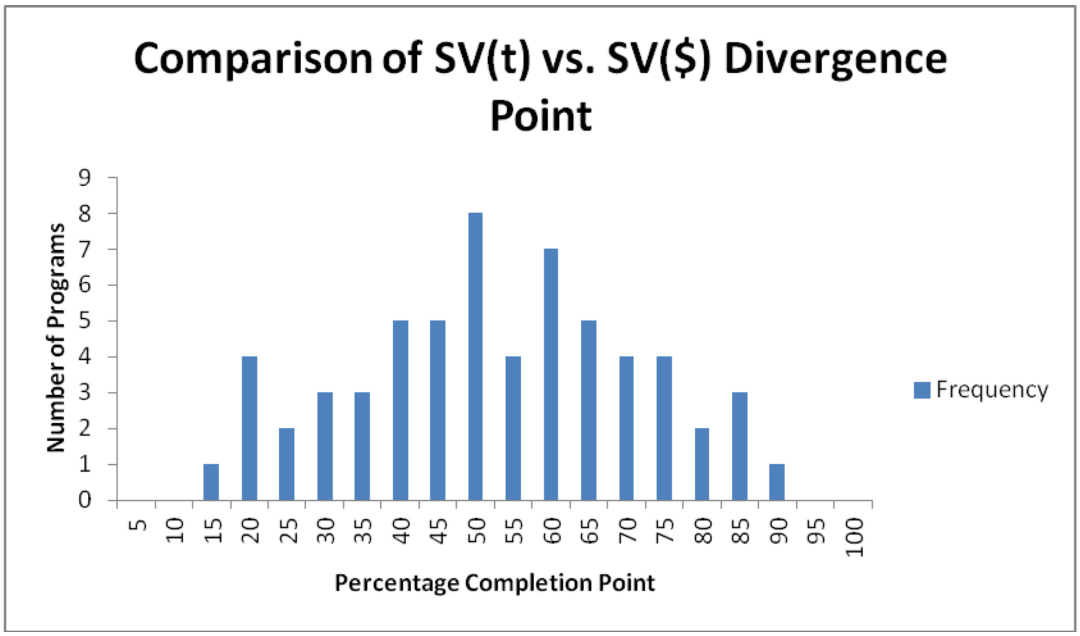

Figure 20: Comparison of SV(t) vs. SV($) Divergence Point

The results of this test indicate that at approximately the 50% program completion point, the SV($) metric provides little value to the decision maker. There are two advantages to using the Earned Schedule metric as a measure of schedule variance. The first, outlined extensively in the literature, is that Earned Schedule puts SV values in terms of time, rather than in terms of dollars. The second advantage, detailed in this research, is that Earned Schedule provides more accurate and realistic schedule variance indicators to the program manager over the second half of a program.

Application to the Critical Path

One criticism to Earned Schedule has been whether it is appplicable when using the Critical Path Method (CPM). The literature, predominantly from Walt Lipke's 2006 paper titled *Applying Earned Schedule to Critical Path Analysis and More*, suggests that Earned Schedule is applicable to the Critical Path. This research investigated Earned Scehdule's applicability to the Critical Path Method on the C130J Block 7.0 Upgrade program. The results show a fundamental disconnect between what Earned Value data is collected and the Critical Path data used by the program office. Our example produced earned value data no deeper than the Work Breakdown Schedule (WBS) level 3 (ex: WBS Element 1.2.3). The Critical Path data is collected much deeper, as detailed as WBS level 7 (ex: WBS Element 1.2.3.4.5.6.7). This disconnect prevented us from conducting a detailed analysis. This does not necessarily suggest that Earned Schedule is inapplicable to the Critical Path Method, but conclusive research demands more detailed Earned Value data.

Conclusion

The result of our qualitative research indicate that Earned Schedule has not been widely implemented in DoD acquisition programs since its introduction a decade ago. While some programs use it as a crosscheck tool, Earned Value Management continues to be the primary schedule analysis tool for all defense acquisiton programs. The results of our quantitative tests conclude that there is a stastistically significant difference between the results of Earned Value Management and Earned Schedule, and that Earned Schedule provides more timely and more accurate schedule predictions than traditional DoD methods. The next chapter discusses the implications of these findings and recommendations for future implementation of Earned Schedule.

V. Conclusions and Recommendations

Introduction

Earned Value Management has long been the preferred tool for program management and cost/schedule forecasting on United States Department of Defense (DoD) programs. In 2003, Walt Lipke, in his seminal paper *Schedule is Different*, identified EVM's two major shortcomings as schedule analysis tool: it quantifies schedule overages in terms of dollars, rather than in terms of time, and it is effectively useless over the final third of a program. Earned Schedule uses the same data collected for Earned Value Management calculations, but focuses on giving the program manager more useful information that overcomes the limitations of EVM.

Our research concluded that there is a statistical difference between the results of Earned Schedule and Earned Value Management tests conducted on Major Defense Acquisition Programs from Aeronautical Systems Center. Additionally, we answered our original research questions first introduced in Chapter 1.

Research Questions Answered

Our first question was, "To what extent is Earned Schedule currently utilized in Air Force ACAT I acquisition programs?" We determined that no System Program Offices (SPO), regardless of product center, uses Earned Schedule as their primary schedule analysis tool. Of the seventeen program offices that responded to our inquiry, six program offices use Earned Schedule in some capacity. Those who use Earned

Schedule use it exclusively as a secondary analysis tool, and as a cross-check to the results obtained from the Earned Value Management analysis.

Our next question asked, "Does Earned Schedule provide more accurate schedule predictions than traditional DoD methods?" We determined that Earned Schedule was a more accurate predictor of schedule than Earned Value Management. At the 50% completion point, the average SPI($) metric was .958, while the average SPI(t) metric was .934. Earned Schedule showed its value as a more accurate schedule predictor even later in the program: at the 90% completion point, the average SPI($) was .974, while the SPI(t) for the same data was .923. Another measure of how ES is more accurate than EVM was in how frequently each suggested the program was "in trouble." We determined that any SPI value below .90 meant the program was in trouble. Of the 1,087 points we studied, EVM indicated only 135 points (12.42%) were below .90, while ES disclosed that 220 points (20.24%) were determined to be in trouble. Another measure compared how ES predicted problems over time compared to EVM: at the 60% completion point, ES predicted 14 programs were in trouble, while EVM predicted 5 programs were in trouble. More telling, at the 90% completion point, ES indicated 20 programs were in trouble while EVM predicted only 1 would come in behind schedule. A further measure we used to determine which method was more accurate was the frequency of which method was more optimistic. The more optimistic measure was determined to be the higher of the two SPI values: the higher SPI value indicates the program is more likely to come in on time. Of our 1,087 data points, Earned Value Management was more optimistic for 646 (59.43%) of the data points, while ES was more optimistic for 381 (35.05%) of the data points. Earned Schedule proved to be more accurate later in the life of a program: EVM was more optimistic 38 times, compared to 31 programs, at the 50% completion point. However, at the 90% completion point, EVM was more optimistic on 59 programs, while Earned Schedule was more optimistic on only 5. Our series of tests confirmed that Earned Schedule is a more accurate schedule predictor than the Earned Value Management technique currently employed by the Department of Defense on Major Defense Acquisition Programs.

Our final question was, "Does Earned Schedule provide more timely schedule predictions than traditional DoD methods?" We concluded that Earned Schedule was a more timely predictor of schedule overages than Earned Value Management. While on average, Earned Value Management first detected a problem in a program (SPI value below .90) at the 17.89% completion point as opposed to Earned Schedule detected at the 29.89% completion point, this failed to account for the 9 programs where EVM neglected to identify a problem existed where ES did. Further, at the 20% completion point, EVM only identified 12 programs that were "in trouble," while ES detected issues with 20 programs. A comparison of the SPI Closer to the Final Schedule in Figure 14 concluded that Earned Schedule was closer to the final result more frequently than Earned Value Management as early as the 20% program completion point. The further the program progressed, the more frequently the SPI(t) was closer to the final schedule. Finally, it was determined that the SV(t) and SV($) had an average divergence point of 50.62%. This conclusion dictates that the SV($) metric is comparatively useless over the final half of the program, while Earned Schedule provides meaningful information over the entire life of a program.

An ancillary finding for our research came when researching the To Complete Schedule Performance Index (TSPI). The literature suggests that when the TSPI reaches 1.10, the program manager must take action to improve the schedule performance in order to deliver the system on time. Our research concluded that using a TSPI of 1.10 didn't alert the program manager, on average, until the 64.22% completion point that a program was experiencing issues. Rather, using a TSPI threshold of greater than 1.01 gave the program manager an indication at the 24.24% completion point that program was in trouble. Of the 64 programs studied, 63 programs achieved a TSPI value greater than 1.10, while 60 programs reached a TSPI greater than 1.01. Therefore, using a TSPI of greater than 1.01 as an indicator of "trouble," would only designate 3 programs with issues that a TSPI of 1.10 failed to, and would alert the program manager, on average, 40% sooner that action must be taken to improve the program's performance.

Recommendations

We recommend that program offices implement Earned Schedule as, at the very least, a supplementary tool for their schedule analysis. Earned Schedule has been on the fringe of gaining acceptance in the defense acquisition community for several years, but we recommend escalating its usage in the program office. One shortcoming to this research is the inability to map the Earned Schedule data to the critical path, but we consider Earned Schedule to be a strong tool for schedule prediction at the summary/contract level.

Another recommendation is to include Earned Schedule in the Defense Acquisition University (DAU) curriculum. Several analysts noted that shrinking workforces are creating work environments where on-the-job training (OJT) is less viable. Introducing Earned Schedule into the DAU curriculum would allow analysts in the program offices the opportunity to learn the basics of Earned Schedule, how to perform the analysis and calculations, and give them insight into what these new metrics offer their program managers.

Future Research

Our research was conducted on the system platforms from a single product center, and was accomplished at a general level. We recommend conducting parallel research on the other two major system platforms: Electronic systems, as well as Space and Missiles systems. There are several differences between the particular platforms that could lead to dissimilar results than what we found: the size of the programs, the length of the acquisition process, the integration of Commercial Off The Shelf (COTS) products, and the level of security classification. Another future opportunity builds off of this research: a comparison of the different classes of aeronautical platforms. Researching if there is a significant difference between implementing Earned Schedule versus Earned Value Management on Fighter Aircraft, Bomber Aircraft, Cargo Aircraft, Unmanned Aircraft, and if the data becomes available, Rotary Wing Aircraft. Again, there are differences between these platforms based on technological sophistication and number of units produced. An additional proposal for future research would be very similar to the comparison of different classes of aeronautical platforms: a comparison of how well

Earned Schedule performs as a schedule predictor versus Earned Value Management for the difference prime contractors used by the DoD.

There was one avenue we hoped to pursue but time prevented us. We noticed, anecdotally, that there seemed to be an inflection point where SPI($) and SPI(t) diverted: SPI($) moving towards 1.0, and SPI(t) away from it. We recommend researching at what program completion point that inflection occurs, as well as researching a potential root cause for such an inflection.

Appendix A

CLASSIFICATION (When Filled In)

CONTRACT PERFORMANCE REPORT
FORMAT 1 - WORK BREAKDOWN STRUCTURE **DOLLARS IN ____________________**

FORM APPROVED
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 3.1hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. SUBMIT COMPLETED FORMS IN ACCORDANCE WITH CONTRACTUAL REQUIREMENTS .**

1. CONTRACTOR	2. CONTRACT		3. PROGRAM	4. REPORT PERIOD
a. NAME	a. NAME		a. NAME	a. FROM (YYYYMMDD)
b. LOCATION (Address and ZIP Code)	b. NUMBER		b. PHASE	b. TO (YYYYMMDD)
	c. TYPE	d. SHARE RATIO	c. EVMS ACCEPTANCE NO YES (YYYYMMDD)	

5. CONTRACT DATA

a. QUANTITY	b. NEGOTIATED COST	c. ESTIMATED COST OF AUTHORIZED UNPRICED WORK	d. TARGET PROFIT/ FEE	e. TARGET PRICE	f. ESTIMATED PRICE	g. CONTRACT CEILING	h. ESTIMATED CONTRACT CEILING	i. DATE OF OTB/OTS (YYYYMMDD)

6. ESTIMATED COST AT COMPLETION	MANAGEMENT ESTIMATE AT COMPLETION (1)	CONTRACT BUDGET BASE (2)	VARIANCE (3)
a. BEST CASE			
b. WORST CASE			
c. MOST LIKELY			

7. AUTHORIZED CONTRACTOR REPRESENTATIVE

a. NAME (Last, First, Middle Initial)	b. TITLE
c. SIGNATURE	d. DATE SIGNED (YYYYMMDD)

8. PERFORMANCE DATA

ITEM	CURRENT PERIOD					CUMULATIVE TO DATE					REPROGRAMMING ADJUSTMENTS			AT COMPLETION		
	BUDGETED COST		ACTUAL COST	VARIANCE		BUDGETED COST		ACTUAL COST	VARIANCE							
	WORK SCHEDULED	WORK PERFORMED	WORK PERFORMED	SCHEDULE	COST	WORK SCHEDULED	WORK PERFORMED	WORK PERFORMED	SCHEDULE	COST	COST VARIANCE	SCHEDULE VARIANCE	BUDGET	BUDGETED	ESTIMATED	VARIANCE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12a)	(12b)	(13)	(14)	(15)	(16)
a. WORK BREAKDOWN STRUCTURE ELEMENT																
b. COST OF MONEY																
c. GENERAL AND ADMINISTRATIVE																
d. UNDISTRIBUTED BUDGET																
e. SUB TOTAL (PERFORMANCE MEASUREMENT BASELINE)																
f. MANAGEMENT RESERVE																
g. TOTAL																

9. RECONCILIATION TO CONTRACT BUDGET BASE

a. VARIANCE ADJUSTMENT																
b. TOTAL CONTRACT VARIANCE																

DD FORM 2734/1, MAR 05 LOCAL REPRODUCTION AUTHORIZED.

CLASSIFICATION (When Filled In)

Figure 21: Example Format 1

CLASSIFICATION (When Filled In)

CONTRACT PERFORMANCE REPORT
FORMAT 2 - ORGANIZATIONAL CATEGORIES

DOLLARS IN ____________________

FORM APPROVED
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average .6 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. SUBMIT COMPLETED FORMS IN ACCORDANCE WITH CONTRACTUAL REQUIREMENTS**.

1. CONTRACTOR	2. CONTRACT		3. PROGRAM	4. REPORT PERIOD
a. NAME	a. NAME		a. NAME	a. FROM (YYYYMMDD)
b. LOCATION (Address and ZIP Code)	b. NUMBER		b. PHASE	b. TO (YYYYMMDD)
	c. TYPE	d. SHARE RATIO	c. EVMS ACCEPTANCE NO YES (YYYYMMDD)	

5. PERFORMANCE DATA

ITEM	CURRENT PERIOD					CUMULATIVE TO DATE					REPROGRAMMING ADJUSTMENTS			AT COMPLETION		
	BUDGETED COST		ACTUAL COST	VARIANCE		BUDGETED COST		ACTUAL COST	VARIANCE							
	WORK SCHEDULED	WORK PERFORMED	WORK PERFORMED	SCHEDULE	COST	WORK SCHEDULED	WORK PERFORMED	WORK PERFORMED	SCHEDULE	COST	COST VARIANCE	SCHEDULE VARIANCE	BUDGET	BUDGETED	ESTIMATED	VARIANCE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12a)	(12b)	(13)	(14)	(15)	(16)
a. ORGANIZATIONAL CATEGORY																
b. COST OF MONEY																
c. GENERAL AND ADMINISTRATIVE																
d. UNDISTRIBUTED BUDGET																
e. SUB TOTAL (PERFORMANCE MEASUREMENT BASELINE)																
f. MANAGEMENT RESERVE																
g. TOTAL																

DD FORM 2734/2, MAR 05

LOCAL REPRODUCTION AUTHORIZED.

CLASSIFICATION (When Filled In)

Figure 22: Example Format 2

CLASSIFICATION (When Filled In)

CONTRACT PERFORMANCE REPORT
FORMAT 3 - BASELINE

DOLLARS IN ______________

FORM APPROVED
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 6.3 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. SUBMIT COMPLETED FORMS IN ACCORDANCE WITH CONTRACTUAL REQUIREMENTS**.

1. CONTRACTOR	2. CONTRACT		3. PROGRAM	4. REPORT PERIOD
a. NAME	a. NAME		a. NAME	a. FROM (YYYYMMDD)
b. LOCATION (Address and ZIP Code)	b. NUMBER		b. PHASE	b. TO (YYYYMMDD)
	c. TYPE	d. SHARE RATIO	c. EVMS ACCEPTANCE NO YES (YYYYMMDD)	

5. CONTRACT DATA

a. ORIGINAL NEGOTIATED COST	b. NEGOTIATED CONTRACT CHANGES	c. CURRENT NEGOTIATED COST (a. + b.)	d. ESTIMATED COST OF AUTHORIZED UNPRICED WORK	e. CONTRACT BUDGET BASE (c. + d.)	f. TOTAL ALLOCATED BUDGET	g. DIFFERENCE (e. - f.)

h. CONTRACT START DATE (YYYYMMDD)	i. CONTRACT DEFINITIZATION DATE (YYYYMMDD)	j. PLANNED COMPLETION DATE (YYYYMMDD)	k. CONTRACT COMPLETION DATE (YYYYMMDD)	l. ESTIMATED COMPLETION DATE (YYYYMMDD)

6. PERFORMANCE DATA

ITEM	BCWS CUMULA-TIVE TO DATE	BCWS FOR REPORT PERIOD	BUDGETED COST FOR WORK SCHEDULED (BCWS) (Non-Cumulative)											UNDIS-TRIBUTED BUDGET	TOTAL BUDGET
			SIX MONTH FORCAST						ENTER SPECIFIED PERIODS						
			+1	+2	+3	+4	+5	+6							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
a. PERFORMANCE MEASUREMENT BASELINE (Beginning of Period)															
b. BASELINE CHANGES AUTHORIZED DURING REPORT PERIOD															
c. PERFORMANCE MEASUREMENT BASELINE (End of Period)															
7. MANAGEMENT RESERVE															
8. TOTAL															

DD FORM 2734/3, MAR 05

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CLASSIFICATION (When Filled In)

Figure 23: Example Format 3

CLASSIFICATION (When Filled In)

CONTRACT PERFORMANCE REPORT
FORMAT 4 - STAFFING

FORM APPROVED
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 5 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. SUBMIT COMPLETED FORMS IN ACCORDANCE WITH CONTRACTUAL REQUIREMENTS**.

1. CONTRACTOR	2. CONTRACT		3. PROGRAM	4. REPORT PERIOD
a. NAME	a. NAME		a. NAME	a. FROM (YYYYMMDD)
b. LOCATION (Address and ZIP Code)	b. NUMBER		b. PHASE	b. TO (YYYYMMDD)
	c. TYPE	d. SHARE RATIO	c. EVMS ACCEPTANCE NO YES (YYYYMMDD)	

5. PERFORMANCE DATA (All figures in whole numbers)

ORGANIZATIONAL CATEGORY	ACTUAL CURRENT PERIOD	ACTUAL END OF CURRENT PERIOD (Cumulative)	FORECAST (Non-Cumulative)											AT COMPLETION
			SIX MONTH FORECAST BY MONTH (Enter Names of Months)						ENTER SPECIFIED PERIODS					
			+1	+2	+3	+4	+5	+6						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
6. TOTAL DIRECT														

DD FORM 2734/4, MAR 05

LOCAL REPRODUCTION AUTHORIZED.

CLASSIFICATION (When Filled In)

Figure 24: Example Format 4

CLASSIFICATION (When Filled In)

CONTRACT PERFORMANCE REPORT FORMAT 5 - EXPLANATIONS AND PROBLEM ANALYSES			FORM APPROVED OMB No. 0704-0188
The public reporting burden for this collection of information is estimated to average 36 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. SUBMIT COMPLETED FORMS IN ACCORDANCE WITH CONTRACTUAL REQUIREMENTS.**			
1. CONTRACTOR	2. CONTRACT	3. PROGRAM	4. REPORT PERIOD
a. NAME	a. NAME	a. NAME	a. FROM (YYYYMMDD)
b. LOCATION (Address and ZIP Code)	b. NUMBER	b. PHASE	b. TO (YYYYMMDD)
	c. TYPE / d. SHARE RATIO	c. EVMS ACCEPTANCE NO YES (YYYYMMDD)	

5. EVALUATION

Discussion should include but is not limited to:

Summary Analysis

- Summary of Overall Contract Variances
- Differences between EAC's (Blocks 6.a, 6.b, 6.c, or Block 8.15)
- Changes in Undistributed Budget
- Changes in Management Reserve
- Significant timephasing shifts in Baseline (BCWS) (Format 3)
- Significant timephasing shifts or Overall Changes in Forecasted Staffing (Format 4)
- Discussion of Over Target Baseline and/or Over Target Schedule incorporation

Analysis of Significant Variances: (identify and describe each)

- Type and Magnitude of Variance
- Explanation of Significant Reasons
- Effect on Immediate Task
- Effect on Total Contract
- Corrective Actions Taken or Planned

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CLASSIFICATION (When Filled In)

Figure 25: Example Format 5

Appendix B

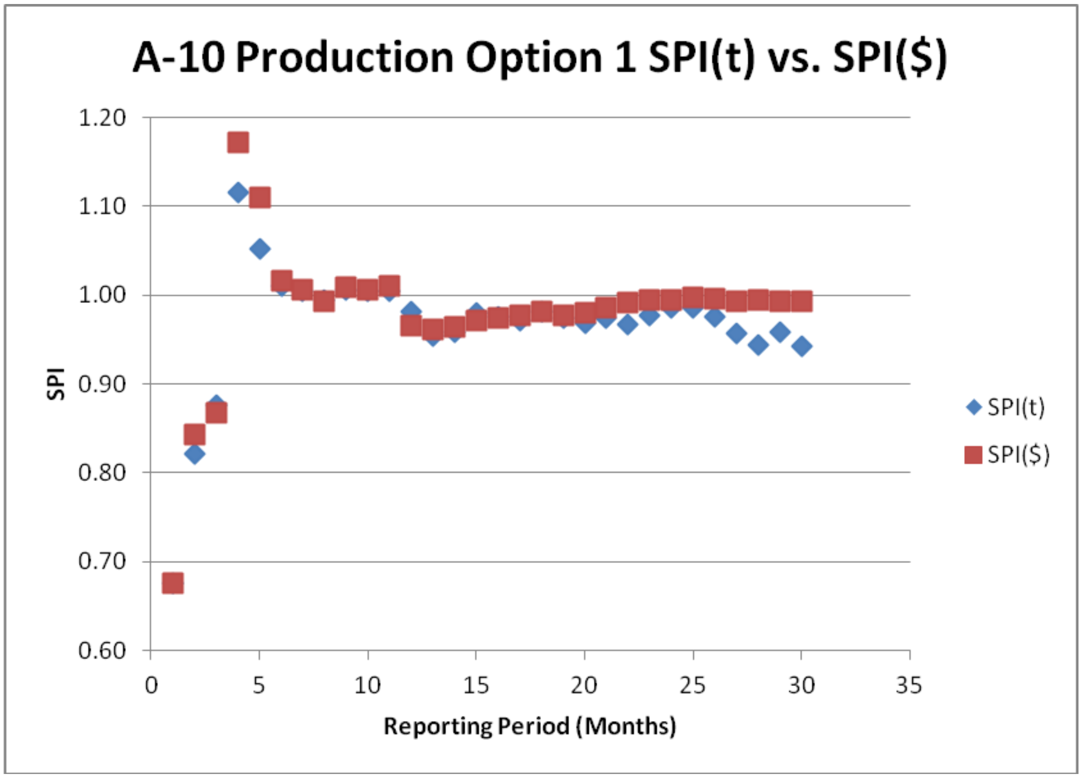

Figure 26: A-10 Production Option 1 SPI(t) vs. SPI($)

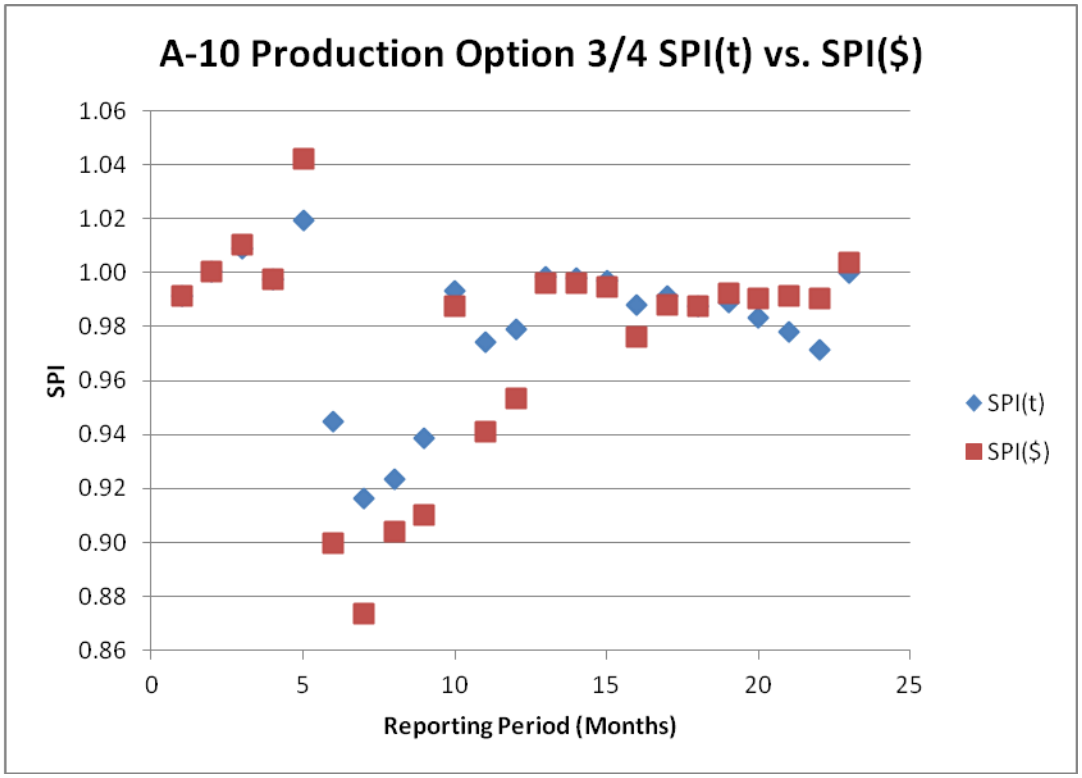

Figure 27: A-10 Production Option 3/4 SPI(t) vs. SPI($)

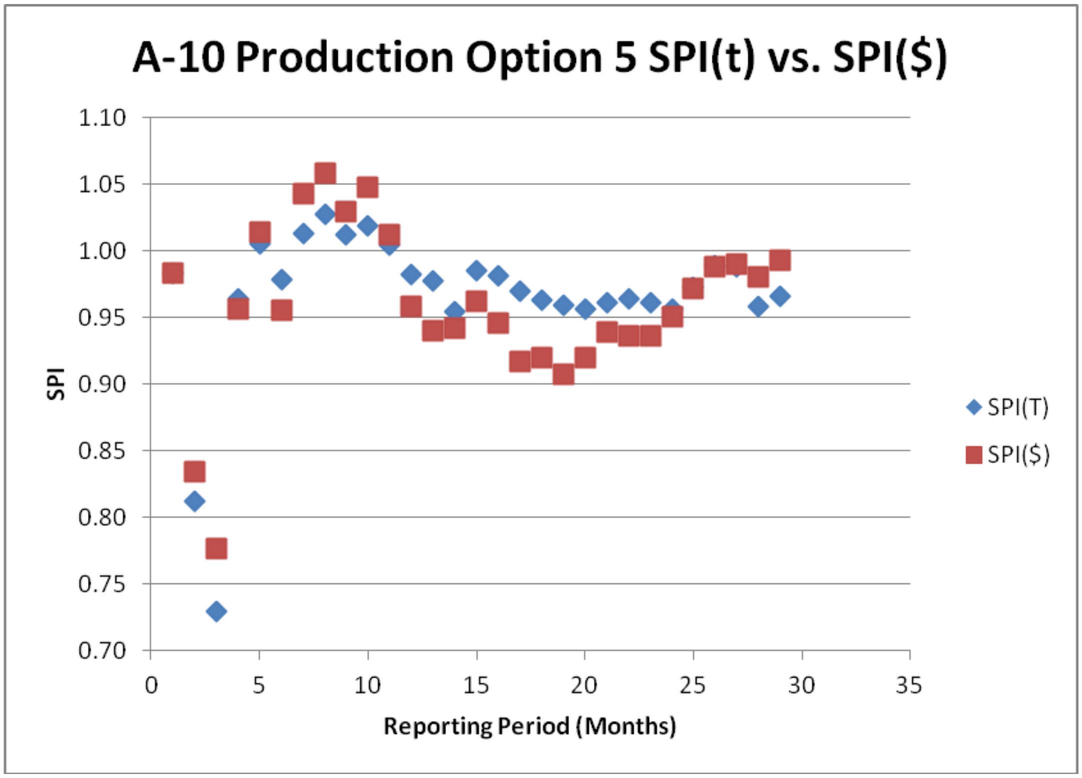

Figure 28: A-10 Production Option 5 SPI(t) vs. SPI($)

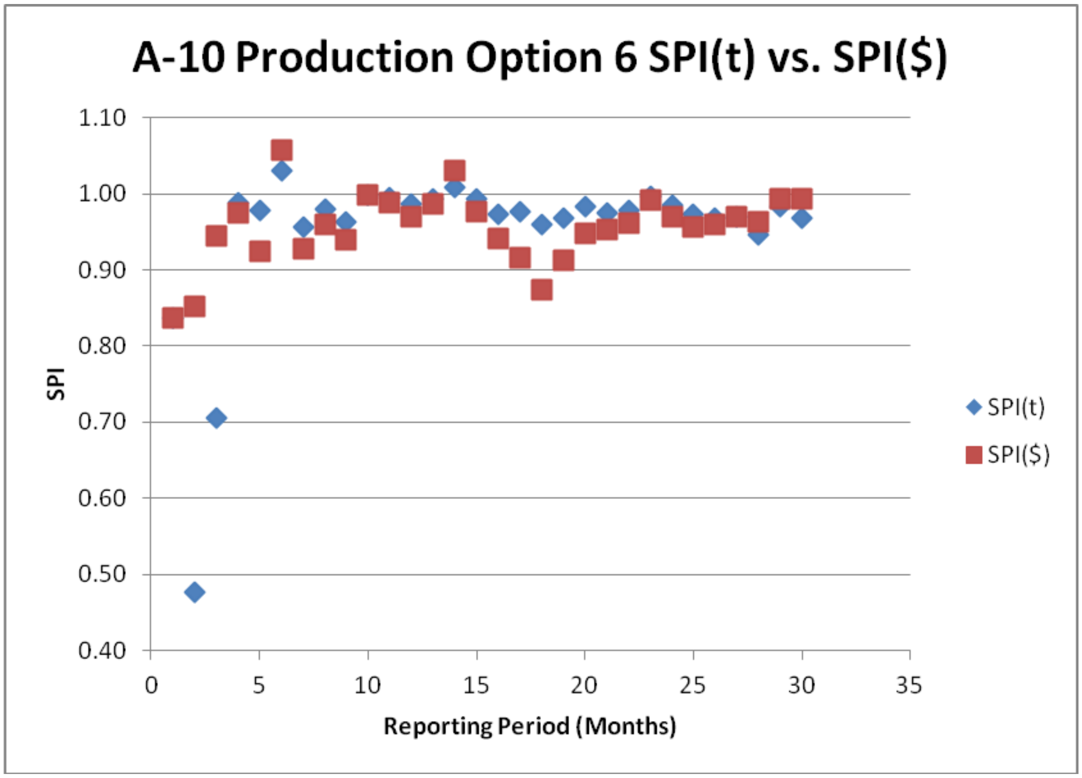

Figure 29: A-10 Production Option 6 SPI(t) vs. SPI($)

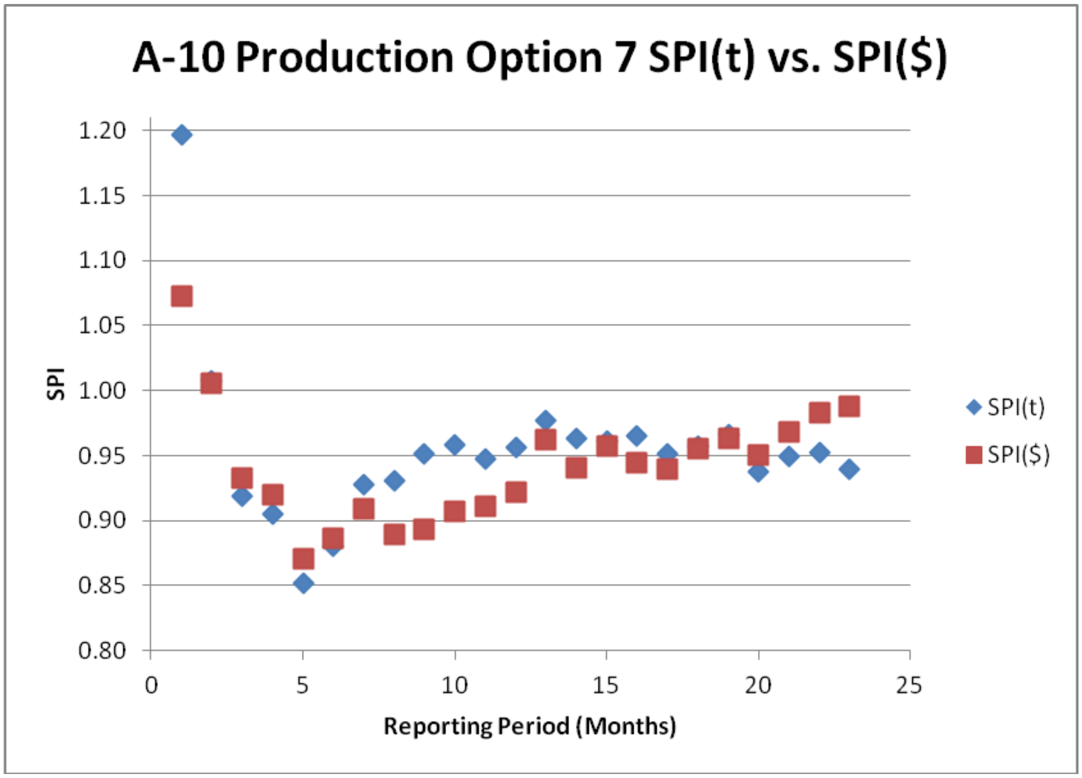

Figure 30: A-10 Production Option 7 SPI(t) vs. SPI($)

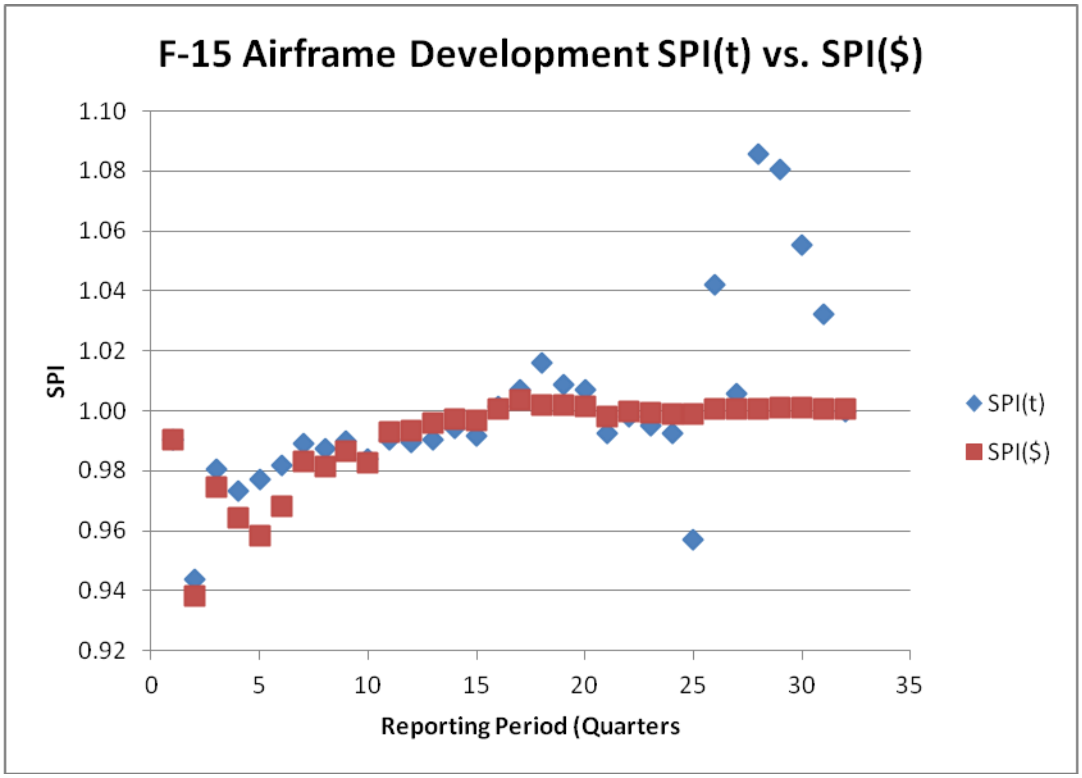

Figure 31: F-15 Airframe Development SPI(t) vs. SPI($)

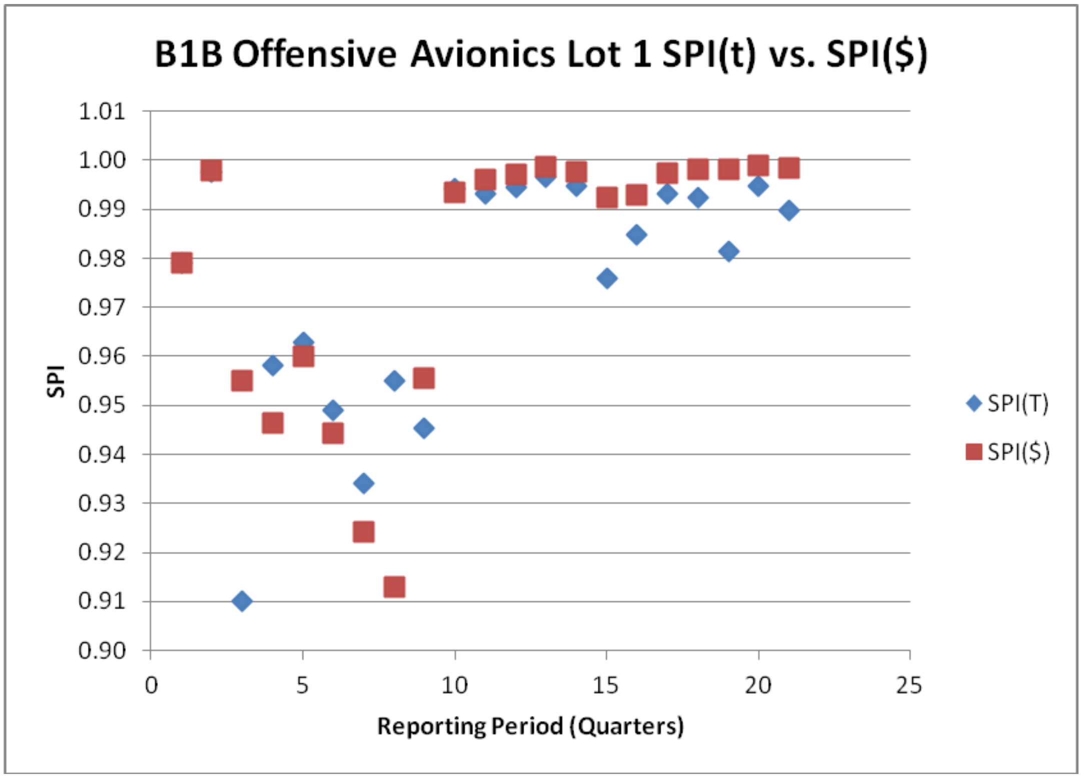

Figure 32: B1B Offensive Avionics Lot 1 SPI(t) vs. SPI($)

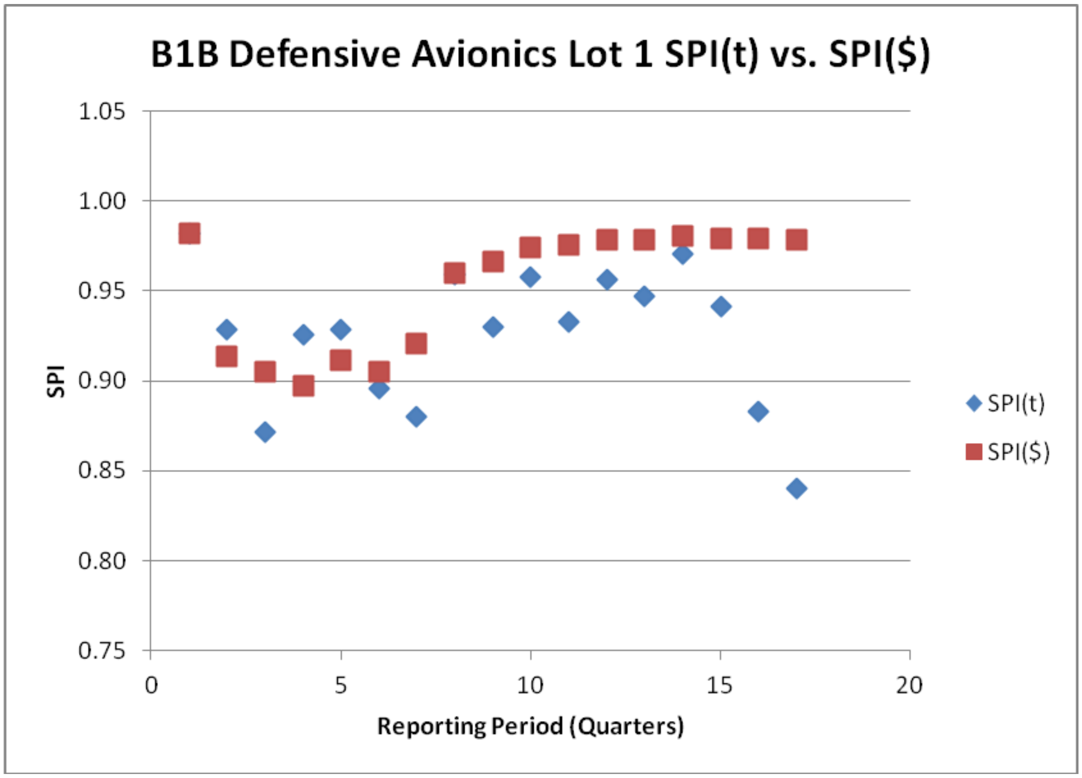

Figure 33: B1B Defensive Avionics Lot 1 SPI(t) vs. SPI($)

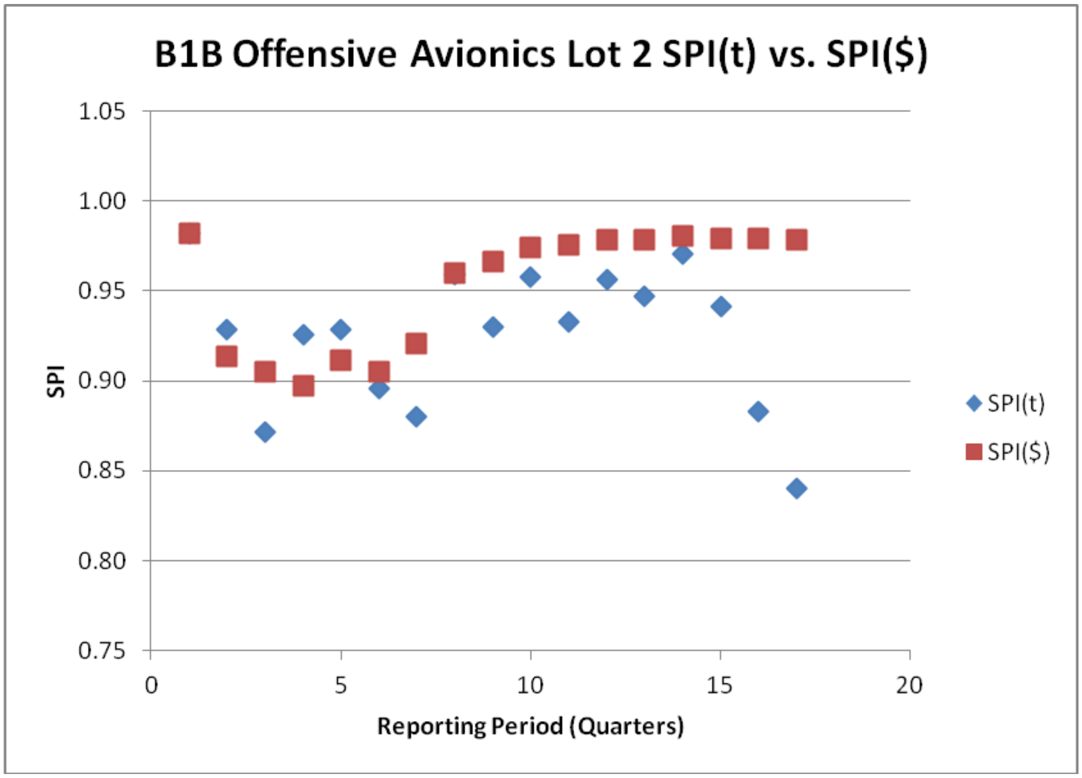

Figure 34: B1B Offensive Avionics Lot 2 SPI(t) vs. SPI($)

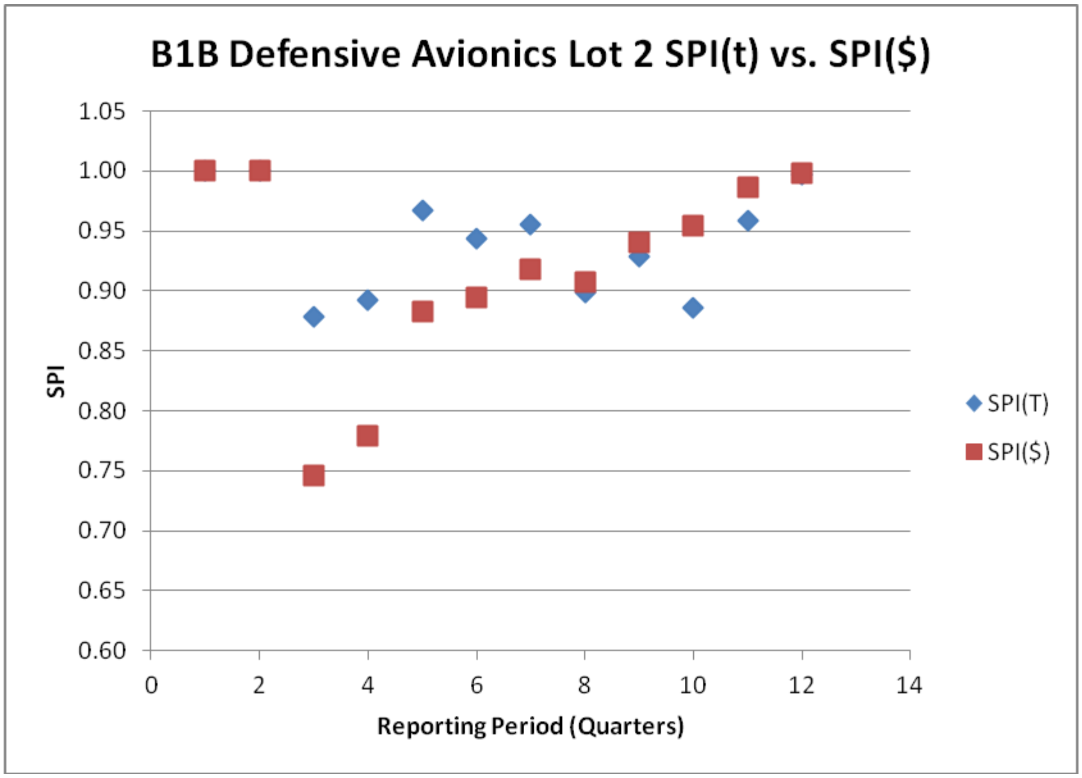

Figure 35: B1B Defensive Avionics Lot 2 SPI(t) vs. SPI($)

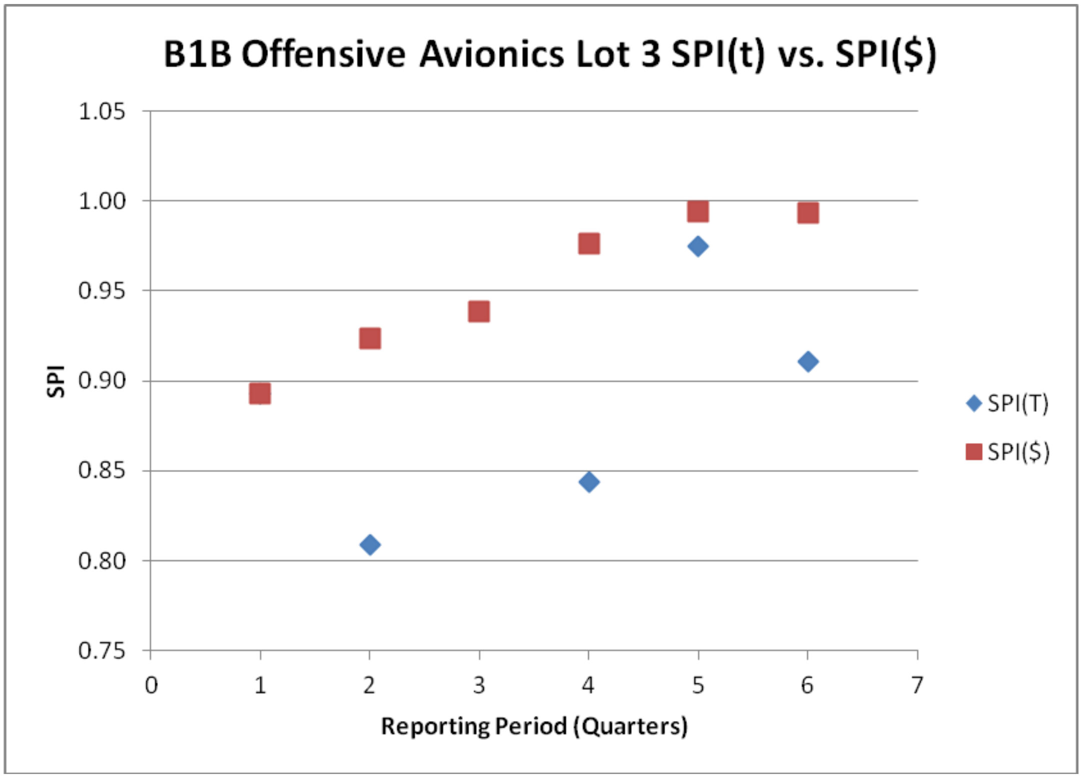

Figure 36: B1B Offensive Avionics Lot 3 SPI(t) vs. SPI($)

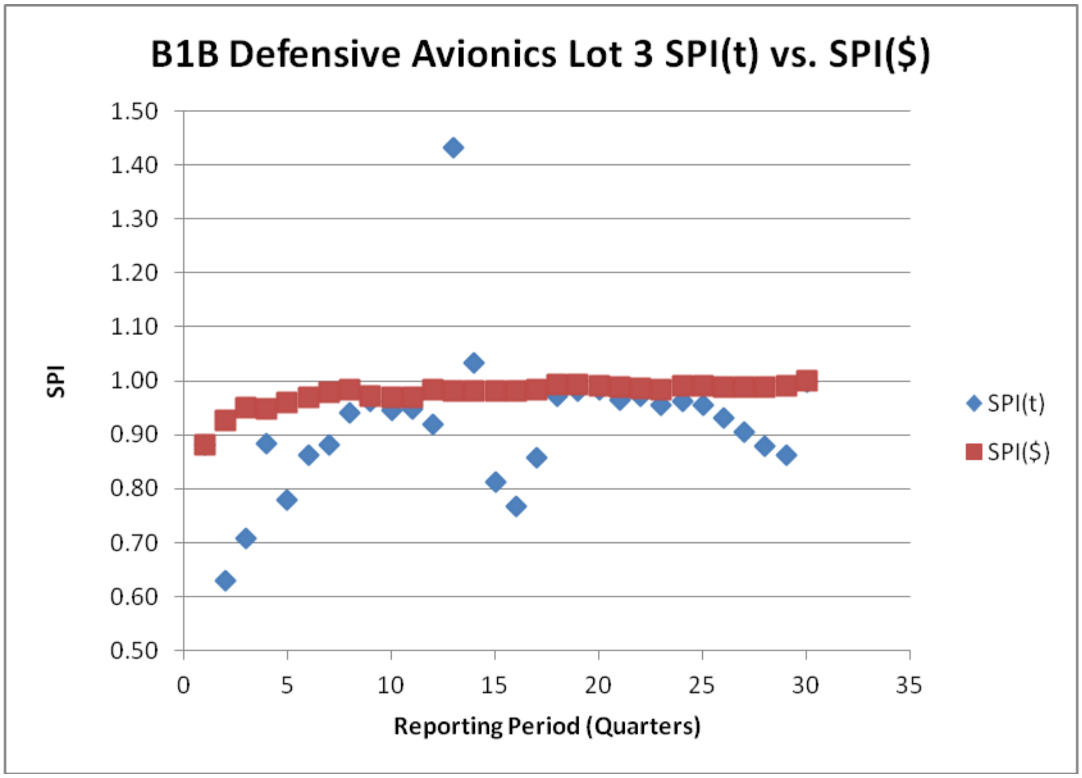

Figure 37: B1B Defensive Avionics Lot 3 SPI(t) vs. SPI($)

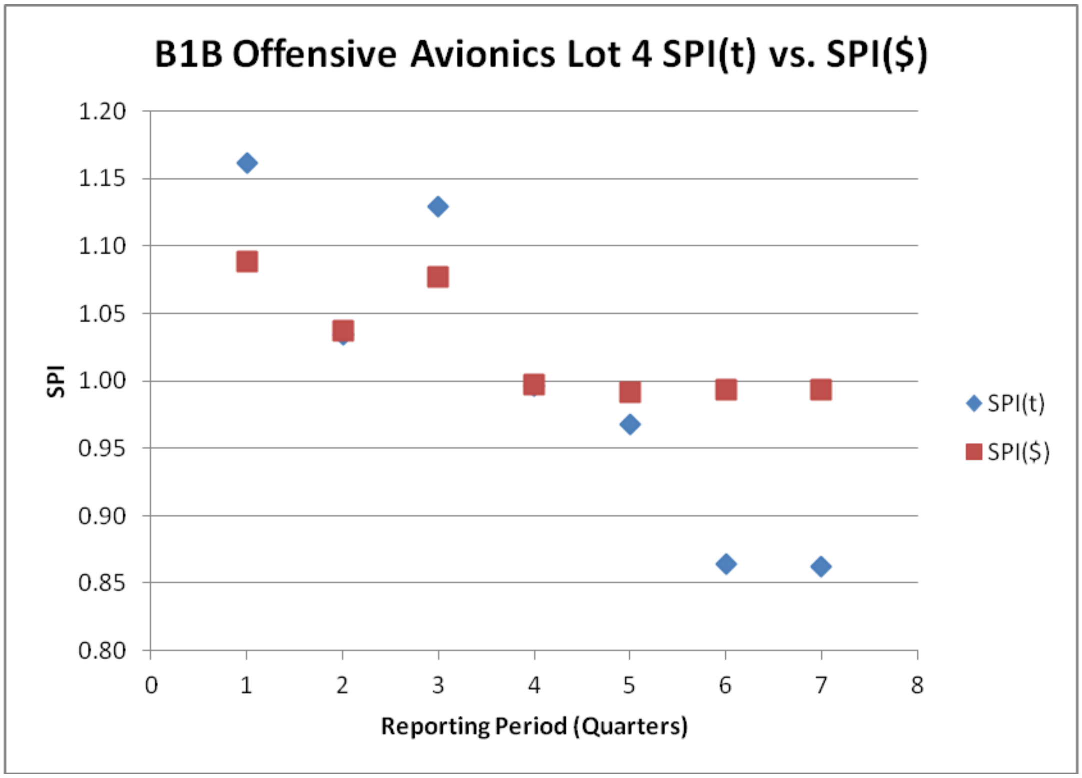

Figure 38: B1B Offensive Avionics Lot 4 SPI(t) vs. SPI($)

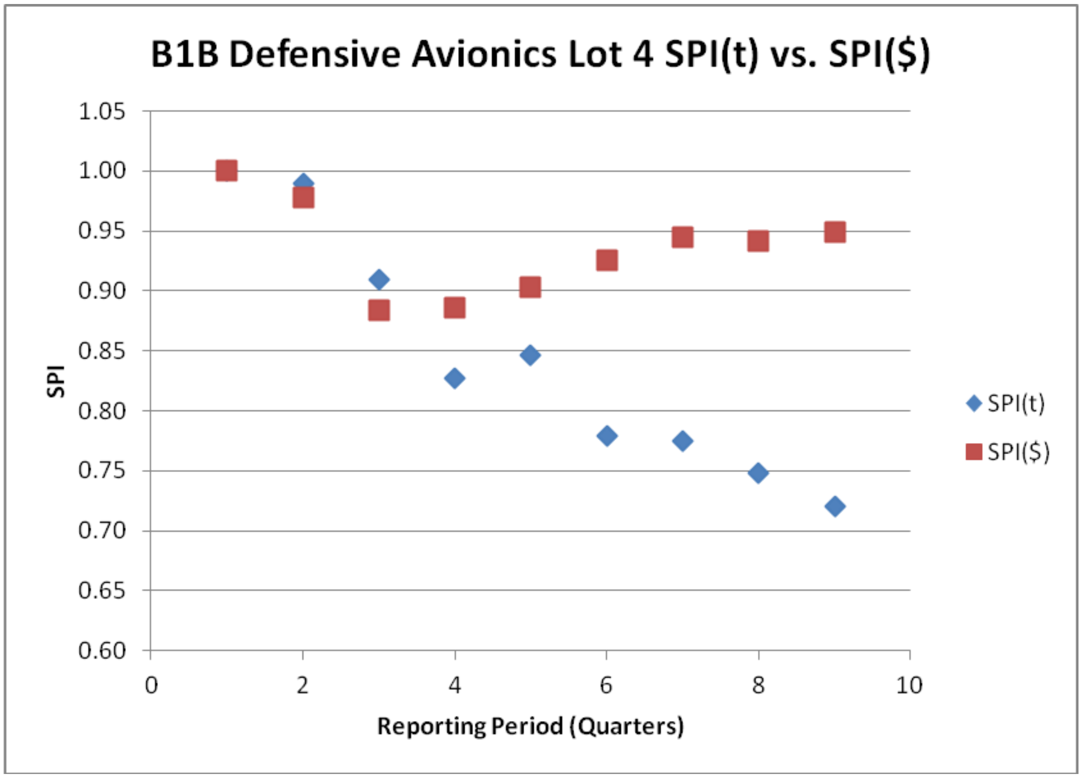

Figure 39: B1B Defensive Avionics Lot 4 SPI(t) vs. SPI($)

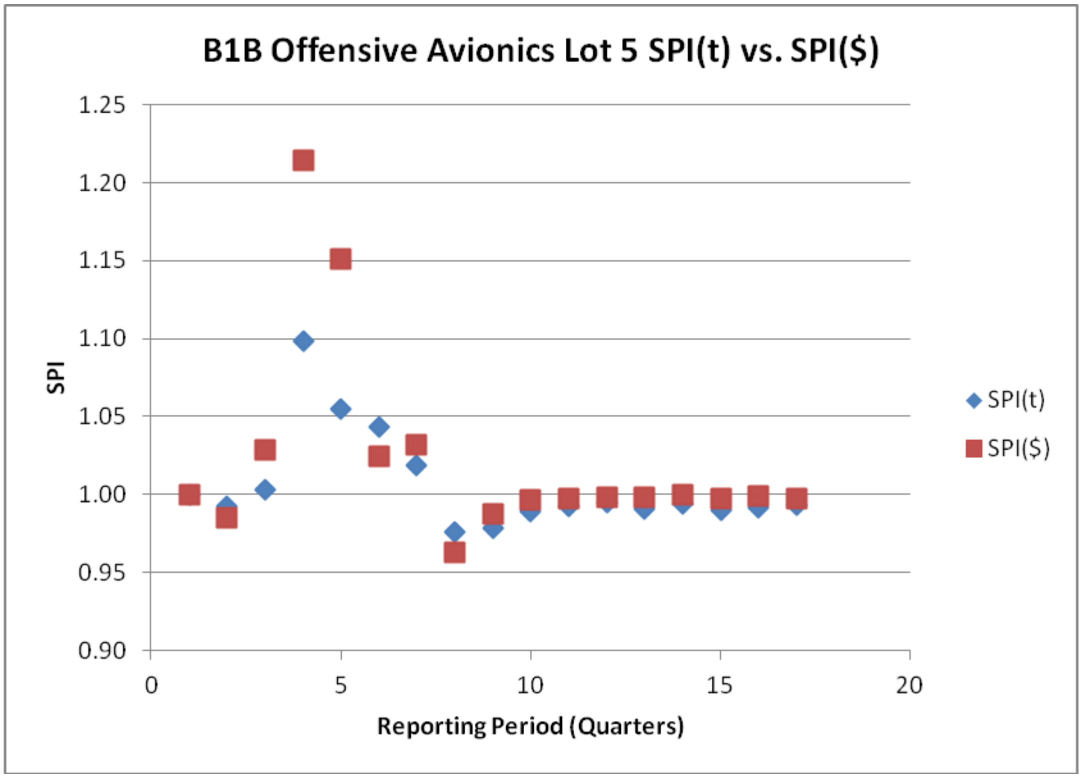

Figure 40: B1B Offensive Avionics Lot 5 SPI(t) vs. SPI($)

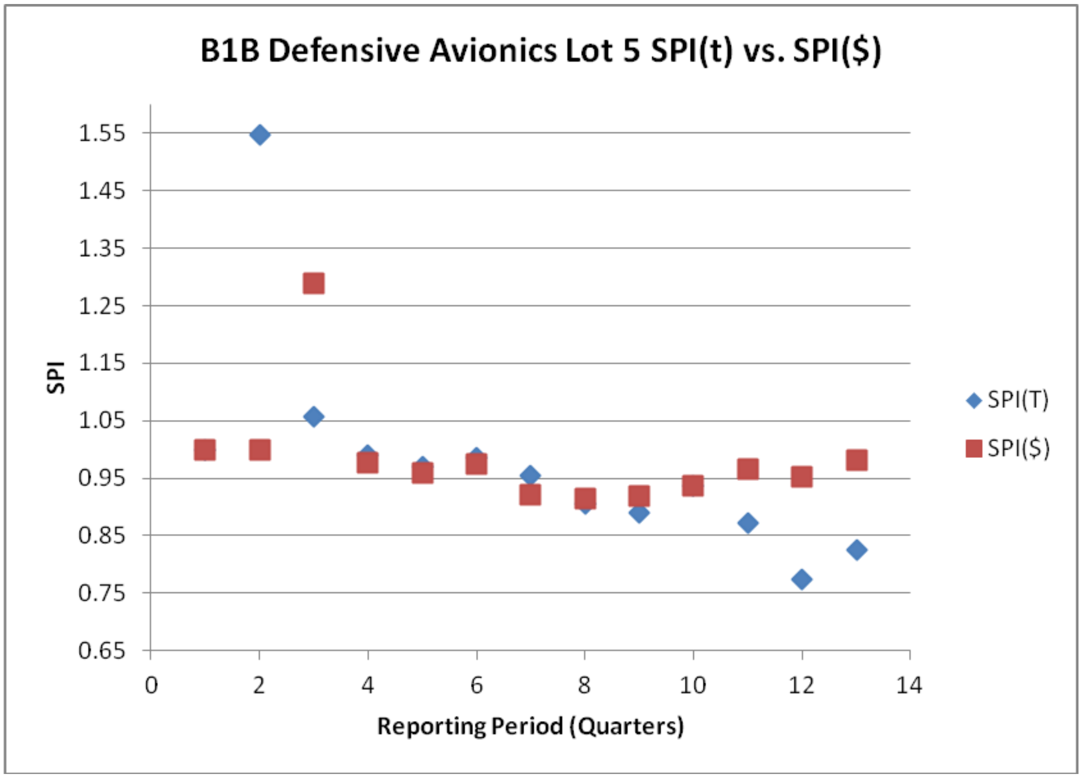

Figure 41: B1B Defensive Avionics Lot 5 SPI(t) vs. SPI($)

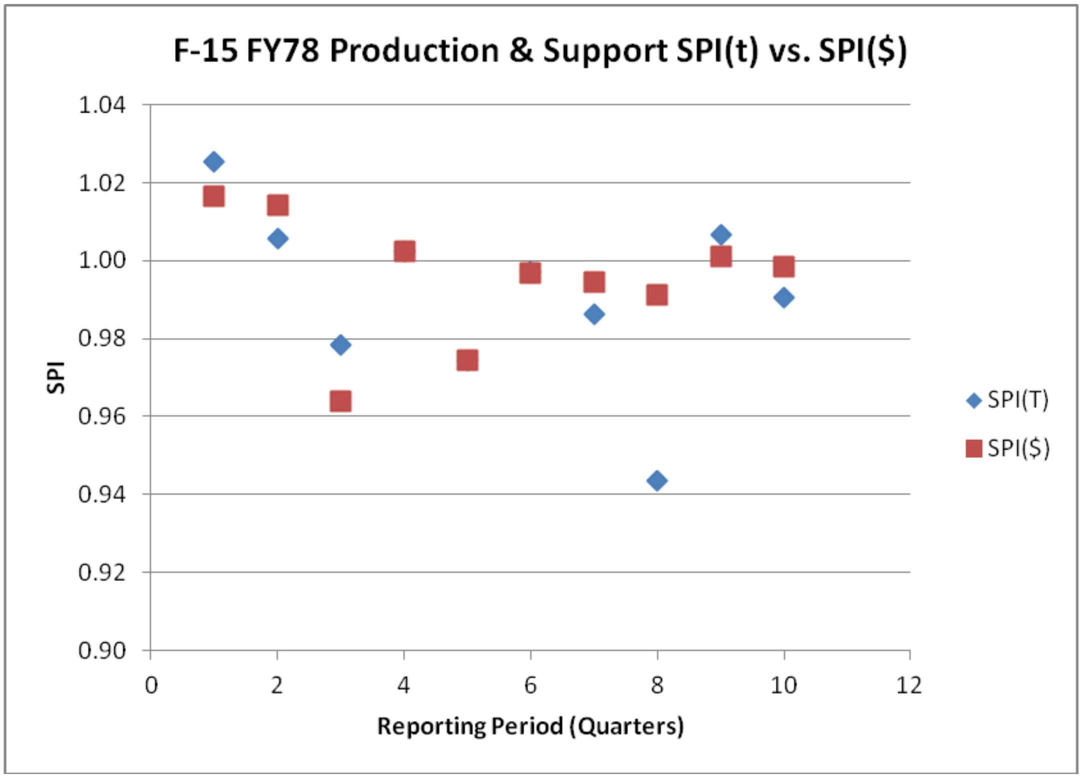

Figure 42: F-15 FY78 Production & Support SPI(t) vs. SPI($)

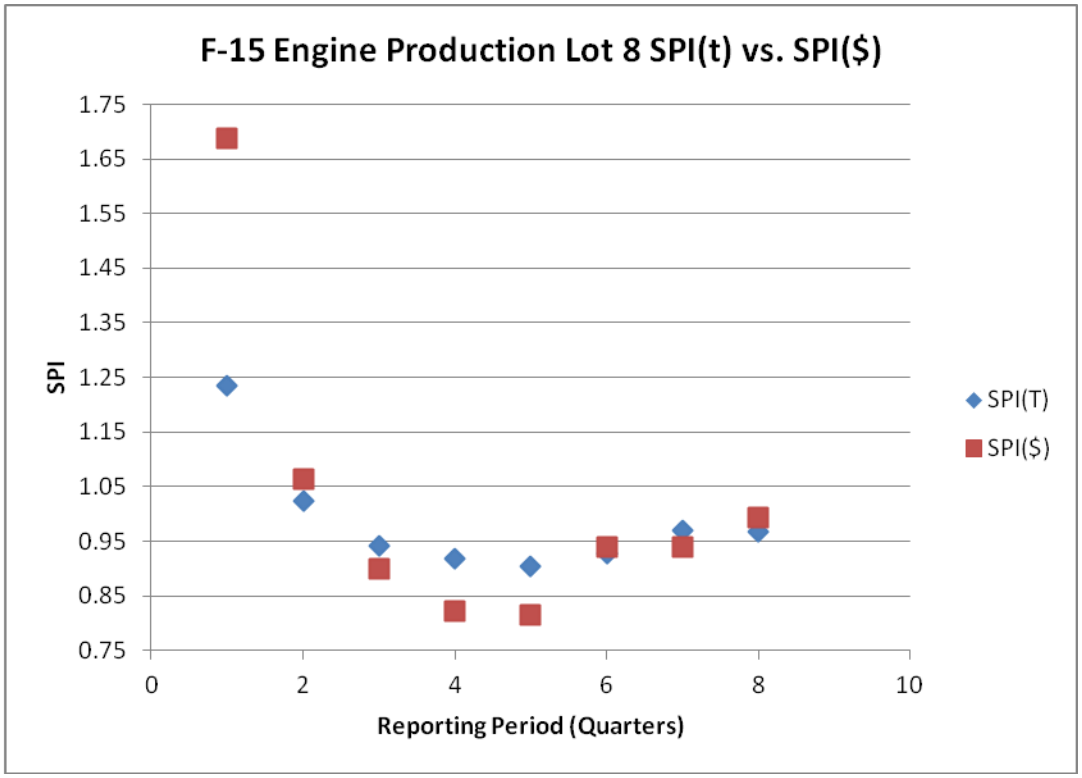

Figure 43: F-15 Engine Production Lot 8 SPI(t) vs. SPI($)

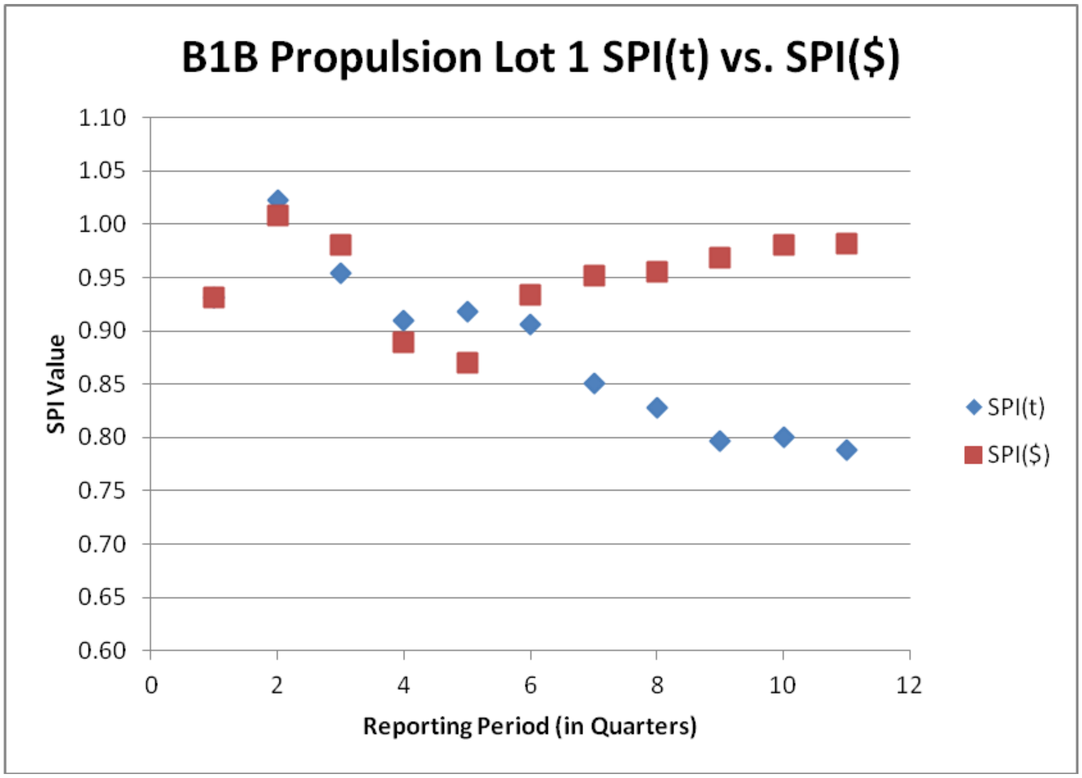

Figure 44: B1B Propulsion Lot 1 SPI(t) vs. SPI($)

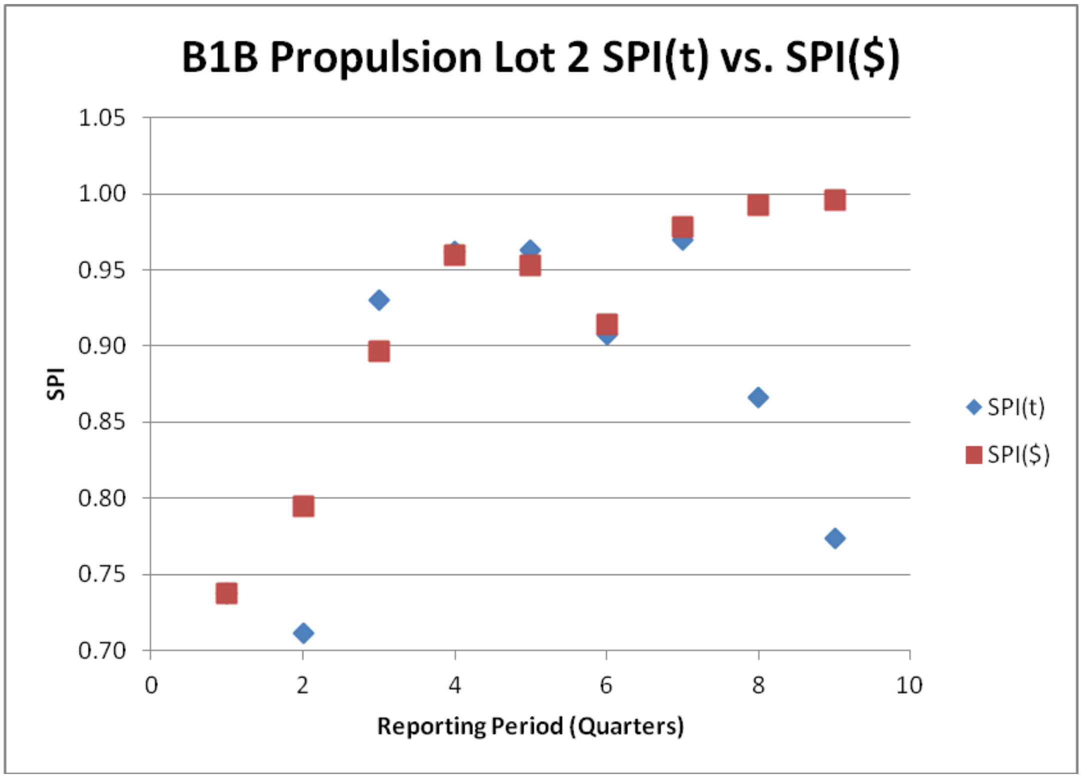

Figure 45: B1B Propulsion Lot 2 SPI(t) vs. SPI($)

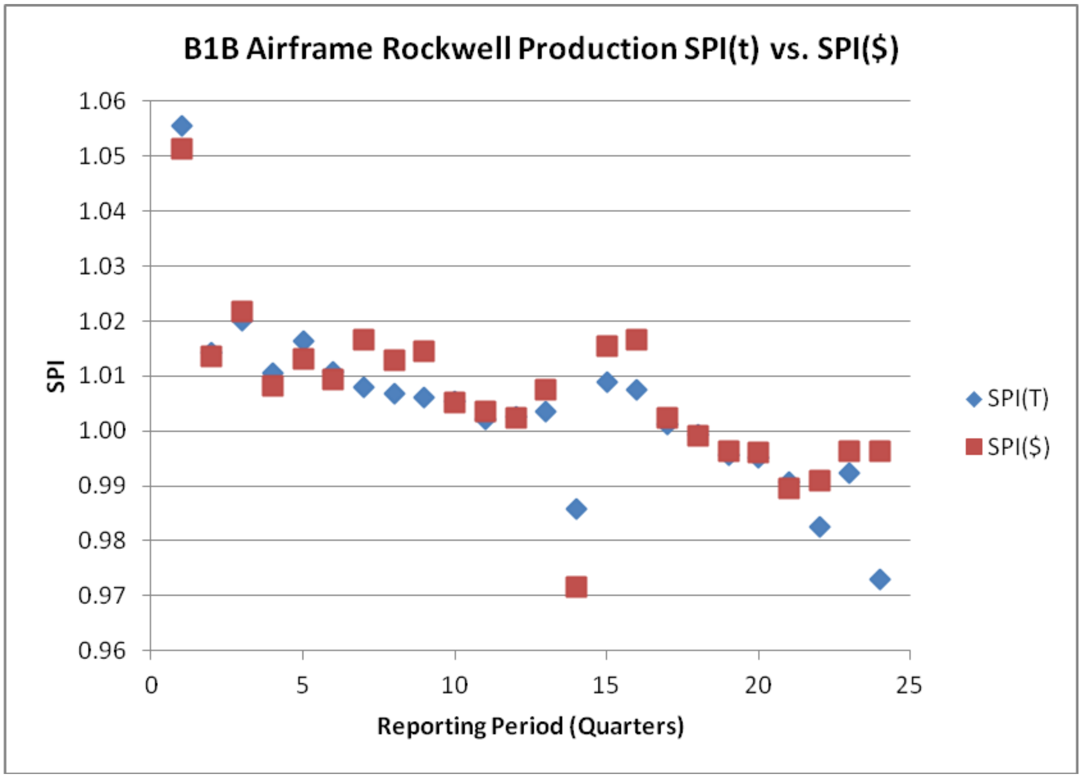

Figure 46: B1B Airframe Rockwell Production SPI(t) vs. SPI($)

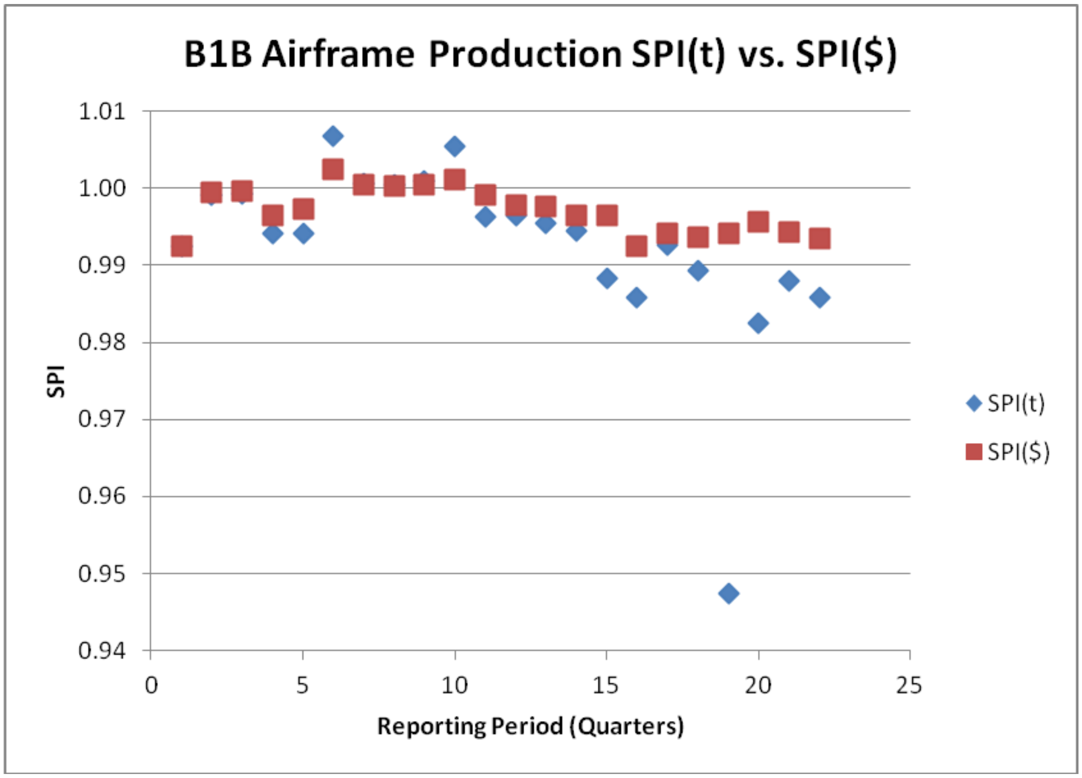

Figure 47: B1B Airframe Production SPI(t) vs. SPI($)

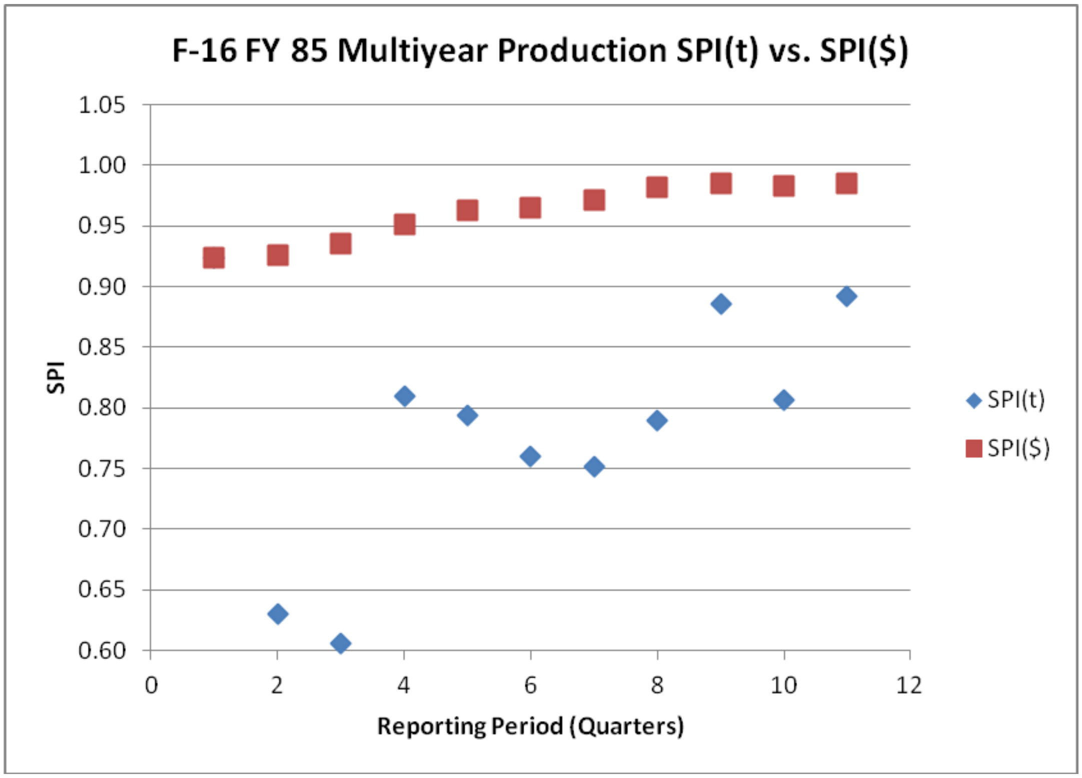

Figure 48: F-16 FY 85 Multiyear Production SPI(t) vs. SPI($)

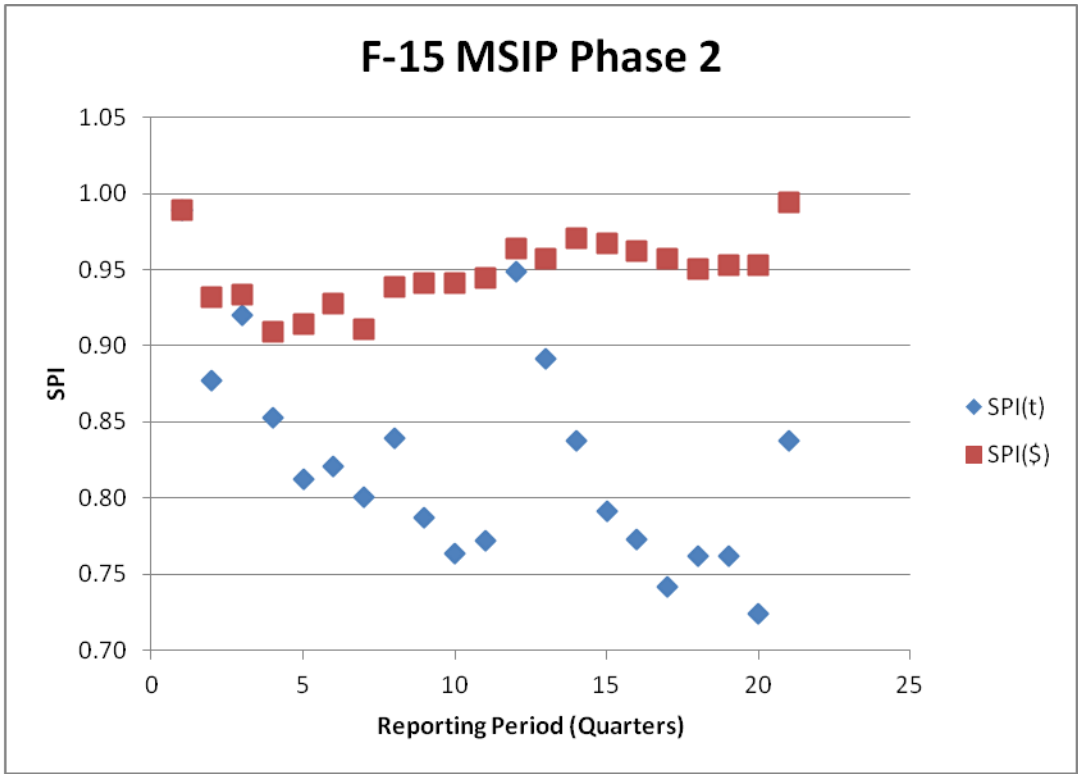

Figure 49: F-15 MSIP Phase 2

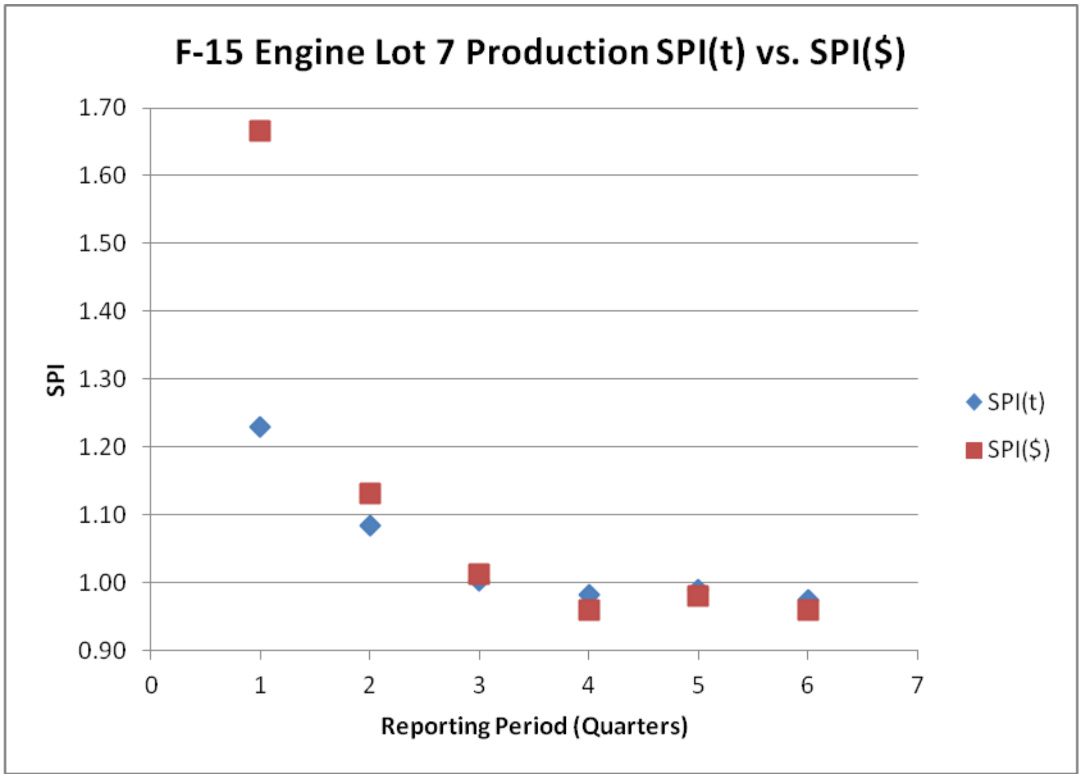

Figure 50: F-15 Engine Lot 7 Production SPI(t) vs. SPI($)

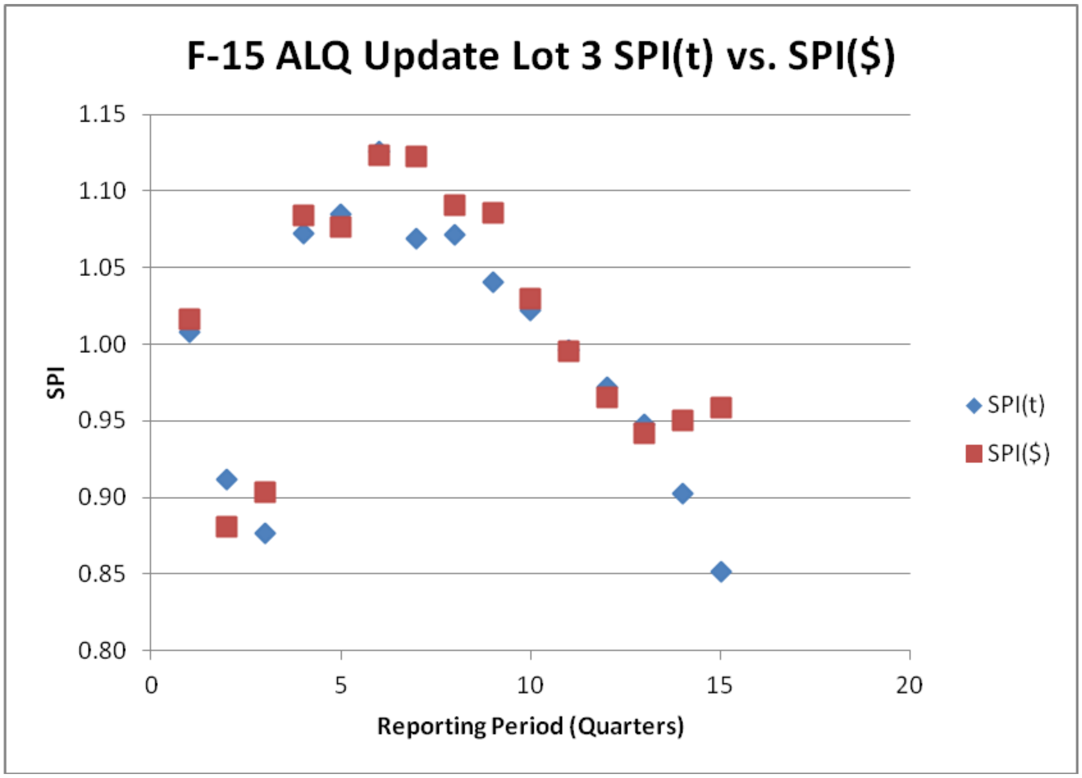

Figure 51: F-15 ALQ Update Lot 3 SPI(t) vs. SPI($)

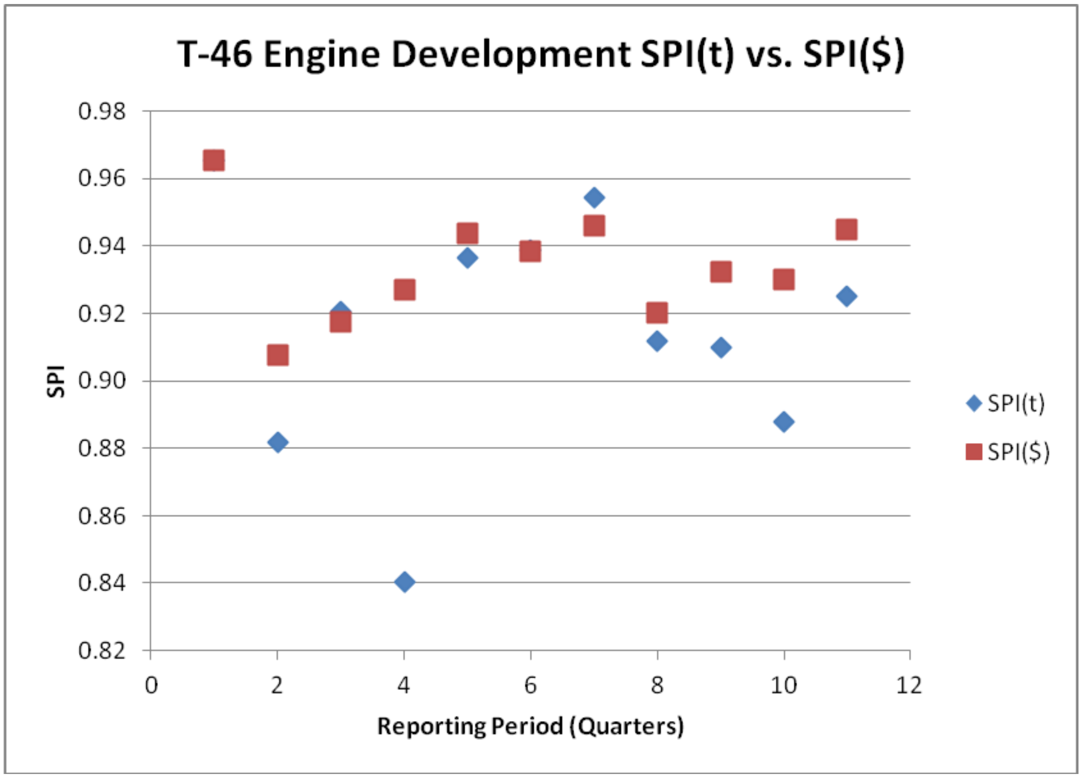

Figure 52: T-46 Engine Development SPI(t) vs. SPI($)

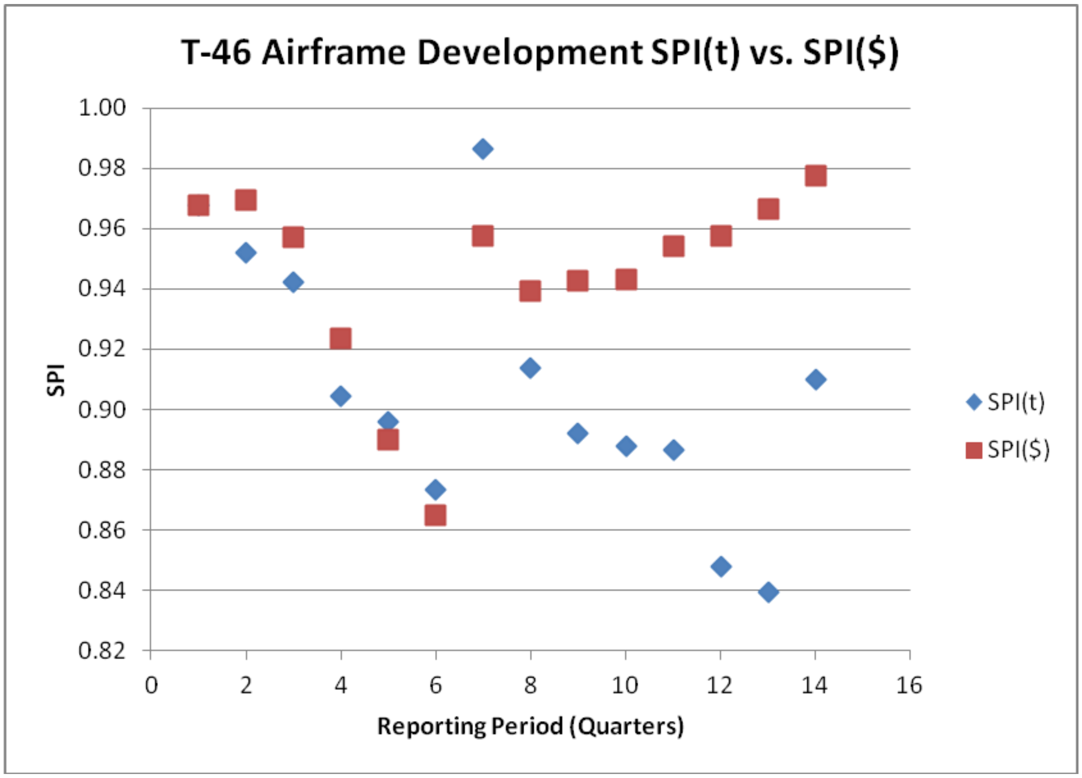

Figure 53: T-46 Airframe Development SPI(t) vs. SPI($)

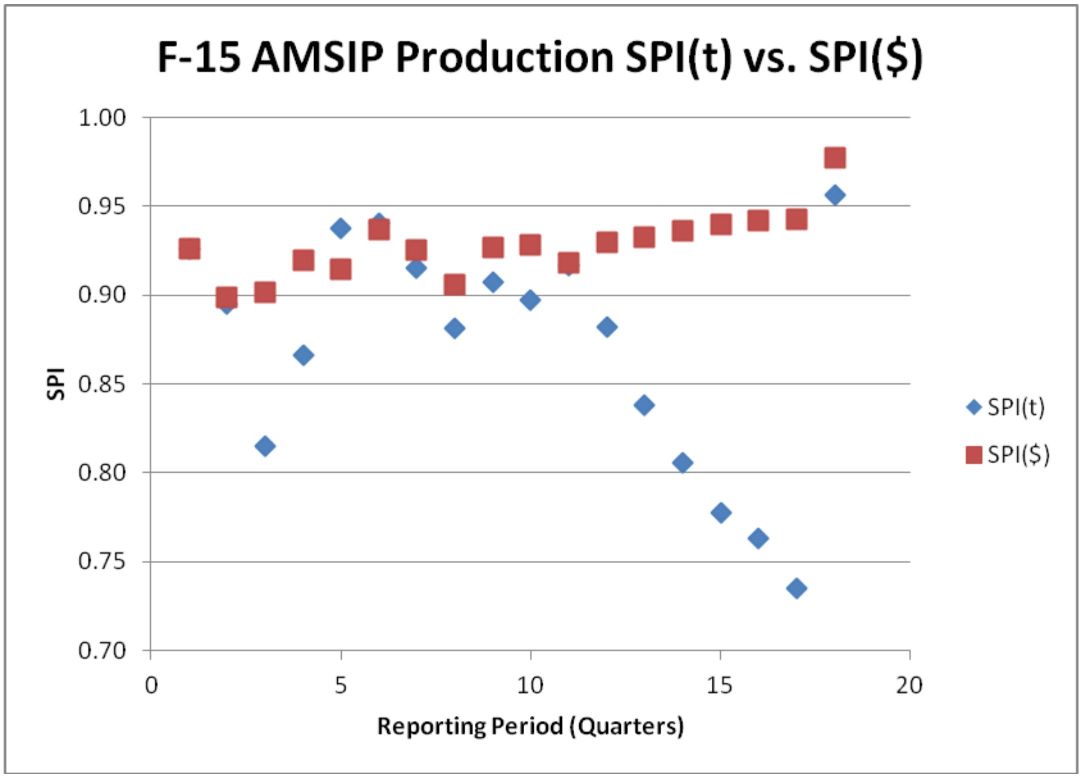

Figure 54: F-15 AMSIP Production SPI(t) vs. SPI($)

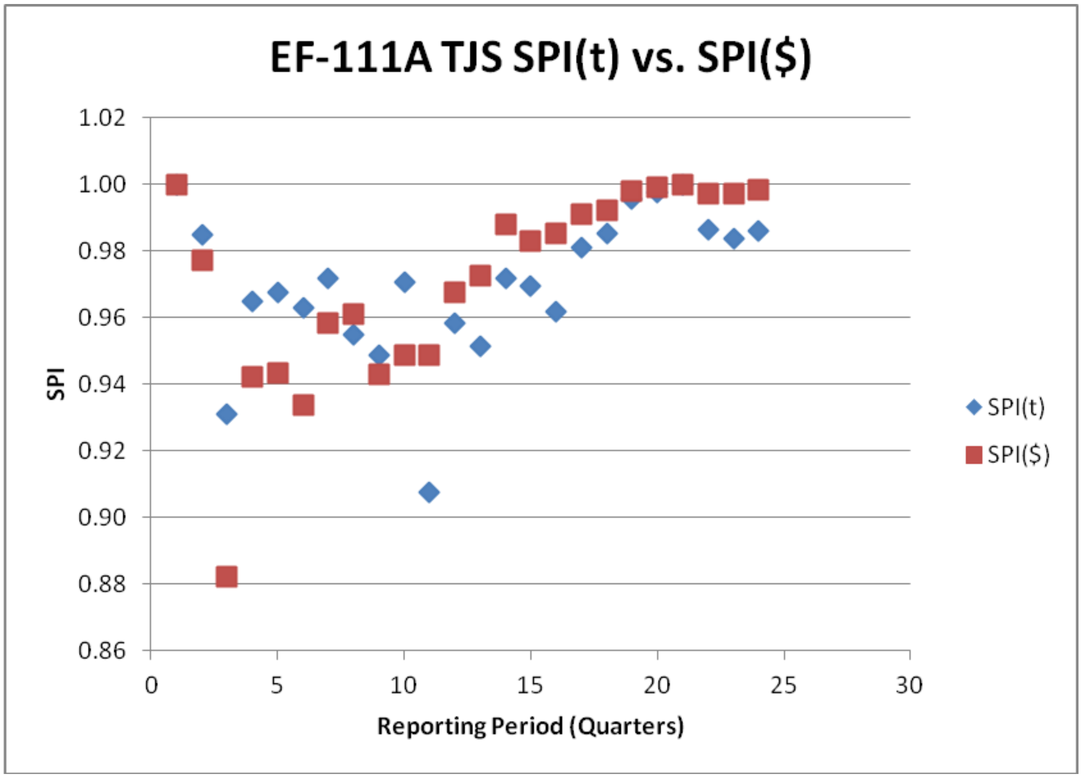

Figure 55: EF-111A TJS SPI(t) vs. SPI($)

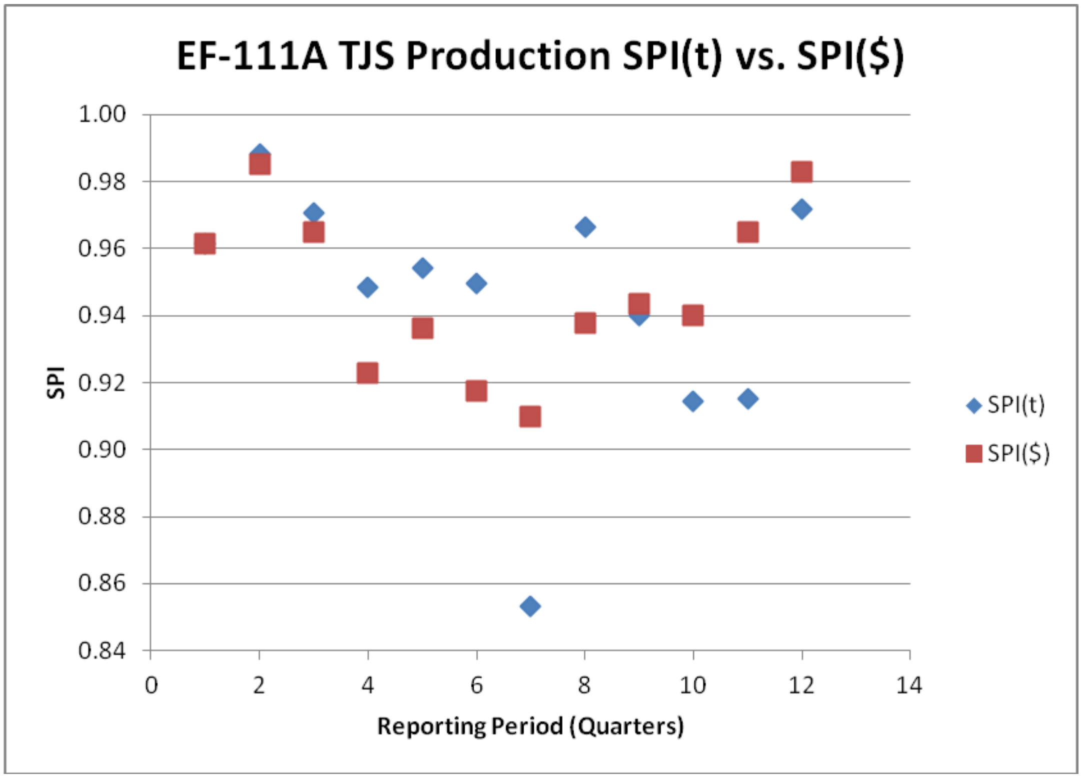

Figure 56: EF-111A TJS Production SPI(t) vs. SPI($)

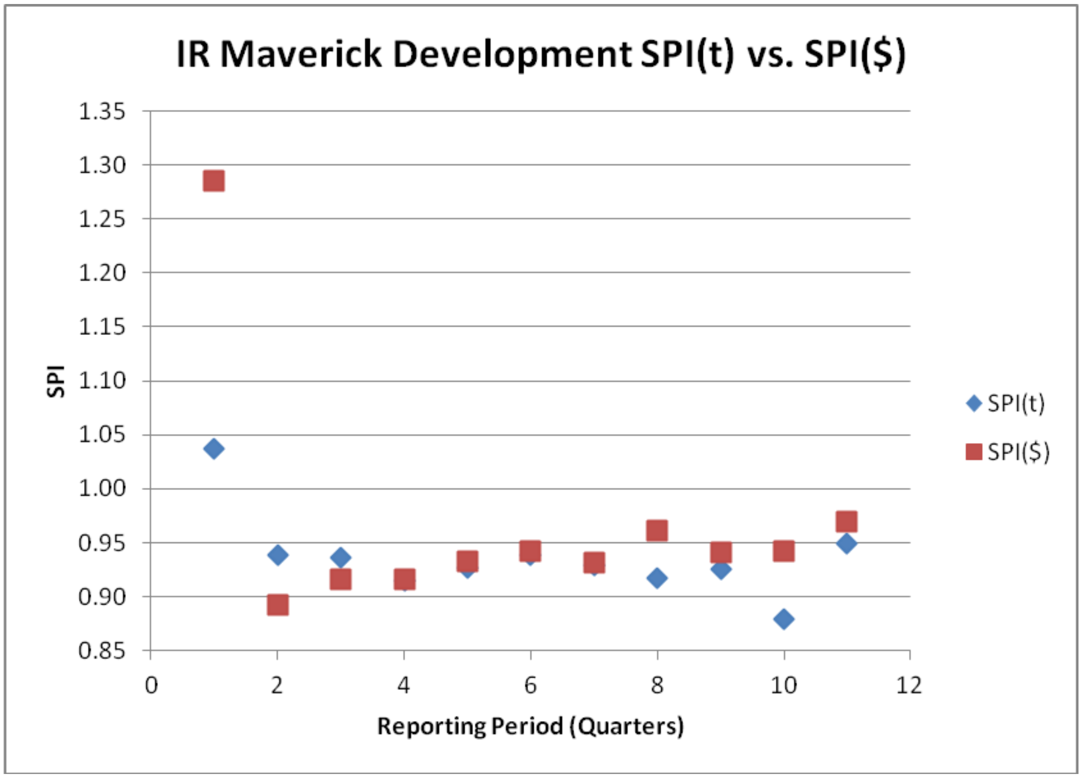

Figure 57: IR Maverick Development SPI(t) vs. SPI($)

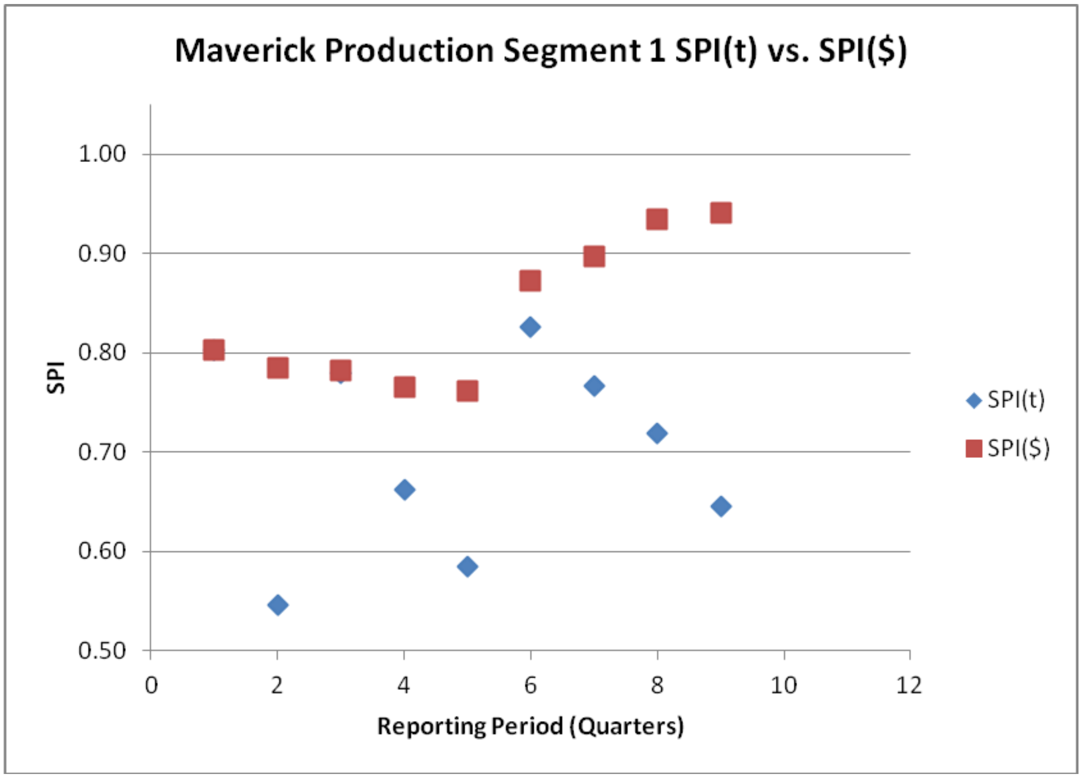

Figure 58: Maverick Production Segment 1 SPI(t) vs. SPI($)

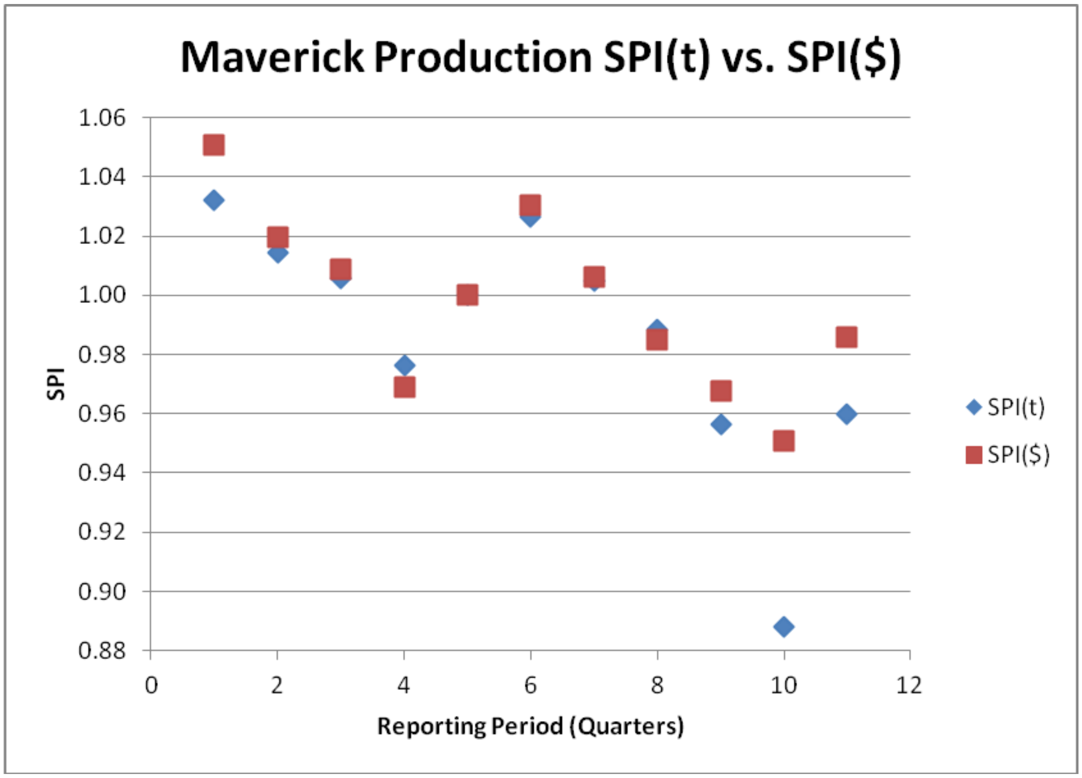

Figure 59: Maverick Production SPI(t) vs. SPI($)

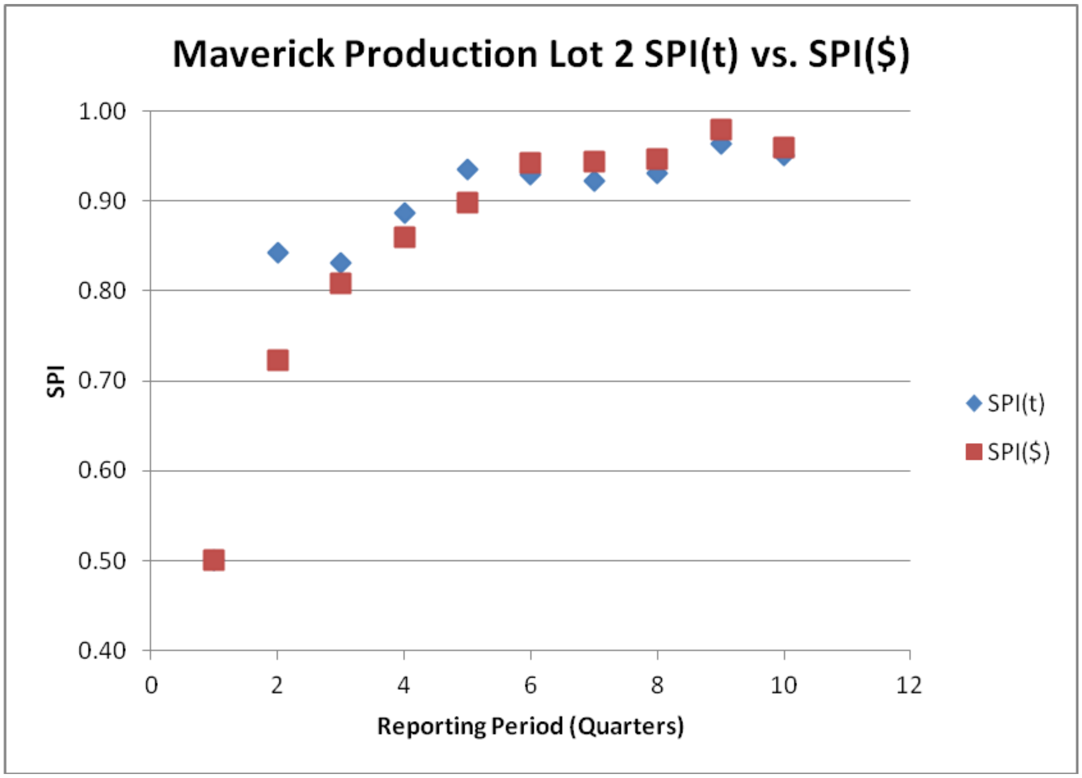

Figure 60: Maverick Production Lot 2 SPI(t) vs. SPI($)

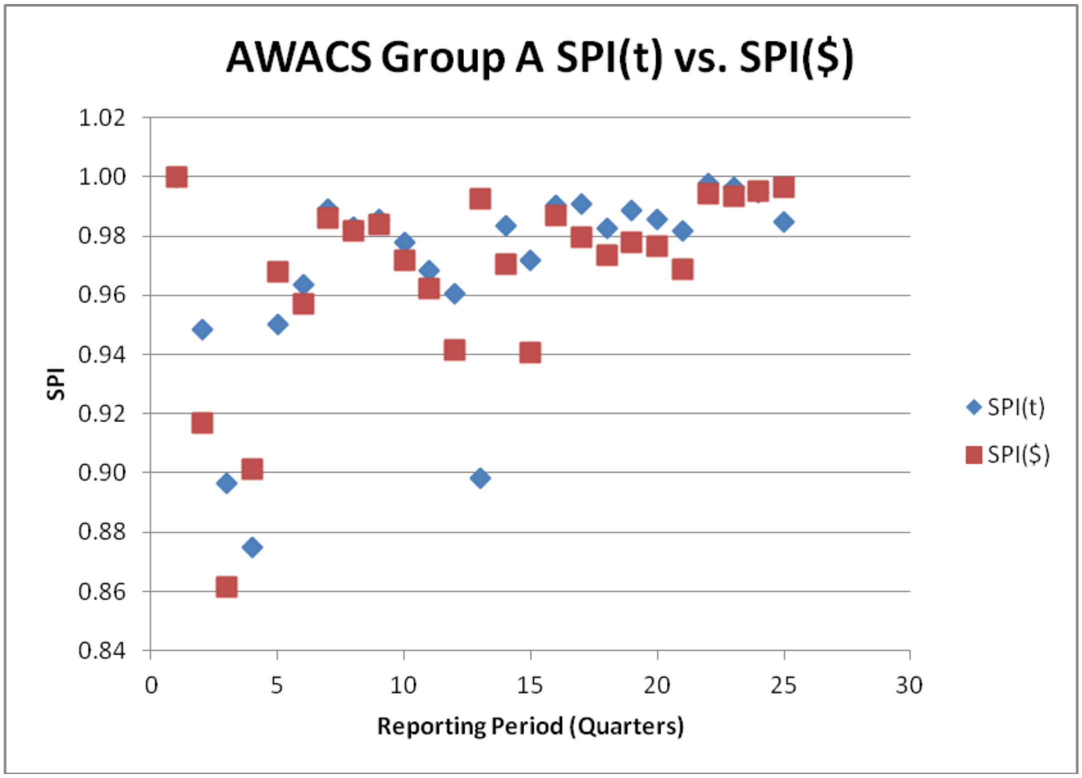

Figure 61: AWACS Group A SPI(t) vs. SPI($)

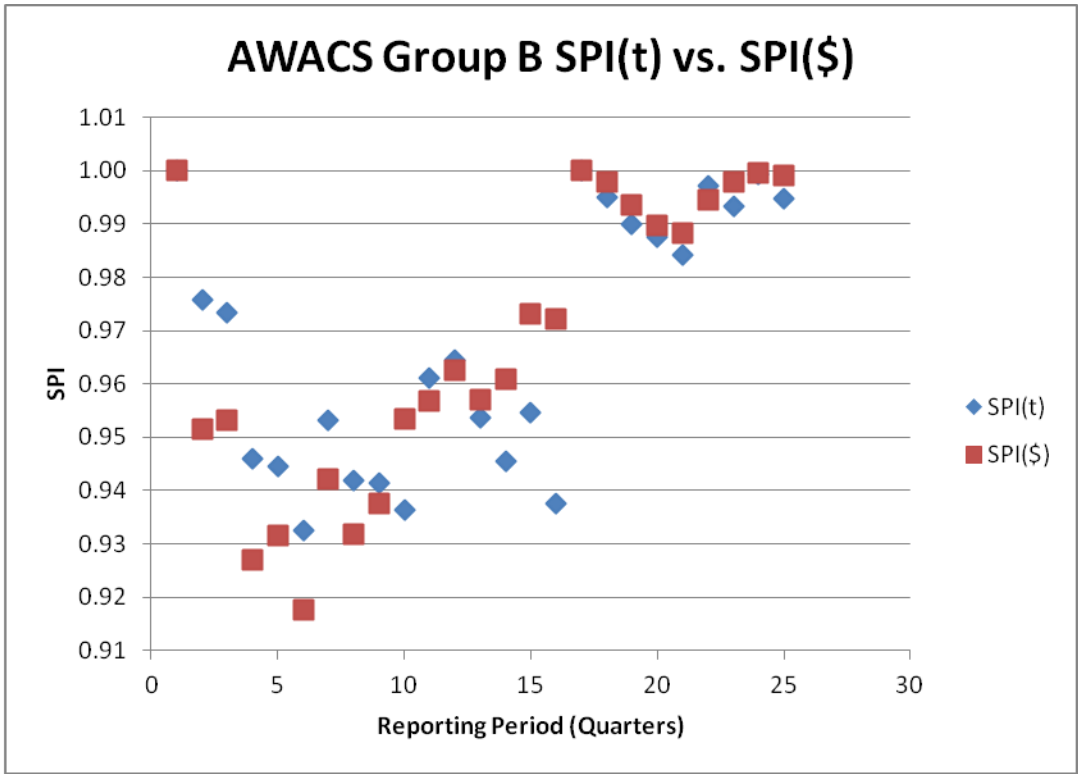

Figure 62: AWACS Group B SPI(t) vs. SPI($)

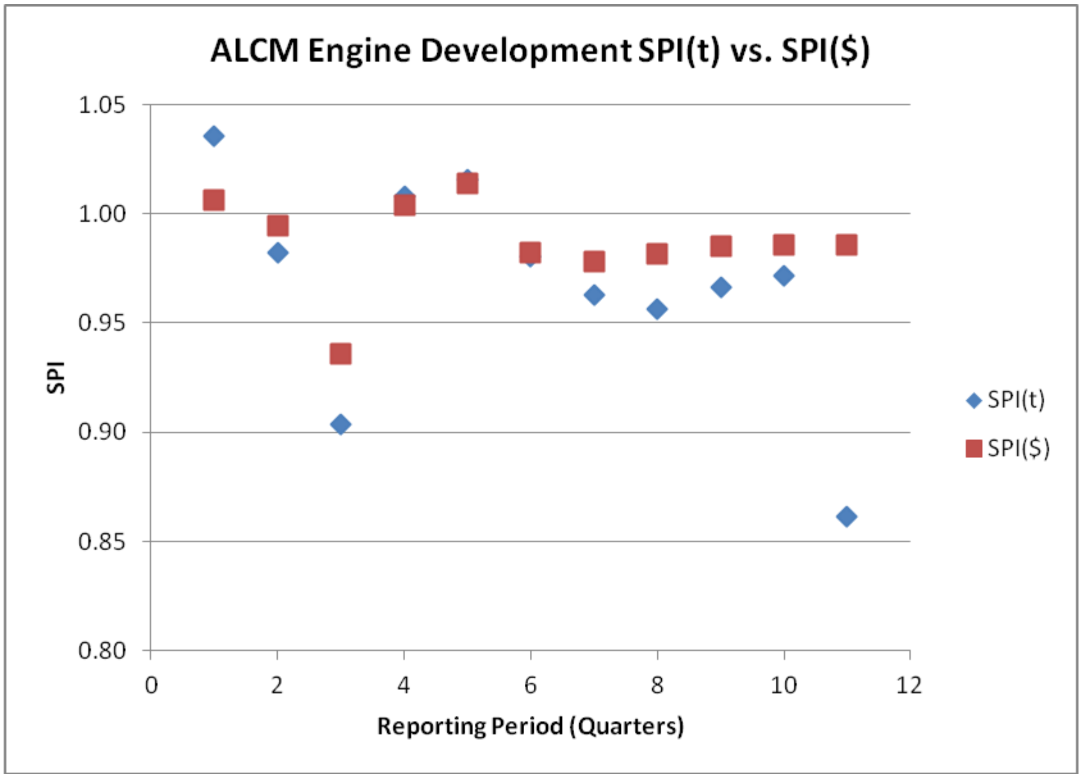

Figure 63: ALCM Engine Development SPI(t) vs. SPI($)

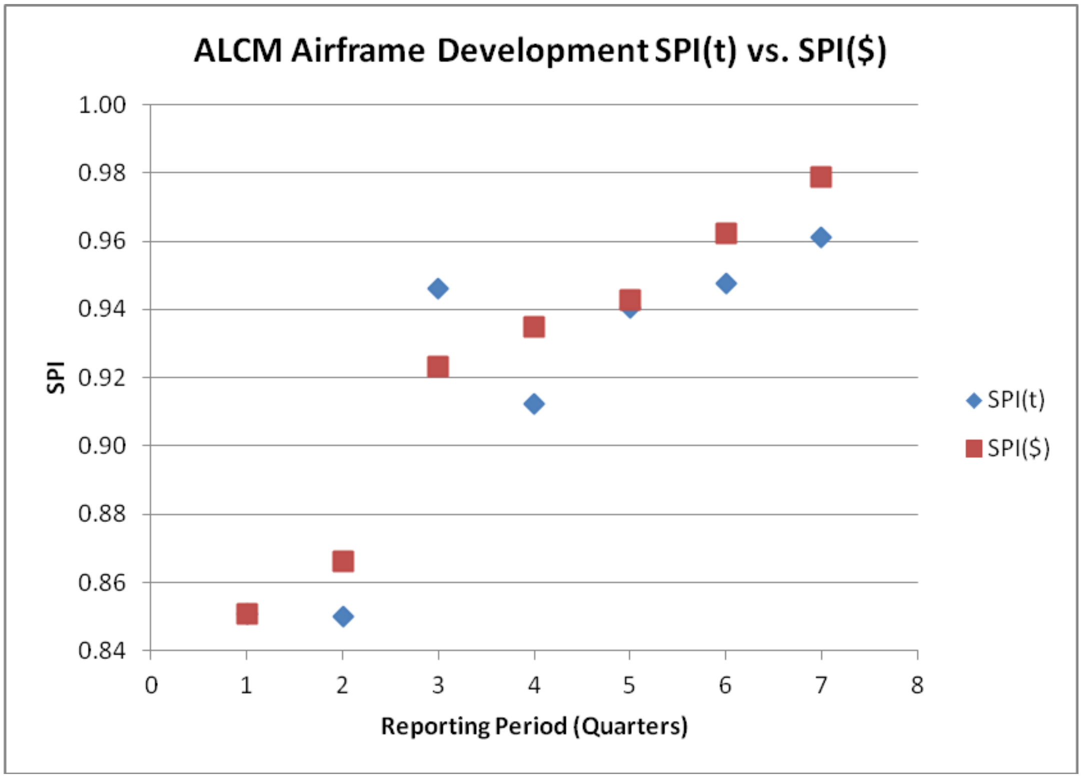

Figure 64: ALCM Airframe Development SPI(t) vs. SPI($)

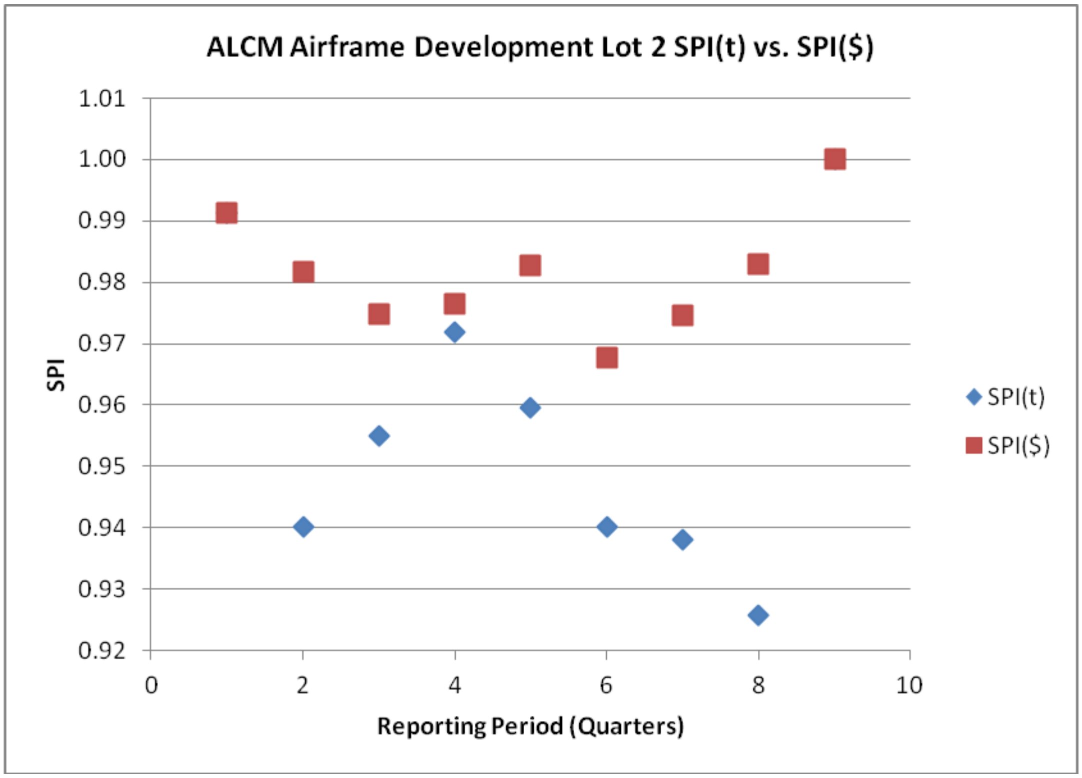

Figure 65: ALCM Airframe Development Lot 2 SPI(t) vs. SPI($)

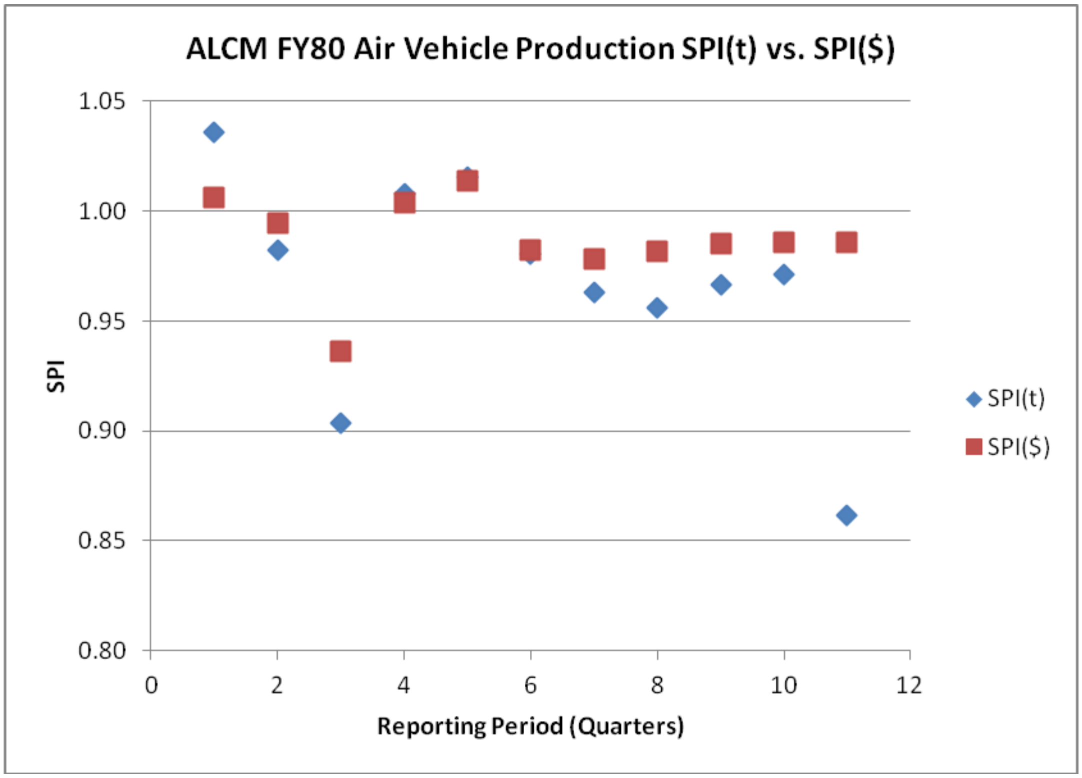

Figure 66: ALCM FY80 Air Vehicle Production SPI(t) vs. SPI($)

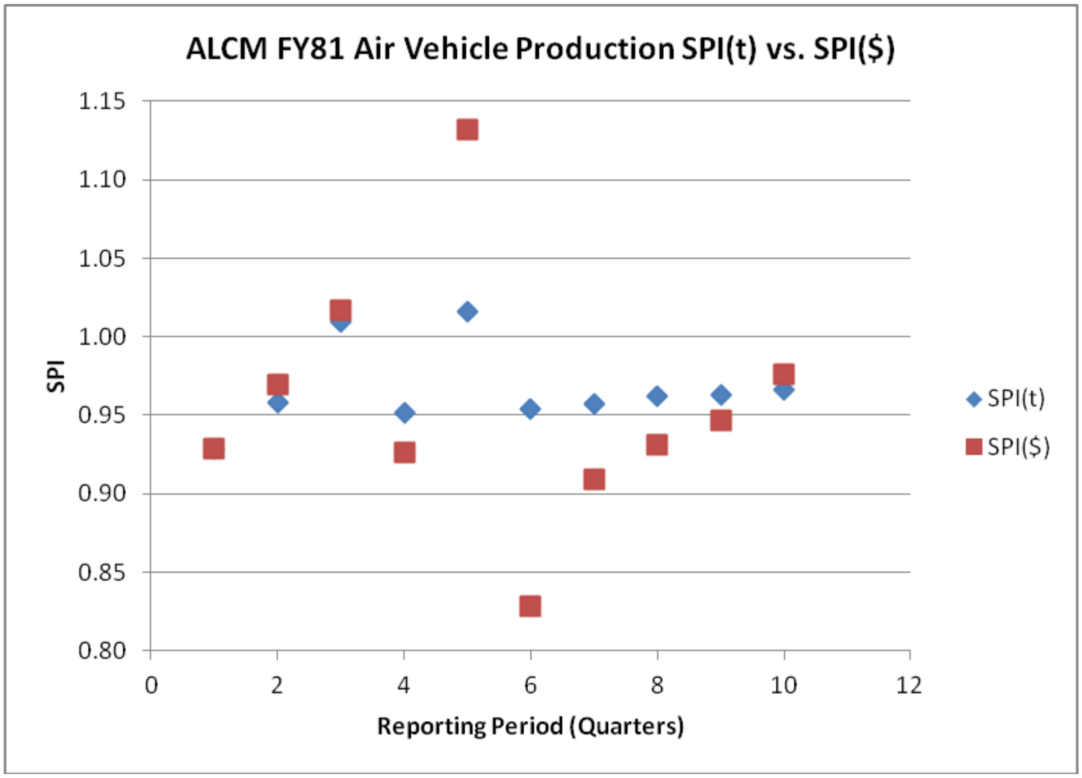

Figure 67: ALCM FY81 Air Vehicle Production SPI(t) vs. SPI($)

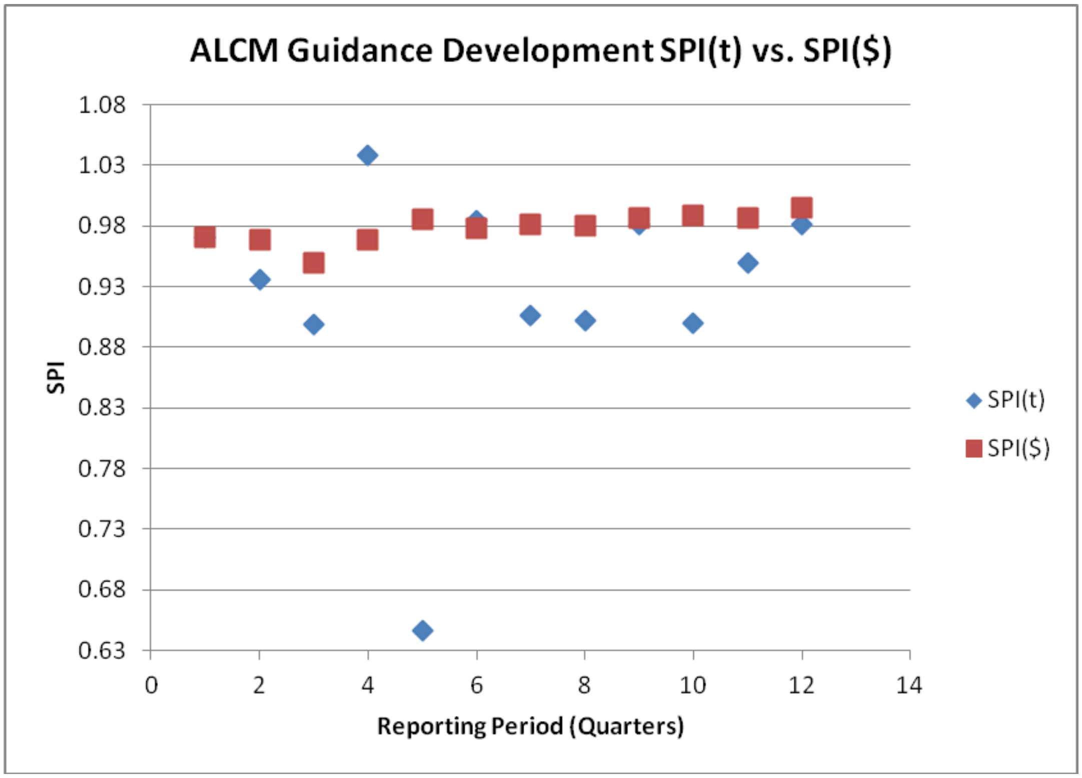

Figure 68: ALCM Guidance Development SPI(t) vs. SPI($)

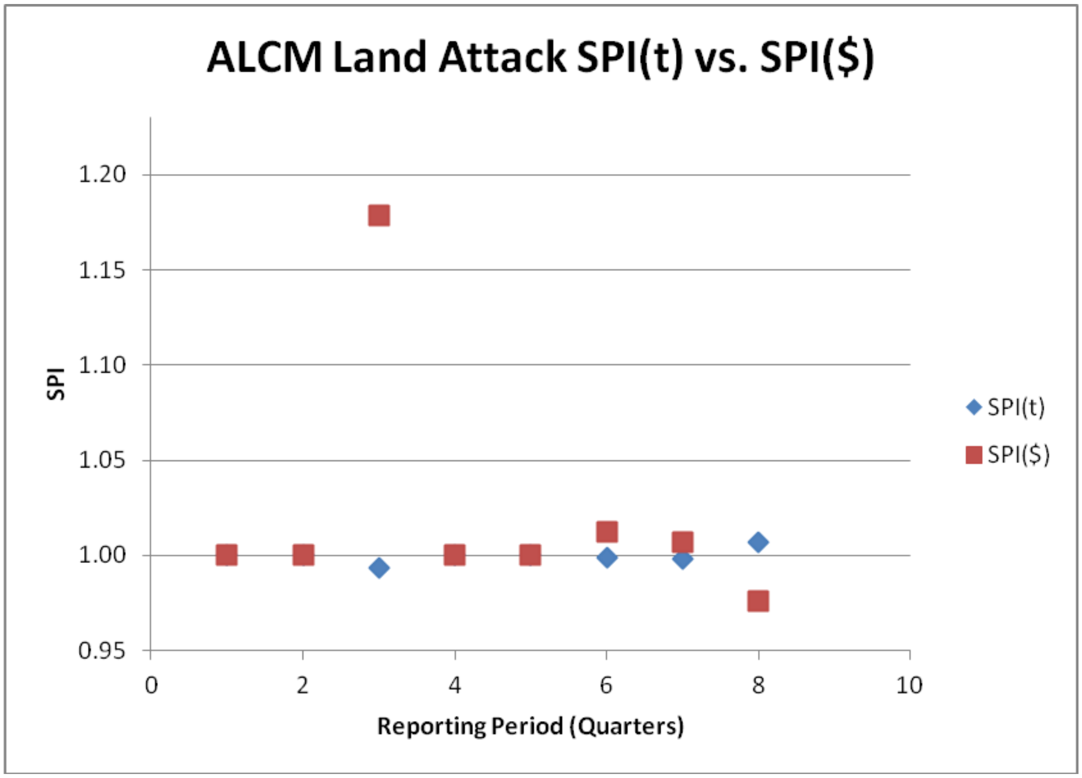

Figure 69: ALCM Land Attack SPI(t) vs. SPI($)

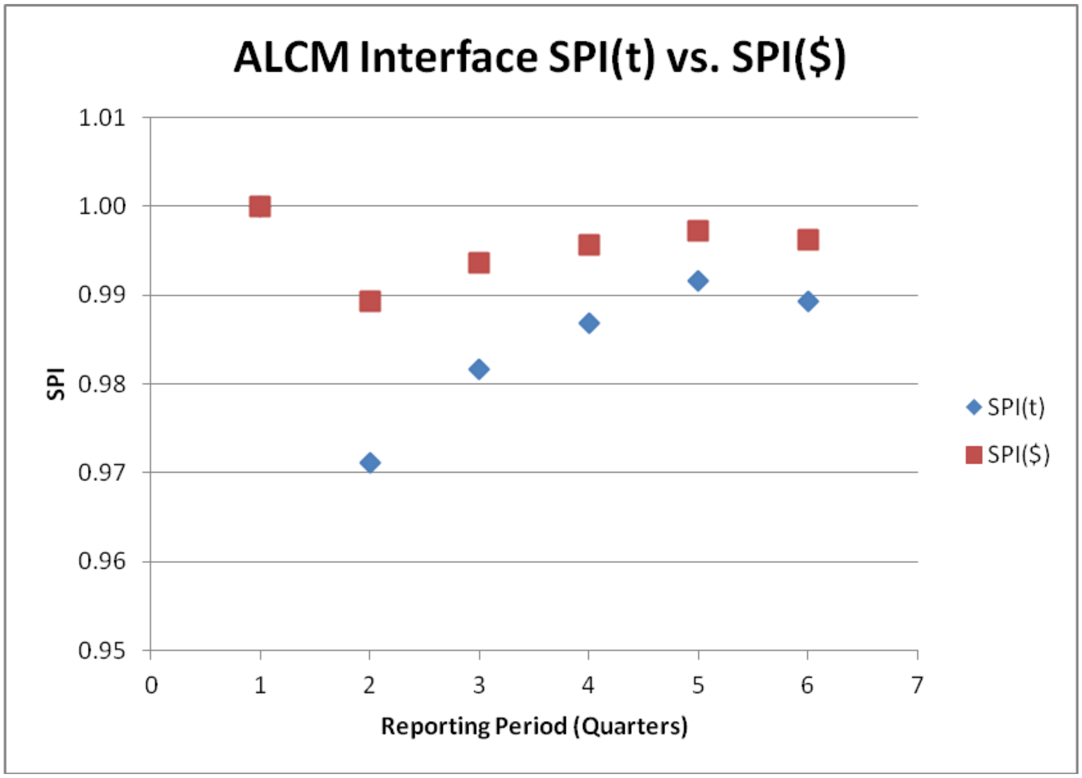

Figure 70: ALCM Interface SPI(t) vs. SPI($)

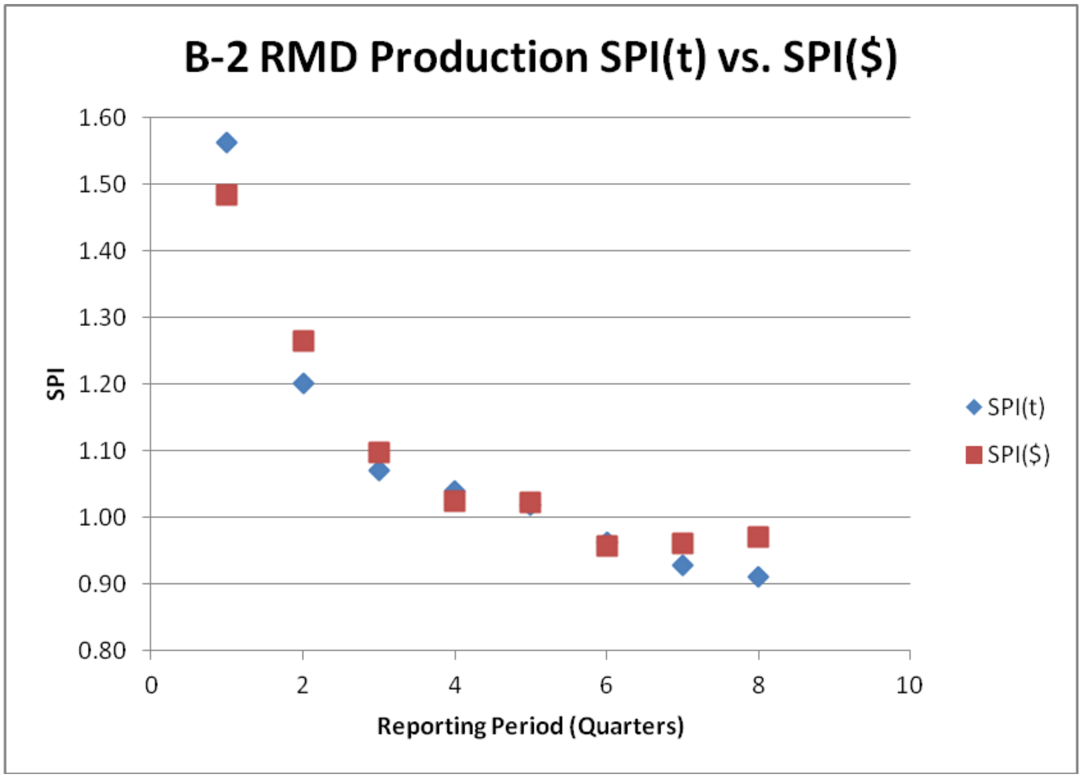

Figure 71: B-2 RMD Production SPI(t) vs. SPI($)

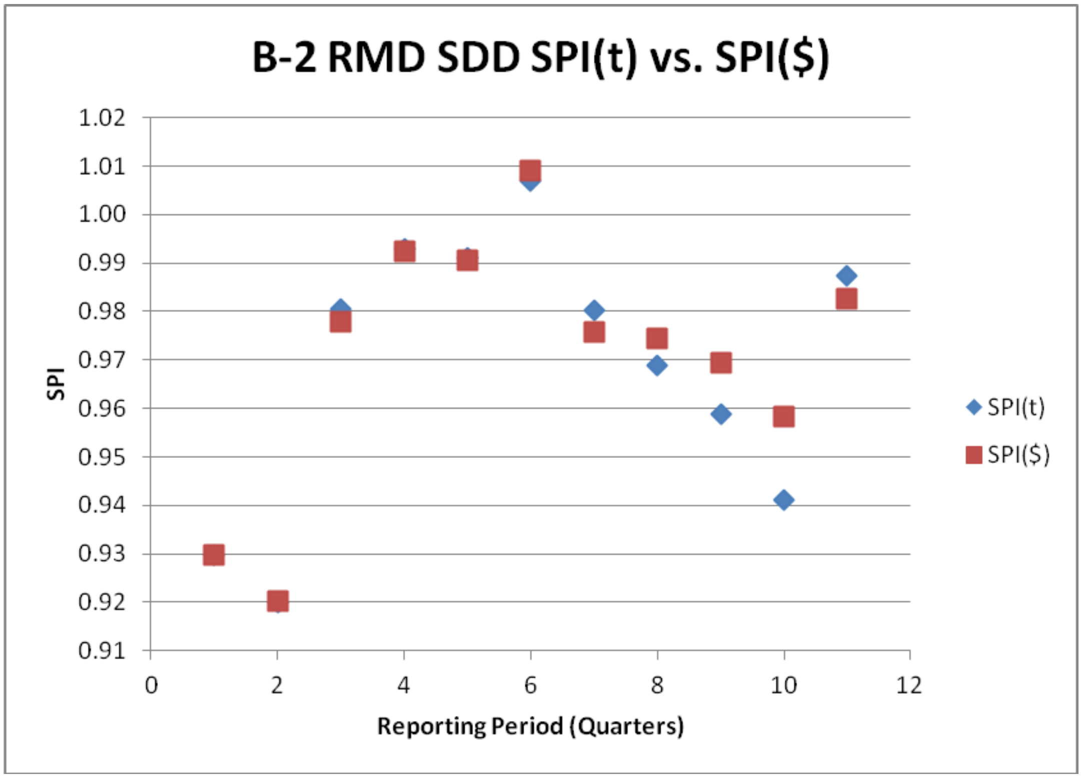

Figure 72: B-2 RMD SDD SPI(t) vs. SPI($)

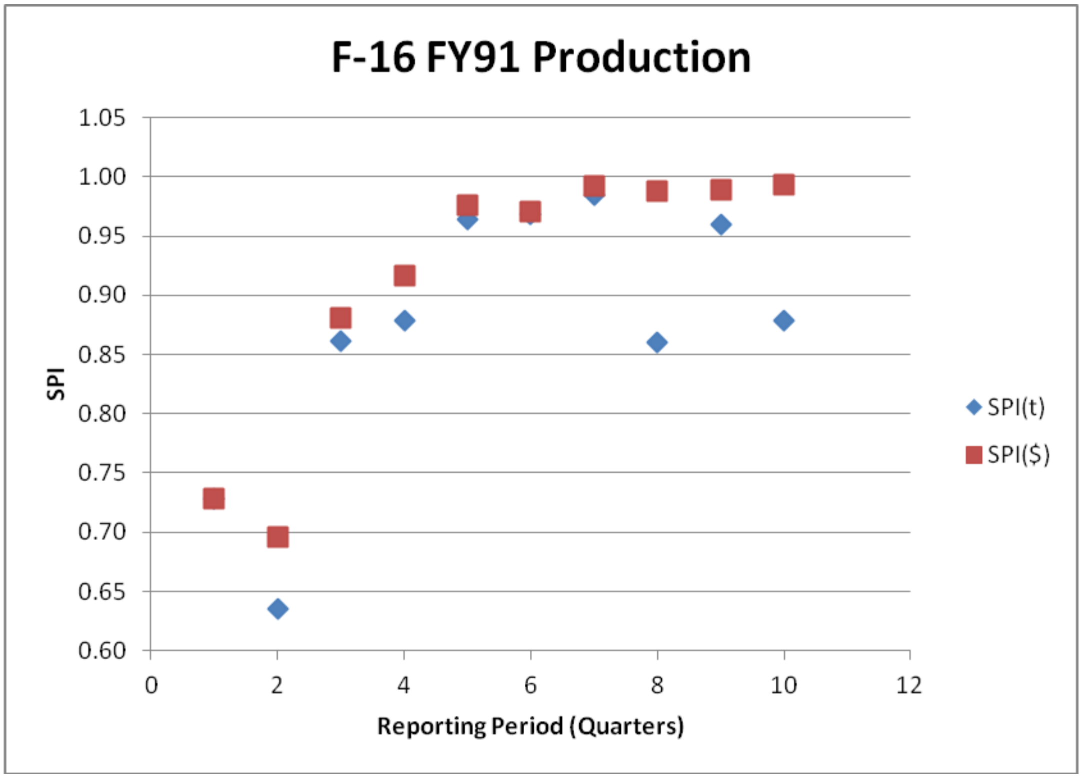

Figure 73: F-16 FY91 Production

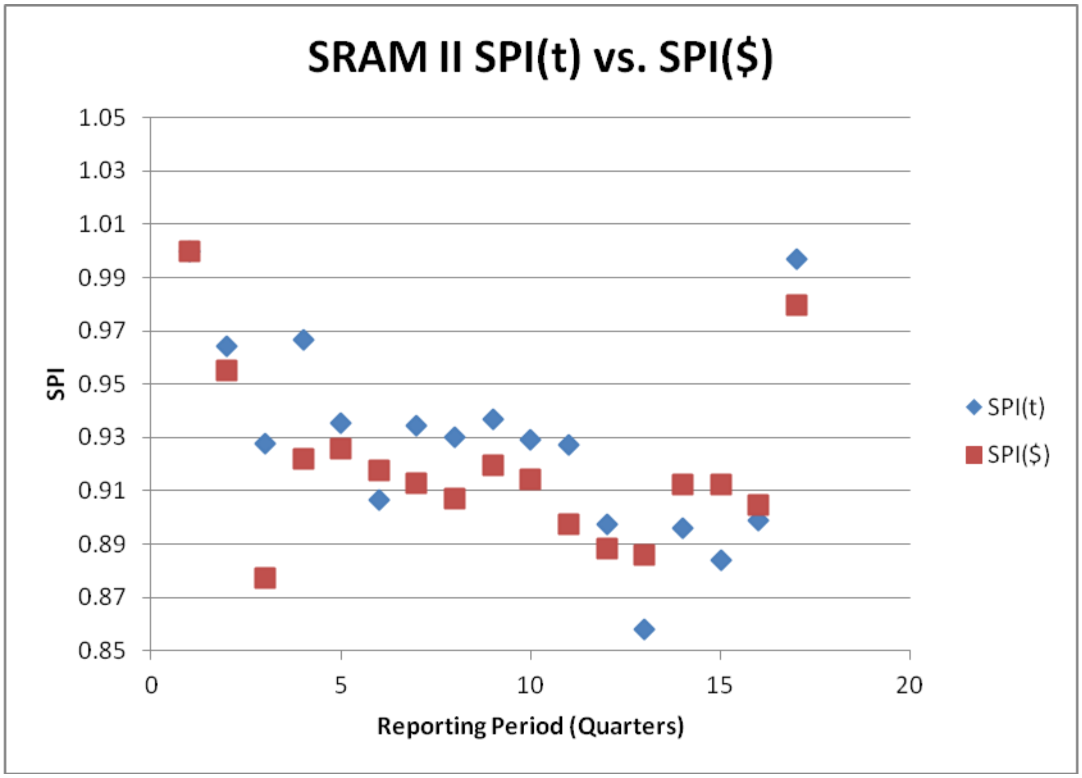

Figure 74: SRAM II SPI(t) vs. SPI($)

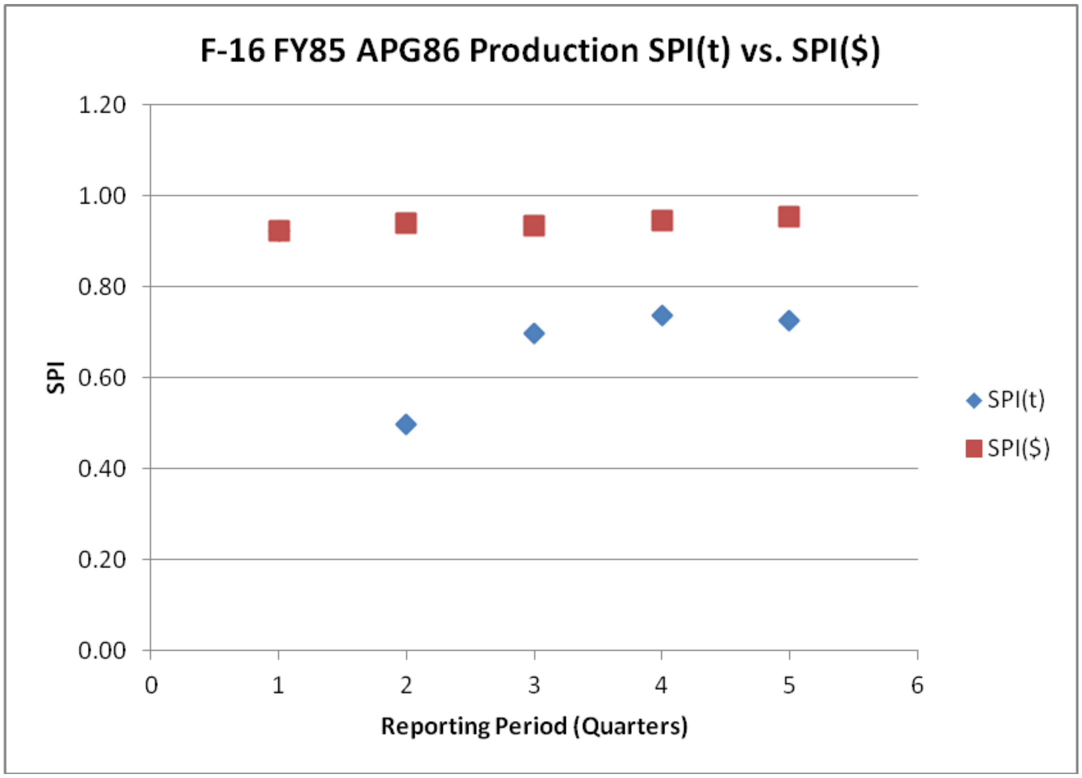

Figure 75: F-16 FY85 APG86 Production SPI(t) vs. SPI($)

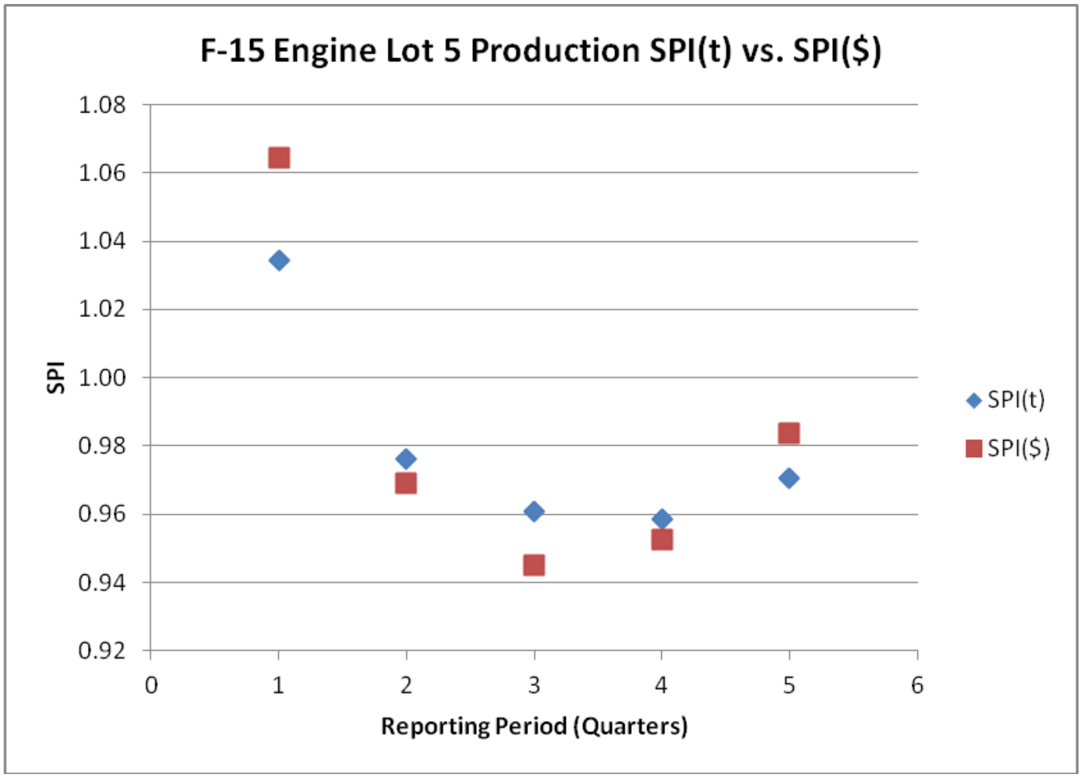

Figure 76: F-15 Engine Lot 5 Production SPI(t) vs. SPI($)

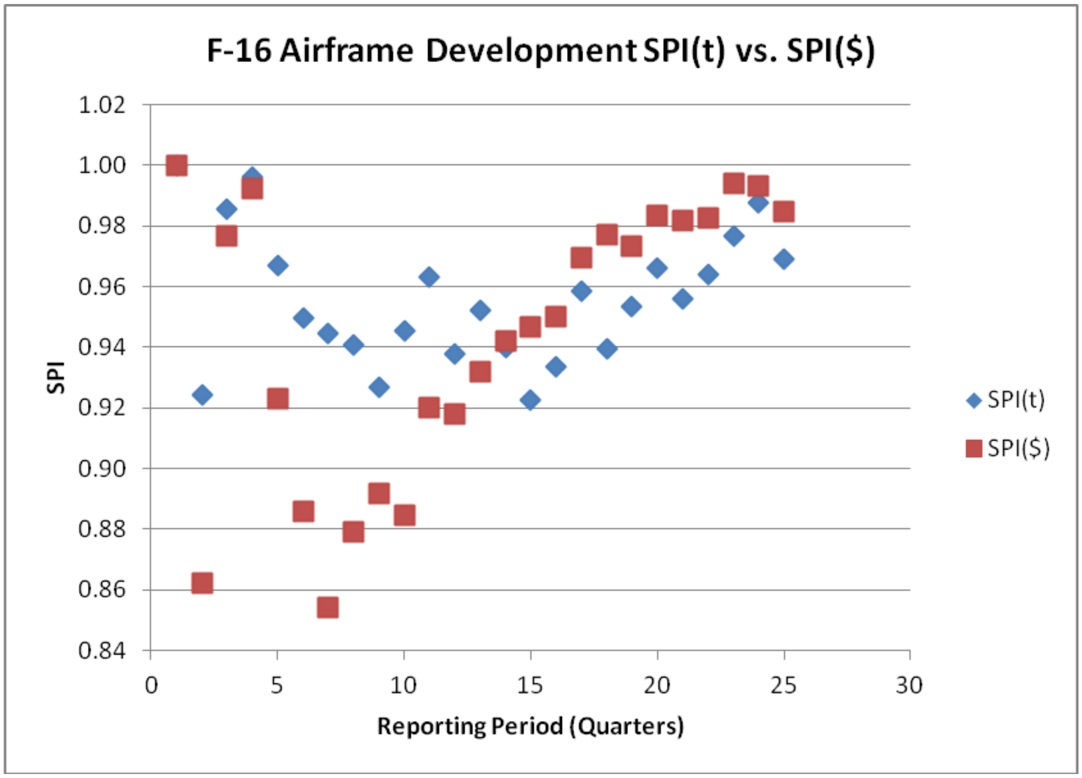

Figure 77: F-16 Airframe Development SPI(t) vs. SPI($)

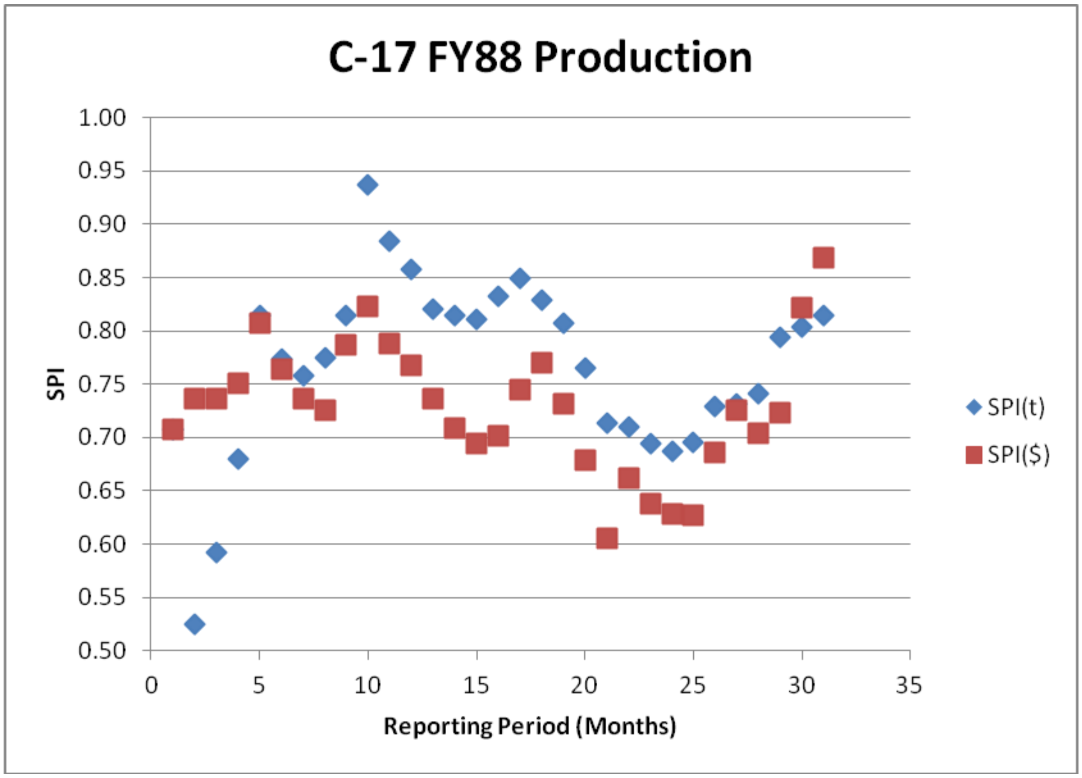

Figure 78: C-17 FY88 Production

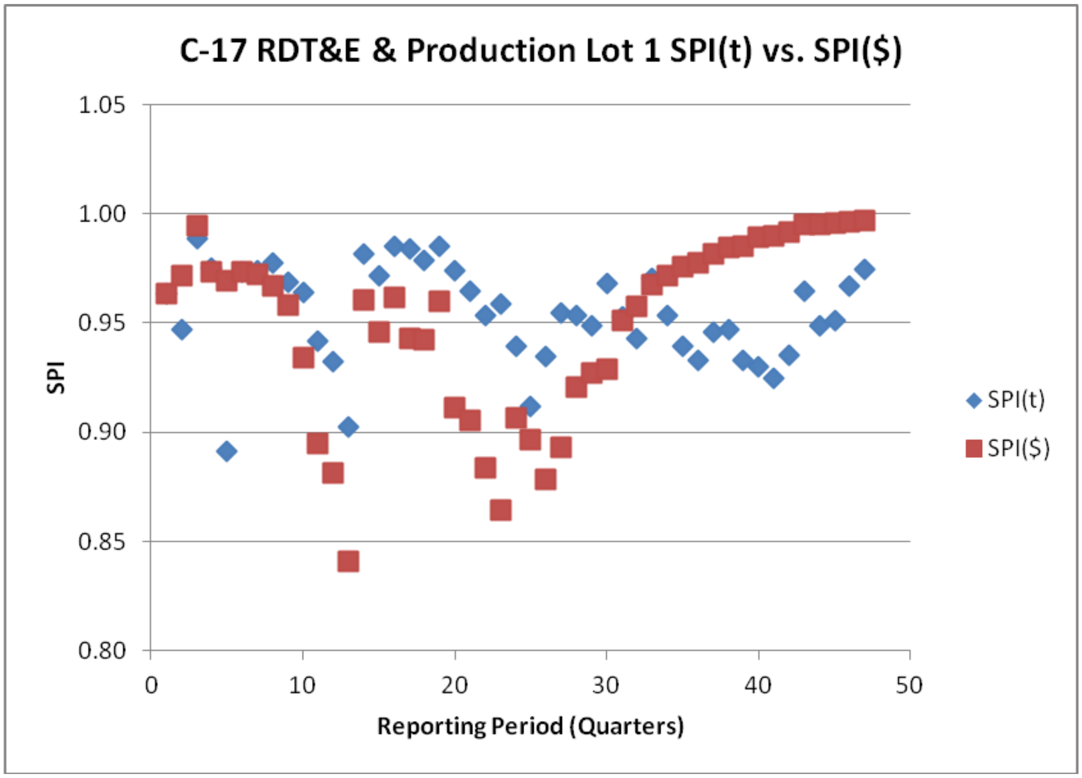

Figure 79: C-17 RDT&E & Production Lot 1 SPI(t) vs. SPI($)

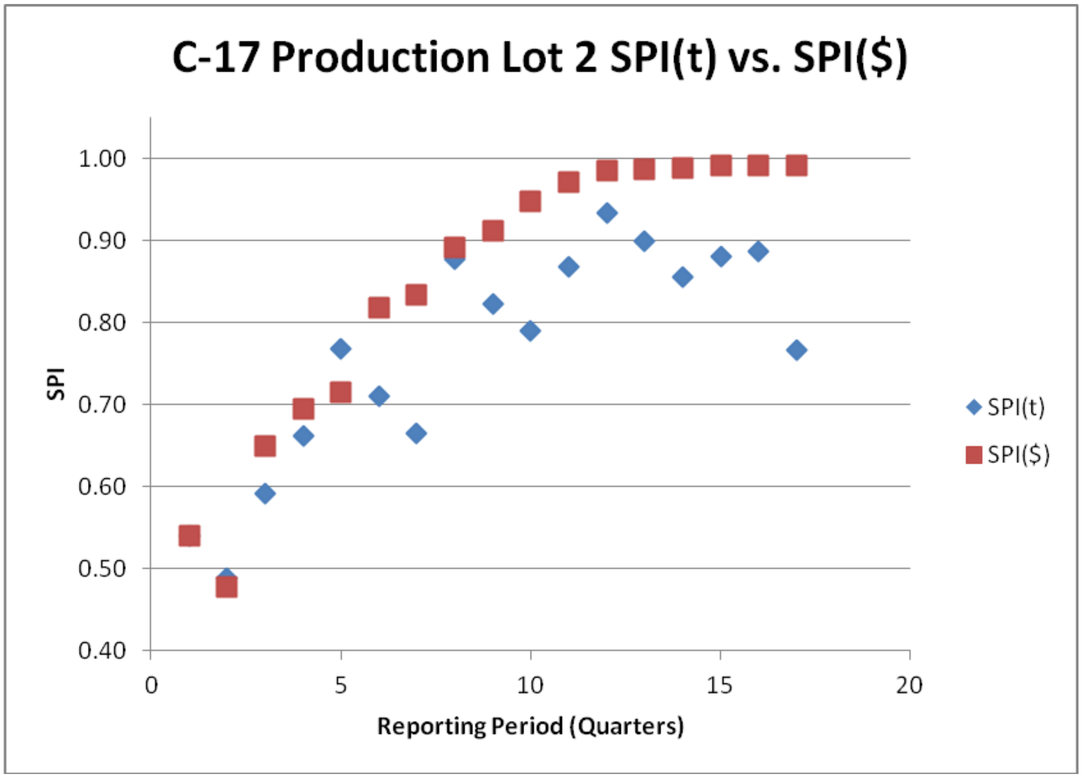

Figure 80: C-17 Production Lot 2 SPI(t) vs. SPI($)

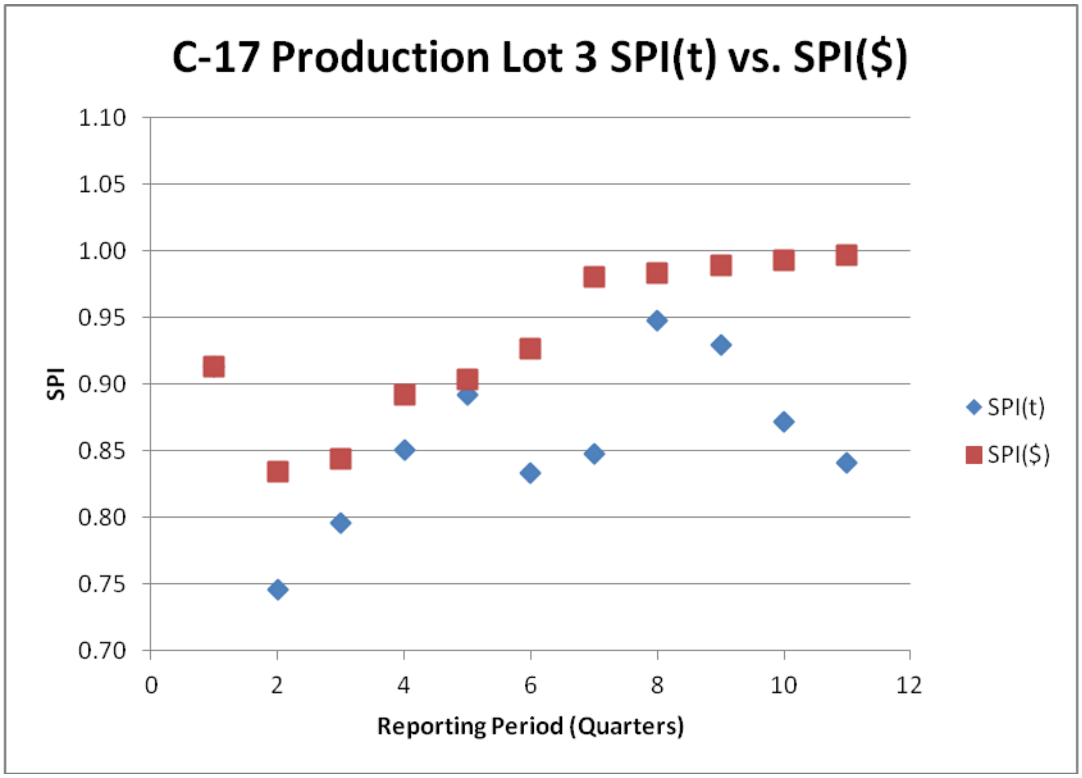

Figure 81: C-17 Production Lot 3 SPI(t) vs. SPI($)

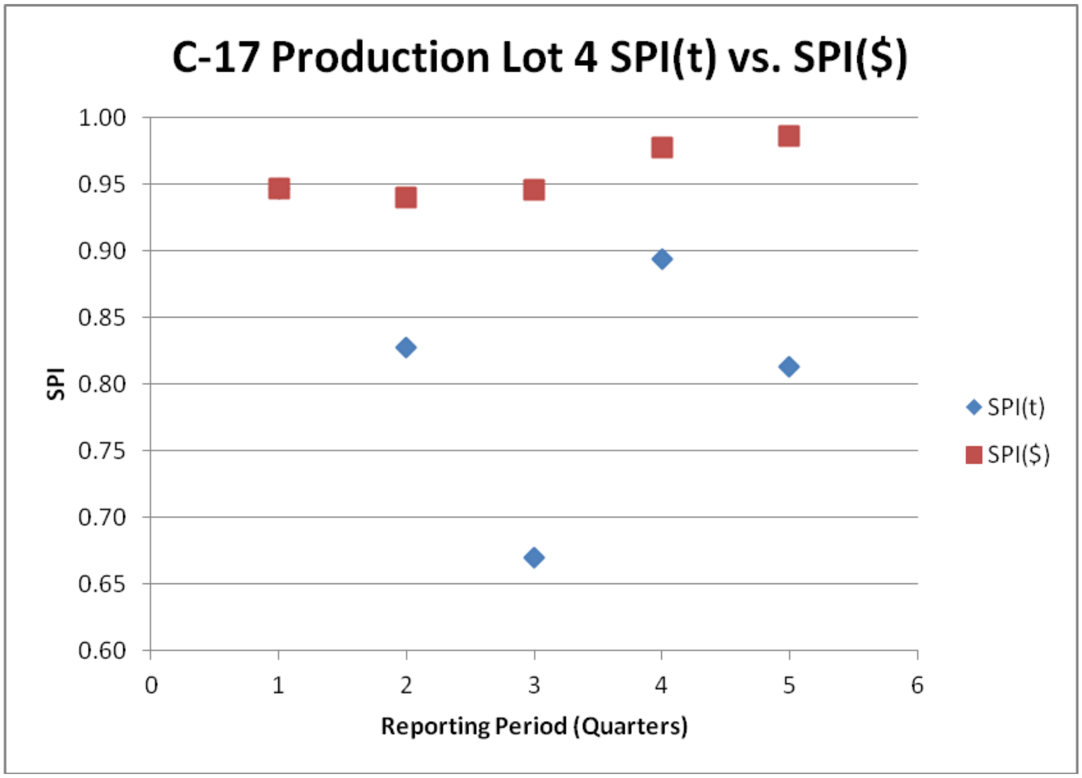

Figure 82: C-17 Production Lot 4 SPI(t) vs. SPI($)

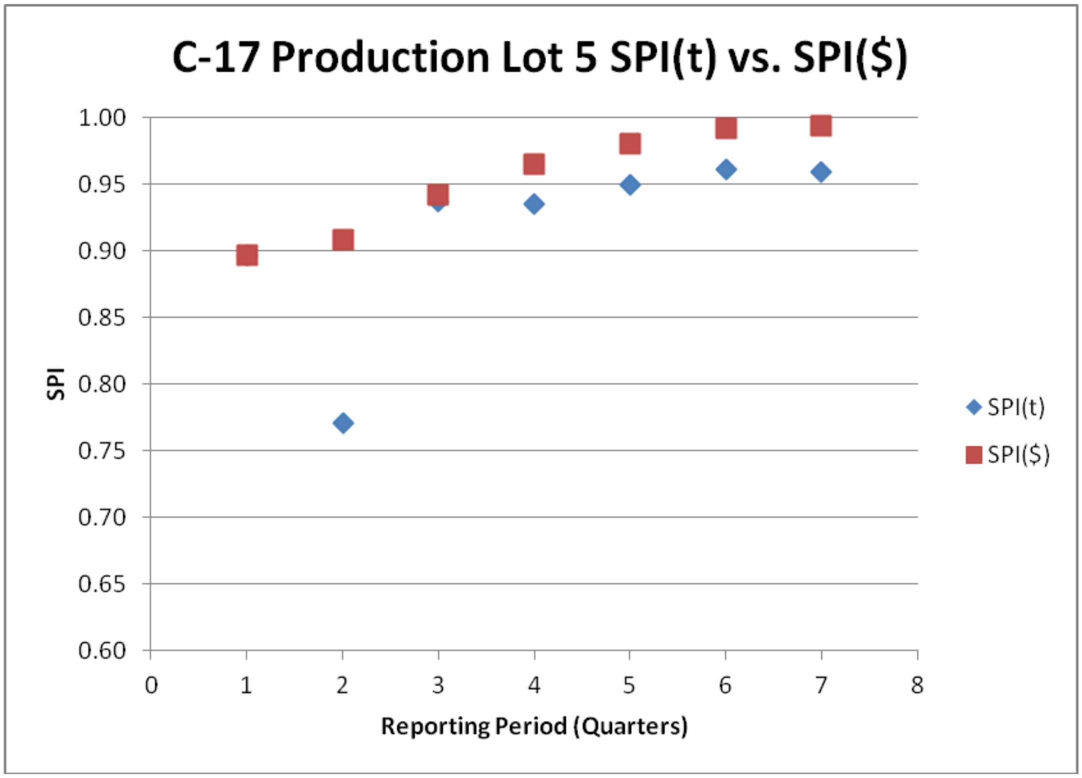

Figure 83: C-17 Production Lot 5 SPI(t) vs. SPI($)

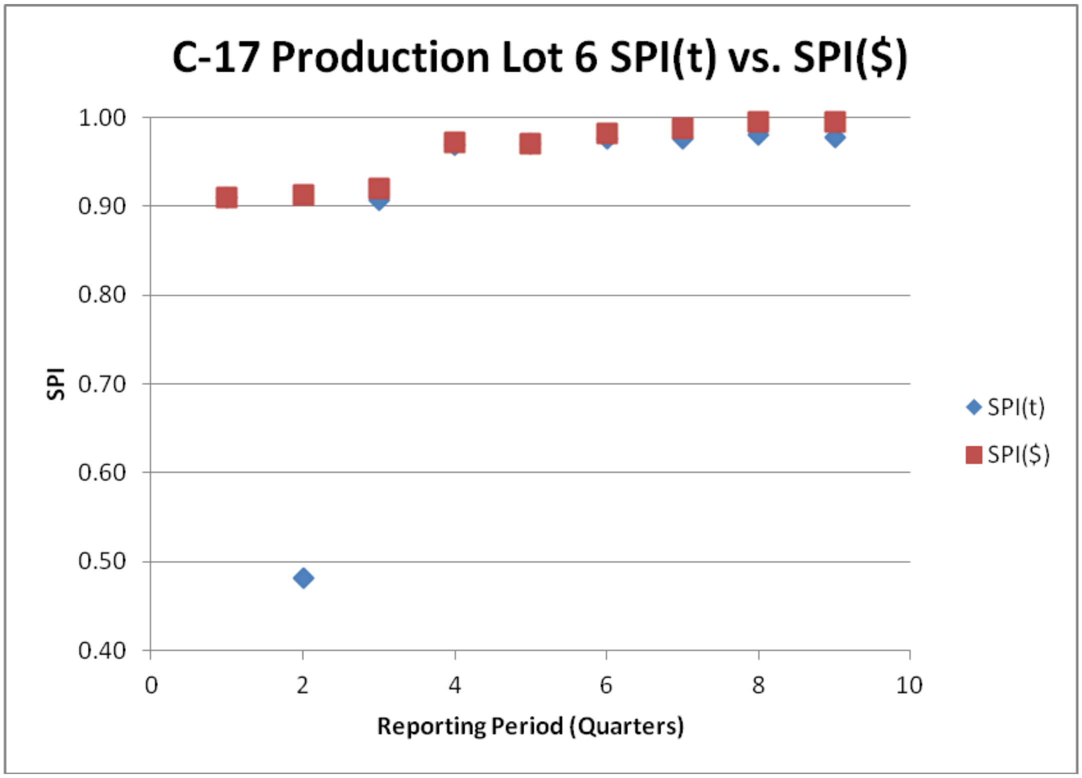

Figure 84: C-17 Production Lot 6 SPI(t) vs. SPI($)

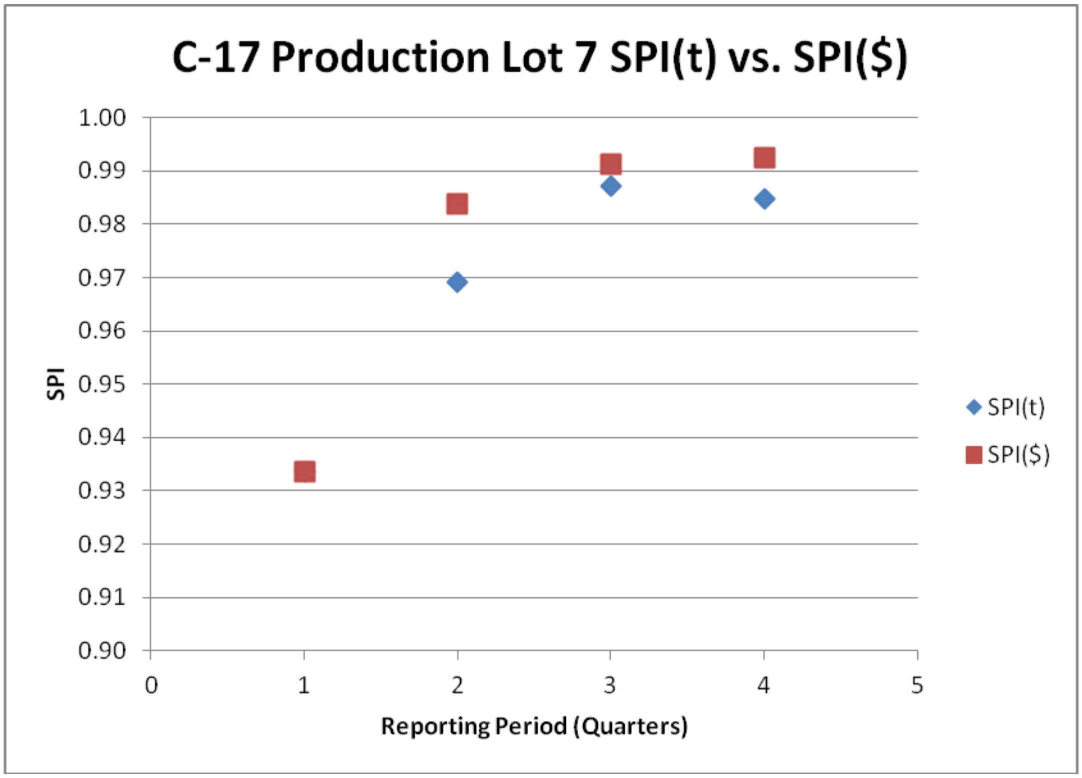

Figure 85: C-17 Production Lot 7 SPI(t) vs. SPI($)

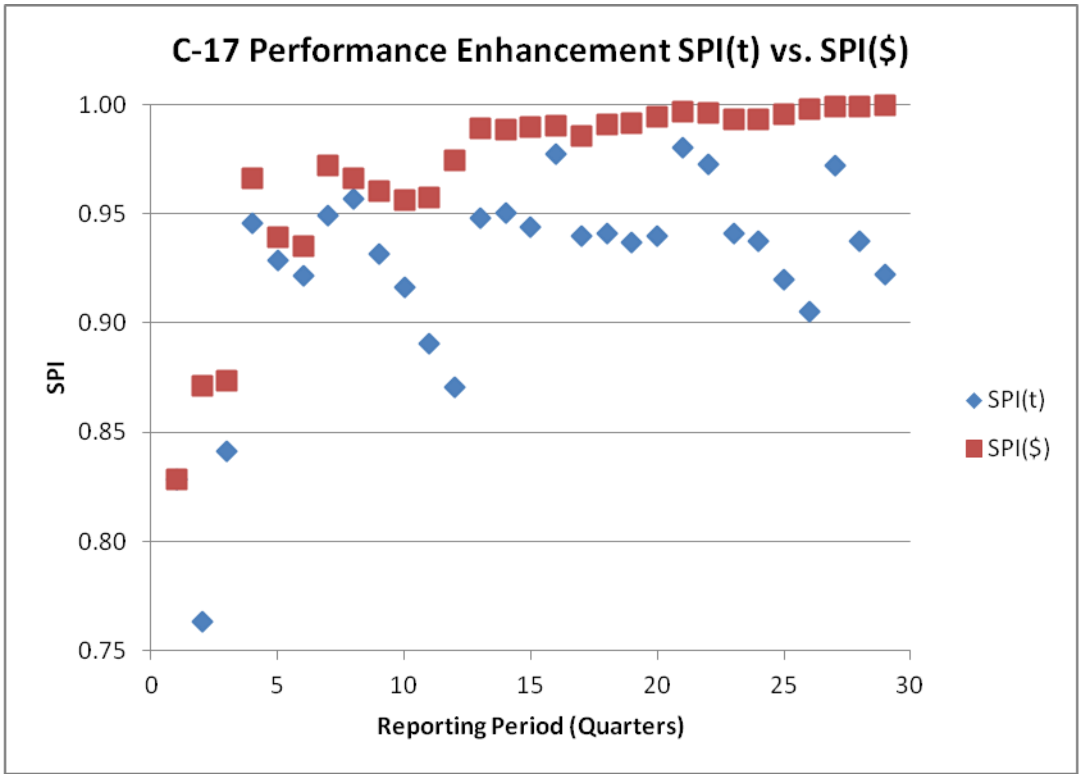

Figure 86: C-17 Performance Enhancement SPI(t) vs. SPI($)

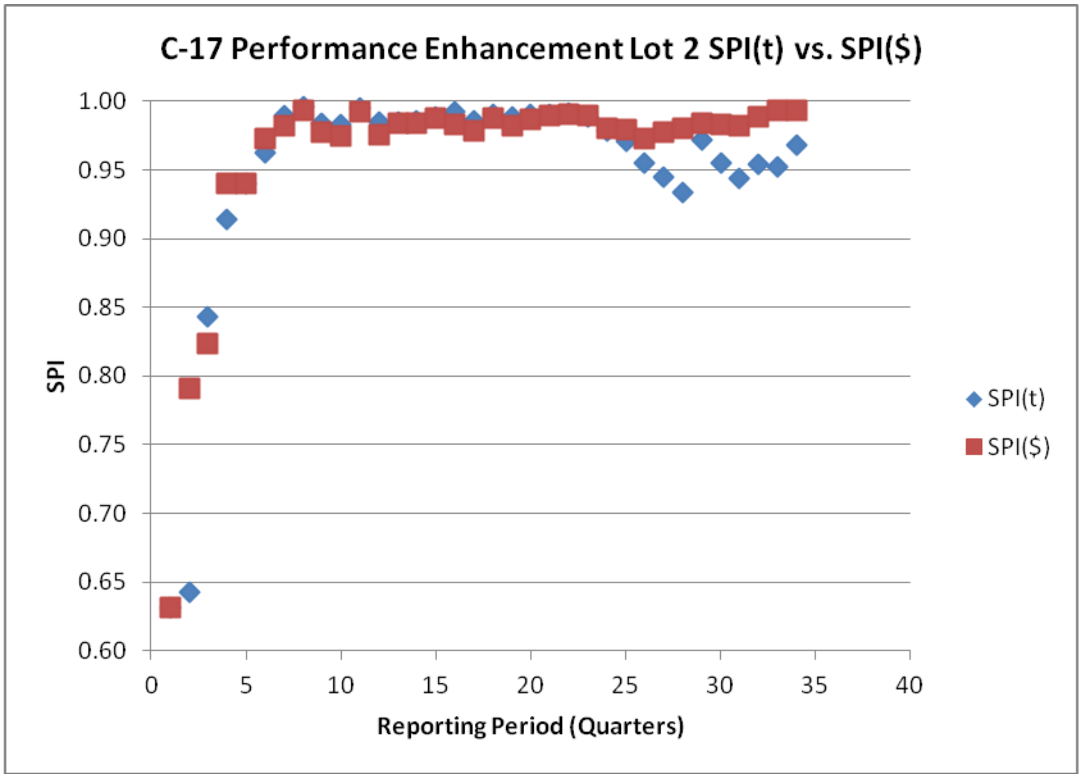

Figure 87: C-17 Performance Enhancement Lot 2 SPI(t) vs. SPI($)

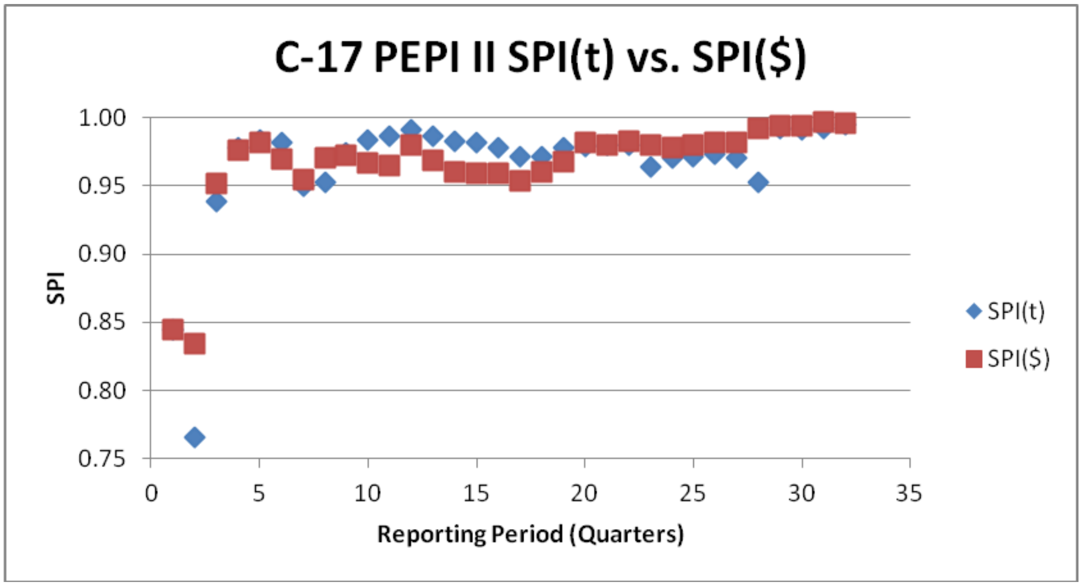

Figure 88: C-17 PEPI II SPI(t) vs. SPI($)

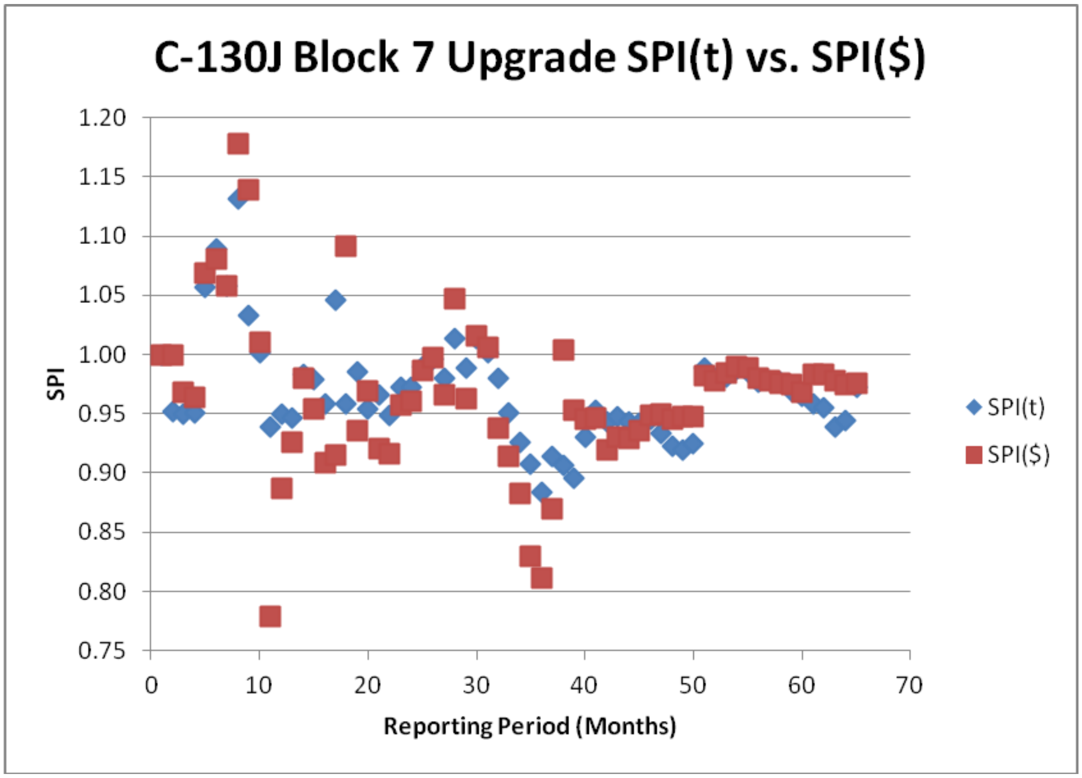

Figure 89: C-130J Block 7 Upgrade SPI(t) vs. SPI($)

Appendix C

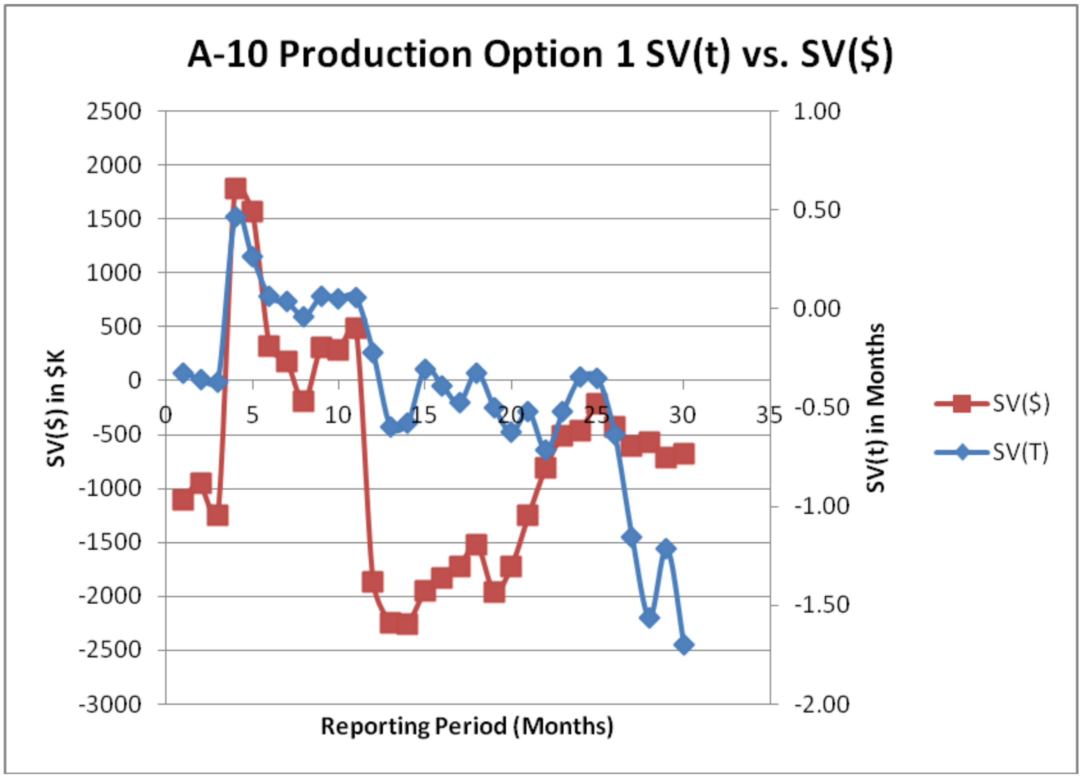

Figure 90: A-10 Production Option 1 SV(t) vs. SV($)

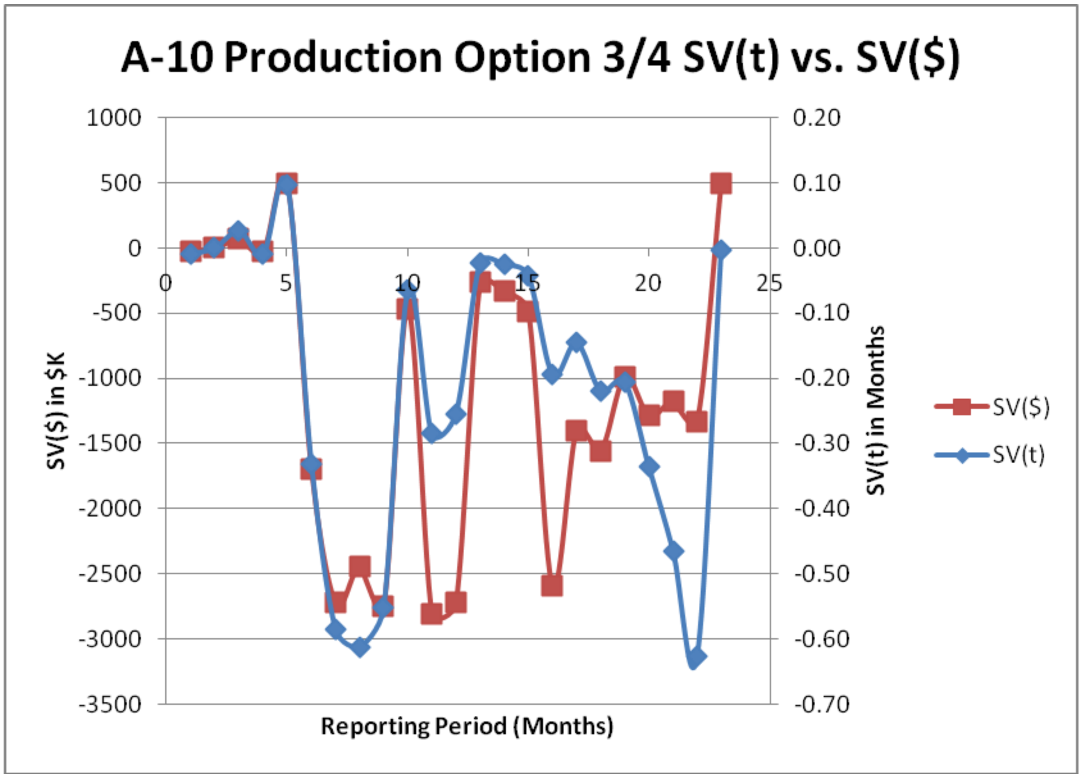

Figure 91: A-10 Production Option 3/4 SV(t) vs. SV($)

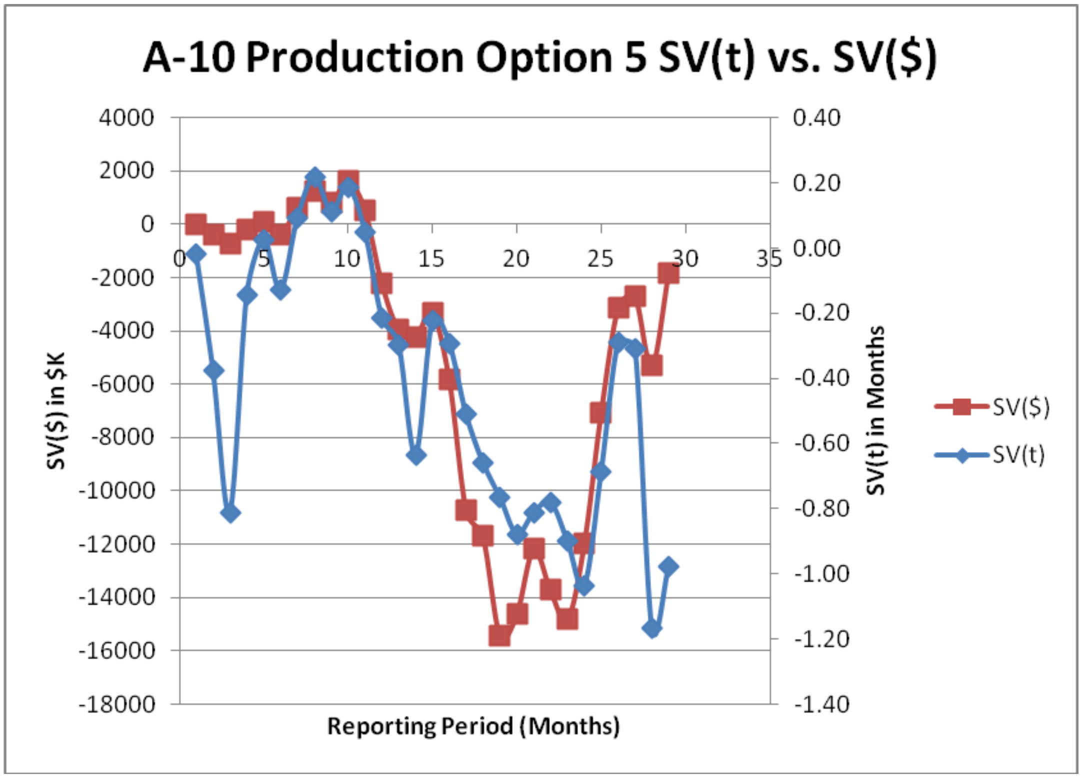

Figure 92: A-10 Production Option 5 SV(t) vs. SV($)

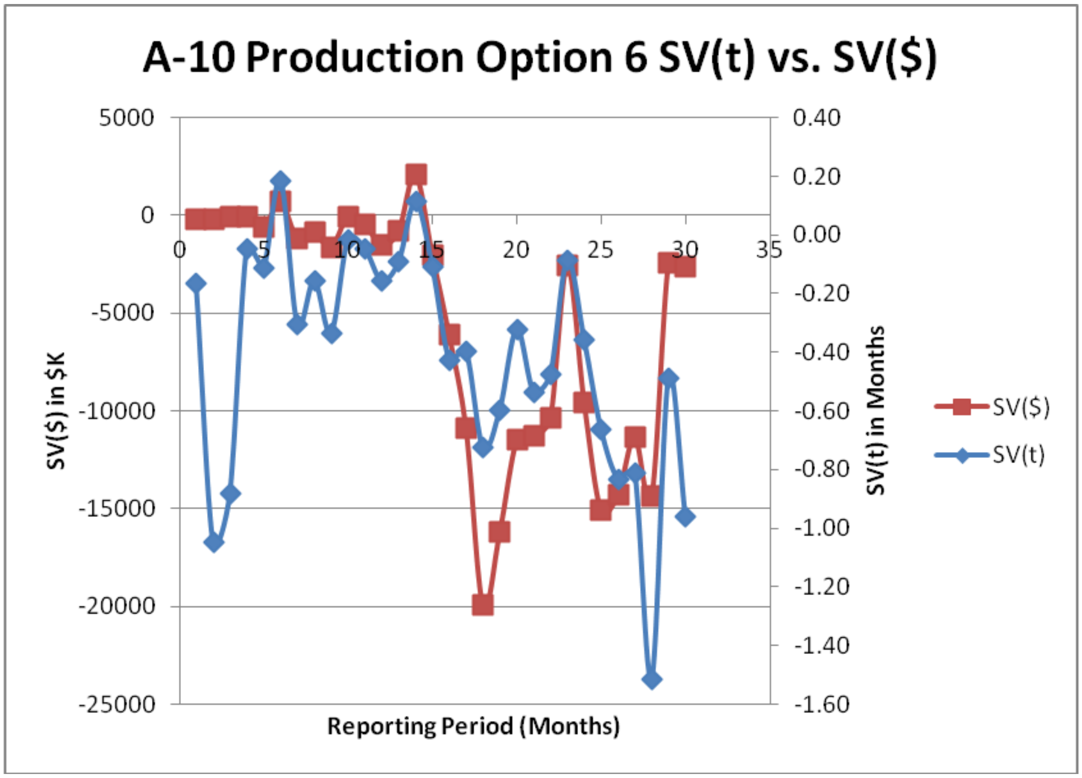

Figure 93: A-10 Production Option 6 SV(t) vs. SV($)

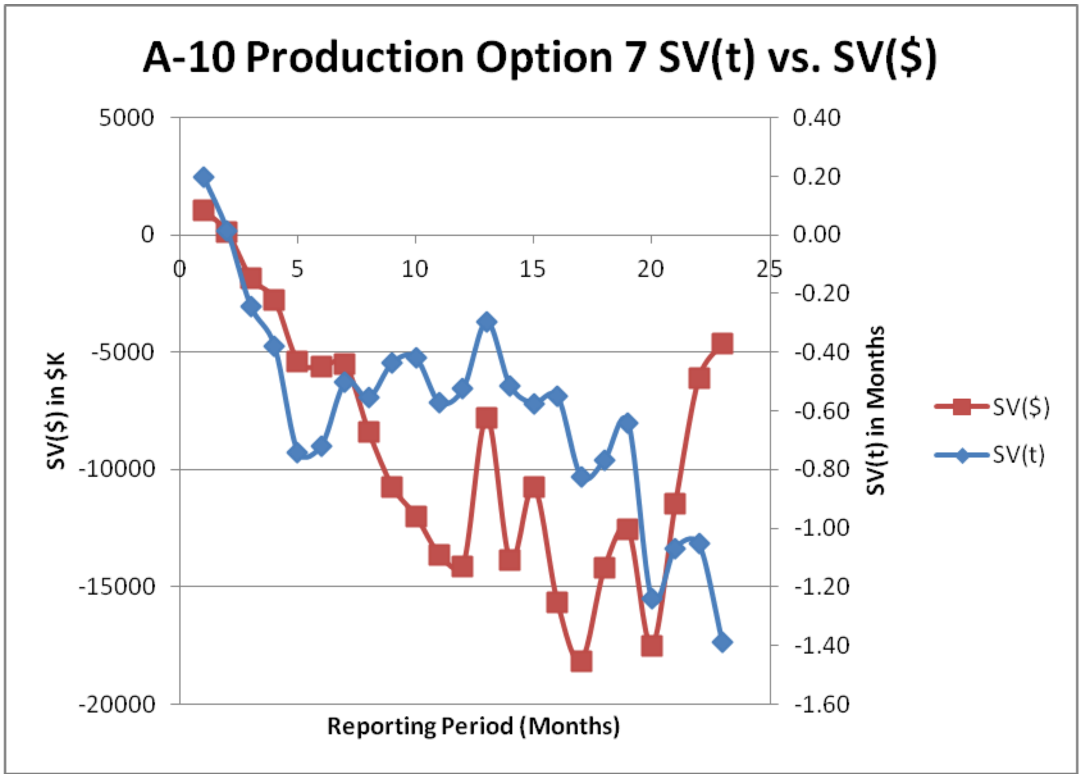

Figure 94: A-10 Production Option 7 SV(t) vs. SV($)

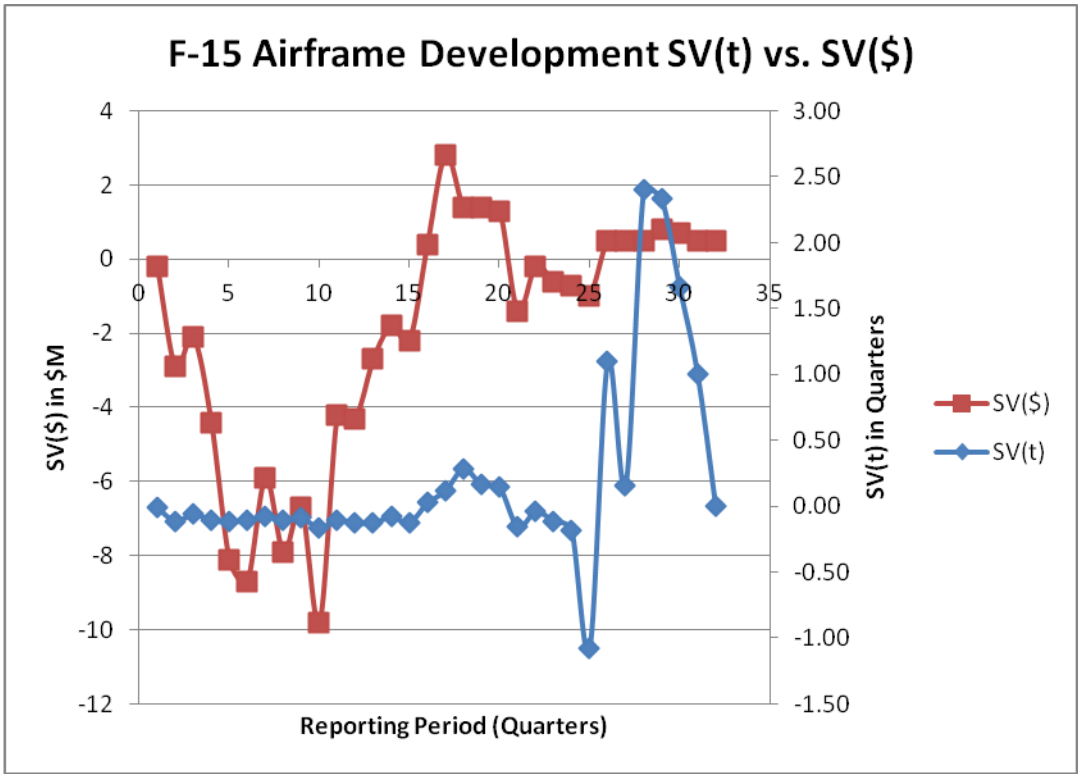

Figure 95: F-15 Airframe Development SV(t) vs. SV($)

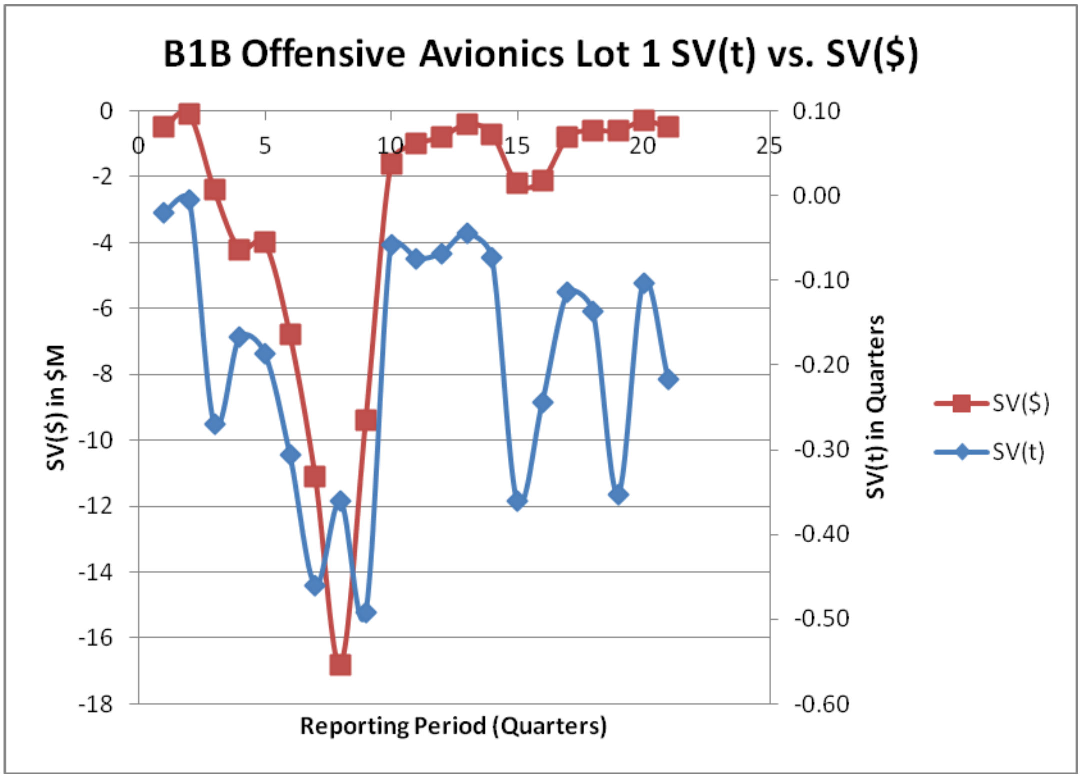

Figure 96: B1B Offensive Avionics Lot 1 SV(t) vs. SV($)

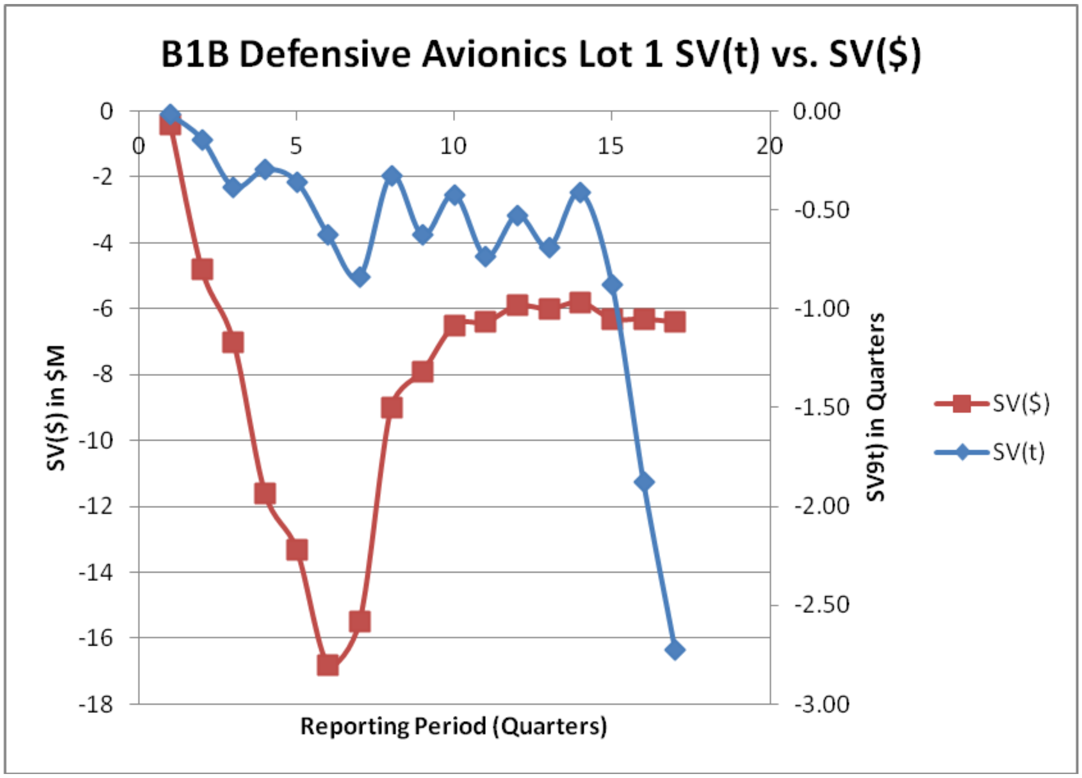

Figure 97: B1B Defensive Avionics Lot 1 SV(t) vs. SV($)

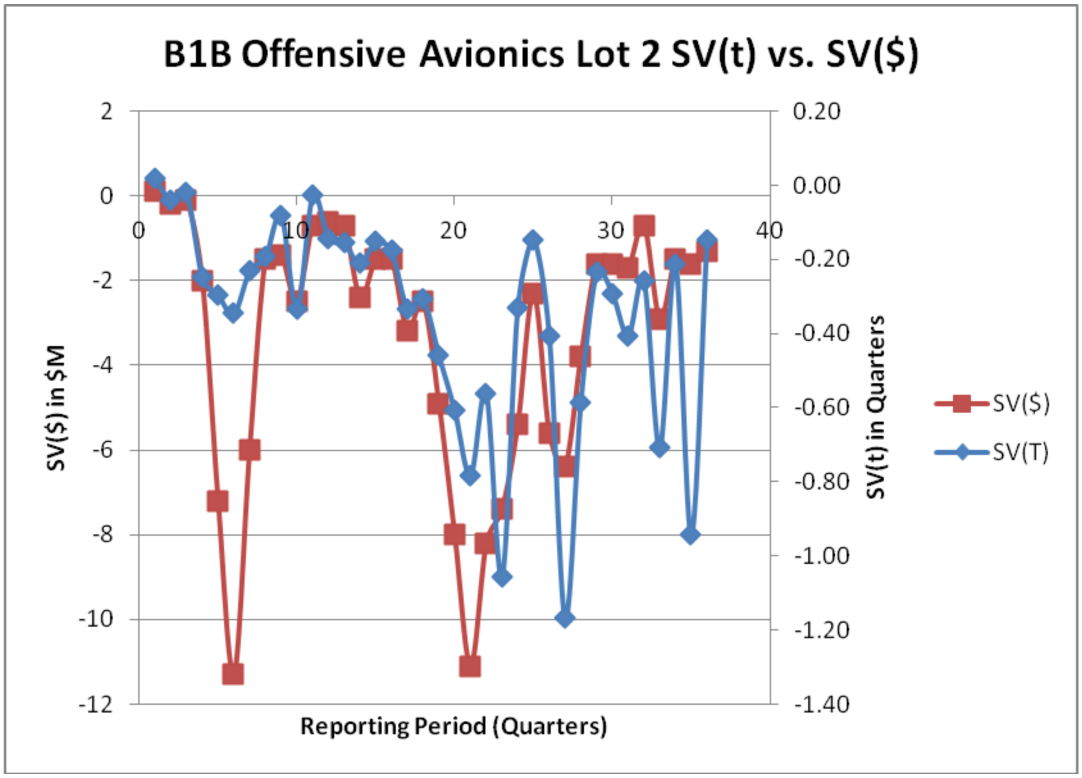

Figure 98: B1B Offensive Avionics Lot 2 SV(t) vs. SV($)

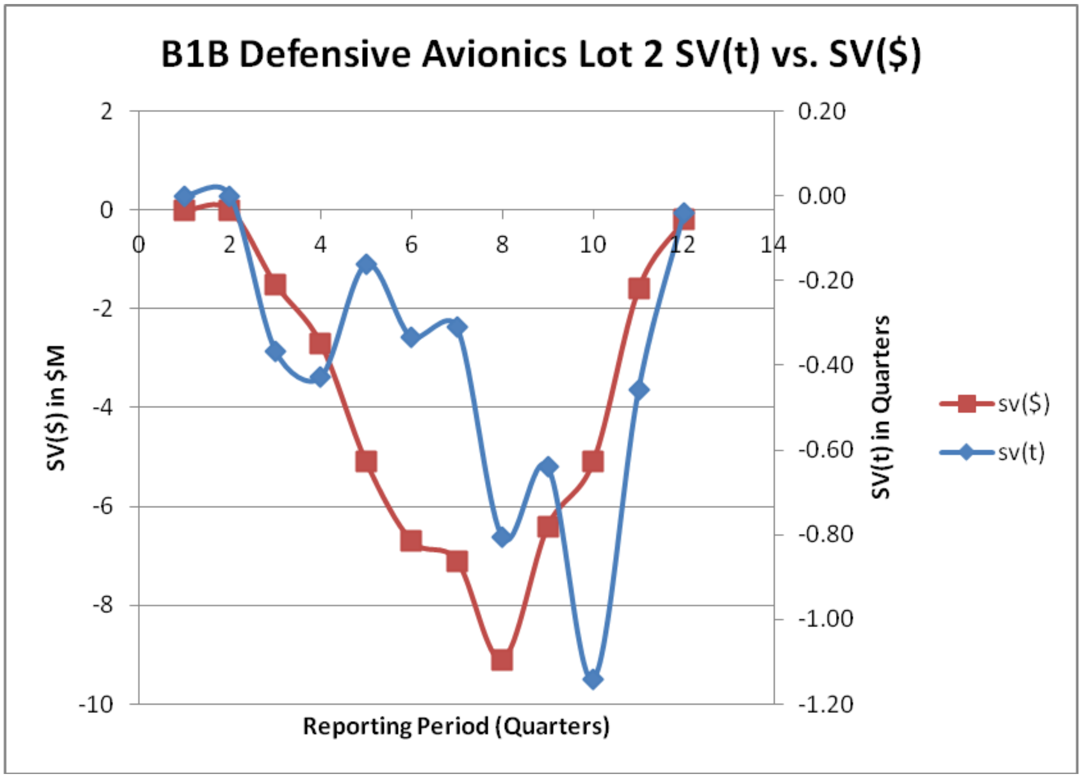

Figure 99: B1B Defensive Avionics Lot 2 SV(t) vs. SV($)

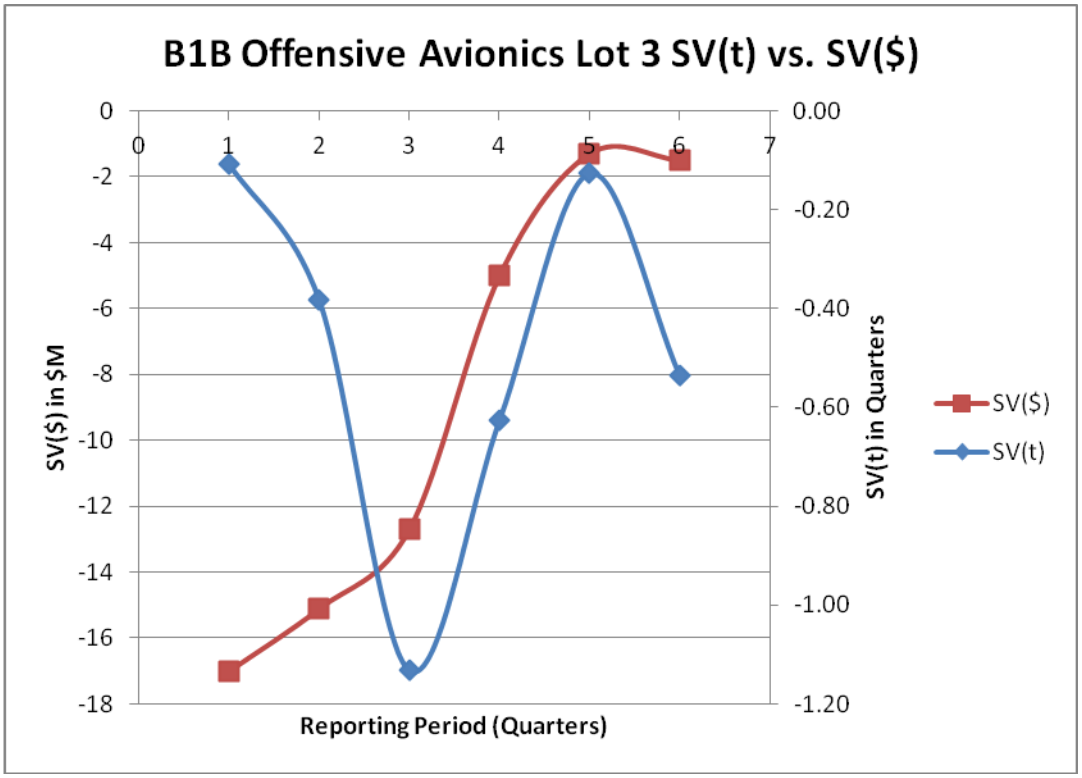

Figure 100: B1B Offensive Avionics Lot 3 SV(t) vs. SV($)

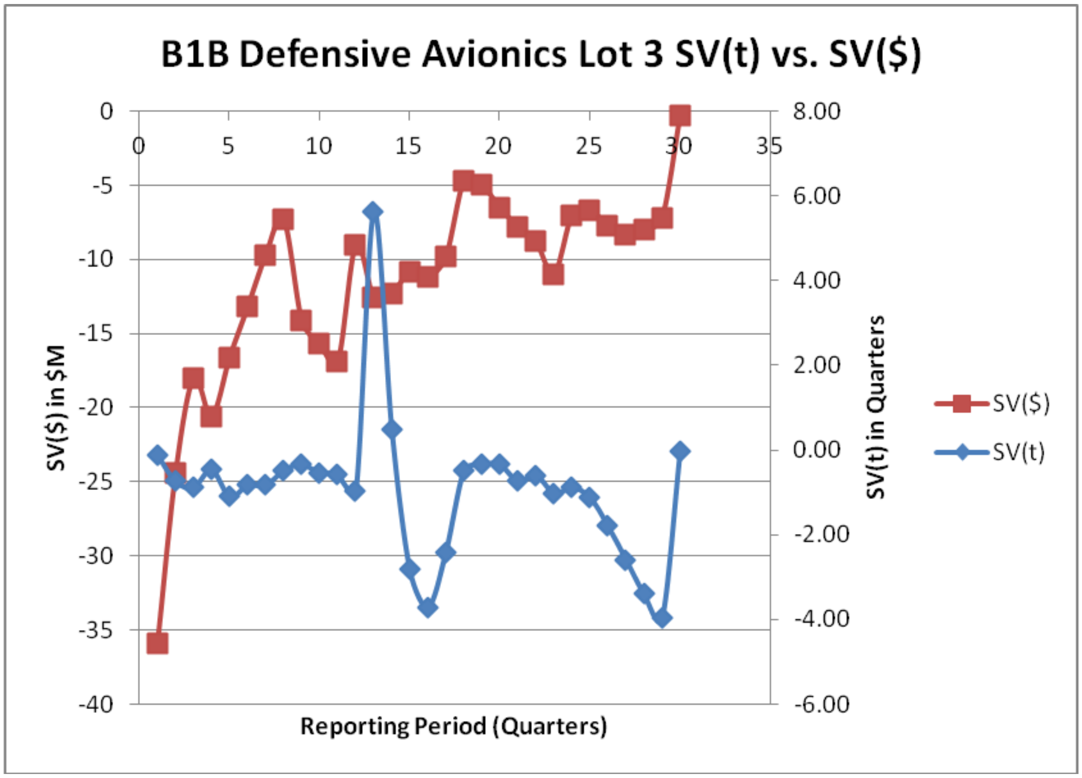

Figure 101: B1B Defensive Avionics Lot 3 SV(t) vs. SV($)

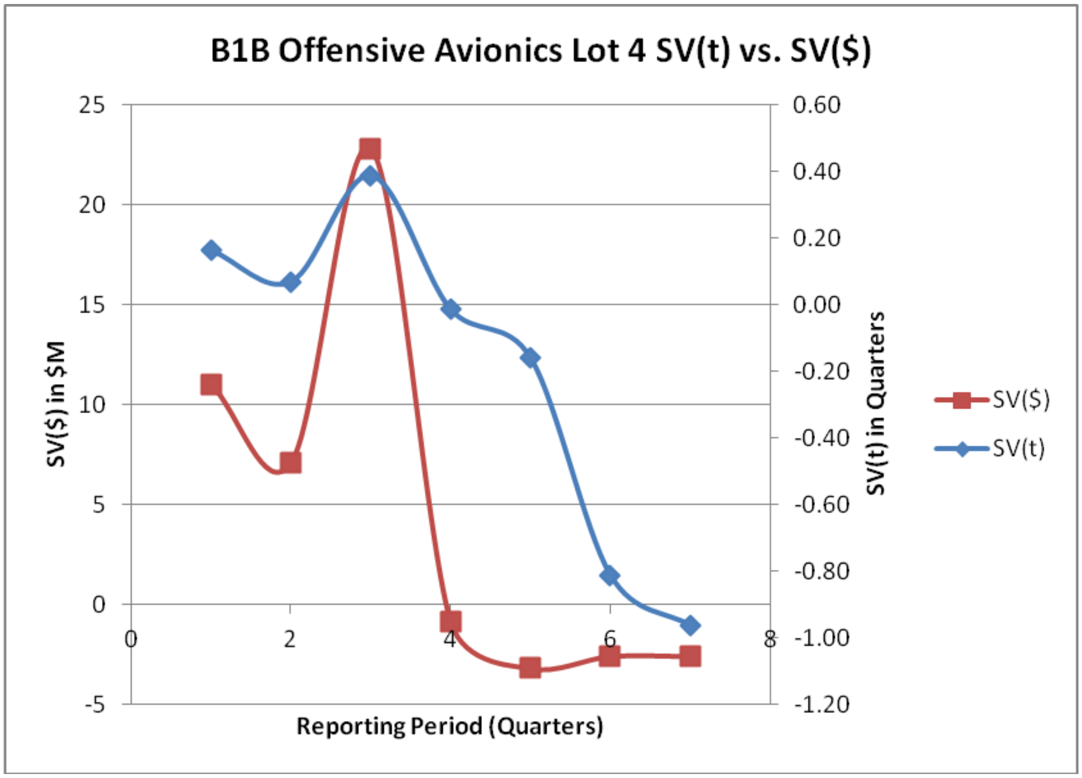

Figure 102: B1B Offensive Avionics Lot 4 SV(t) vs. SV($)

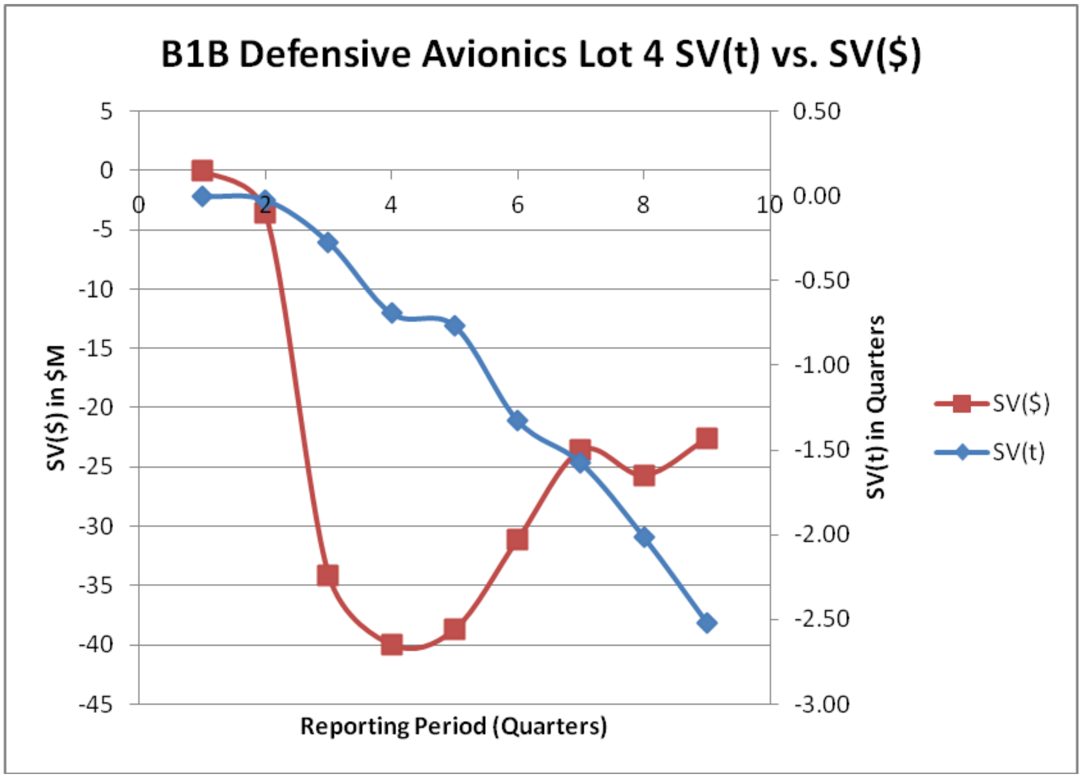

Figure 103: B1B Defensive Avionics Lot 4 SV(t) vs. SV($)

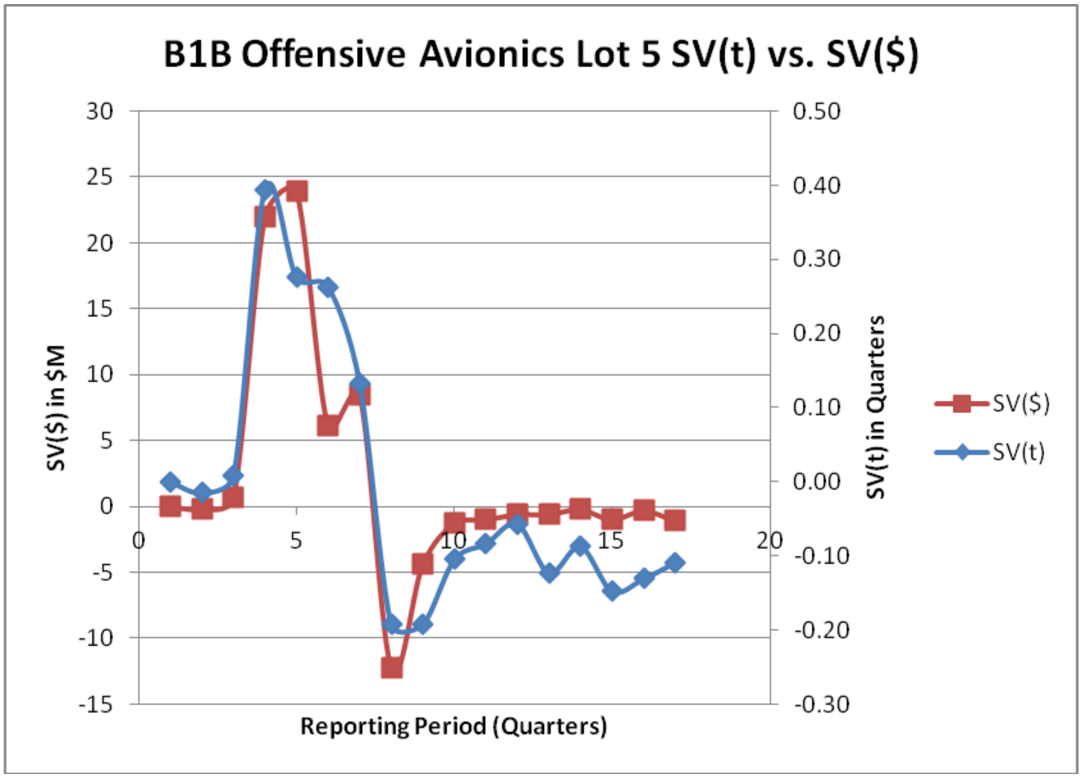

Figure 104: B1B Offensive Avionics Lot 5 SV(t) vs. SV($)

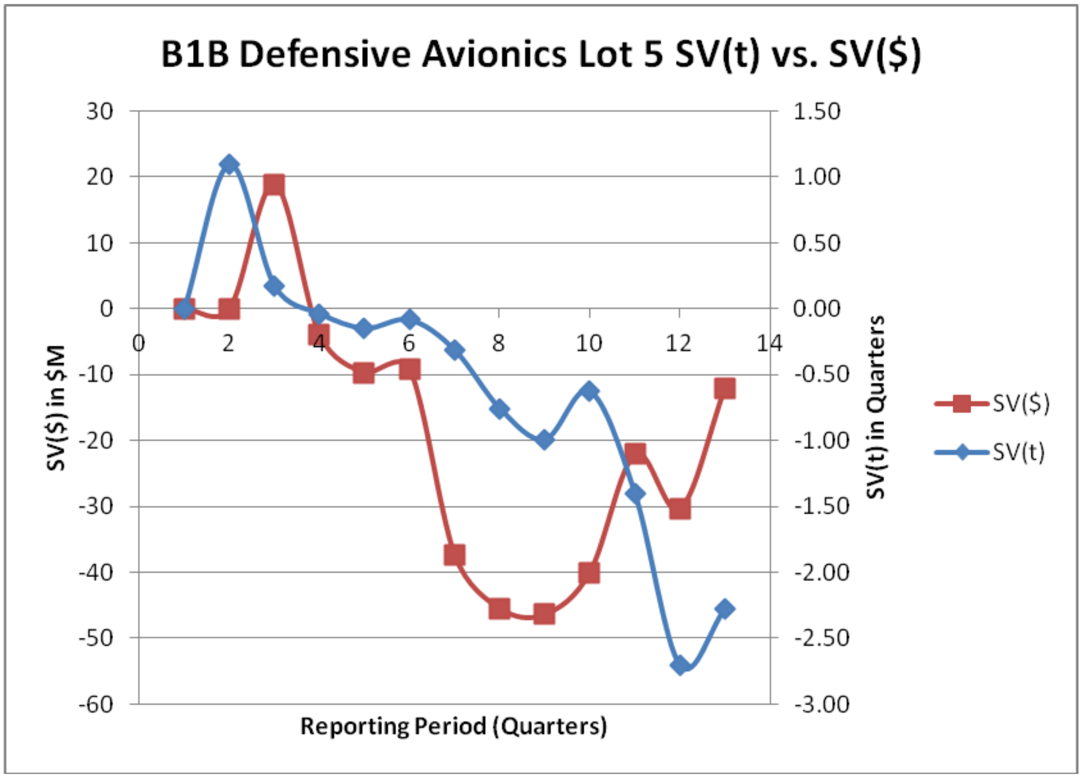

Figure 105: B1B Defensive Avionics Lot 5 SV(t) vs. SV($)

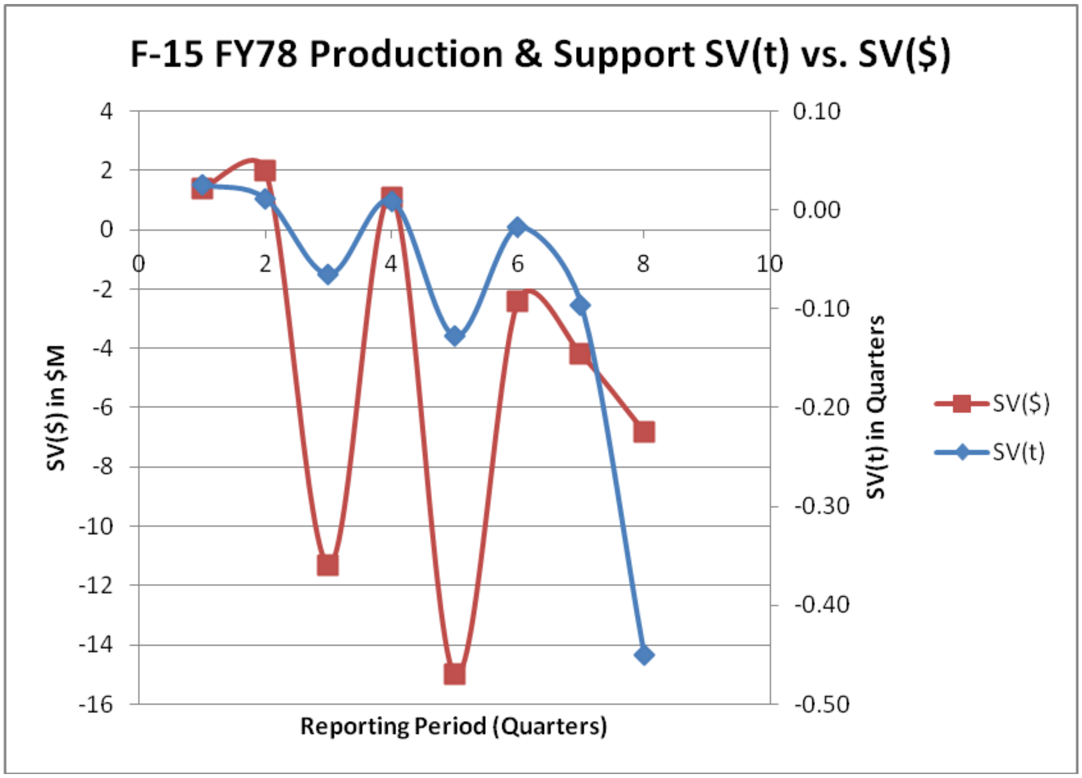

Figure 106: F-15 FY78 Production & Support SV(t) vs. SV($)

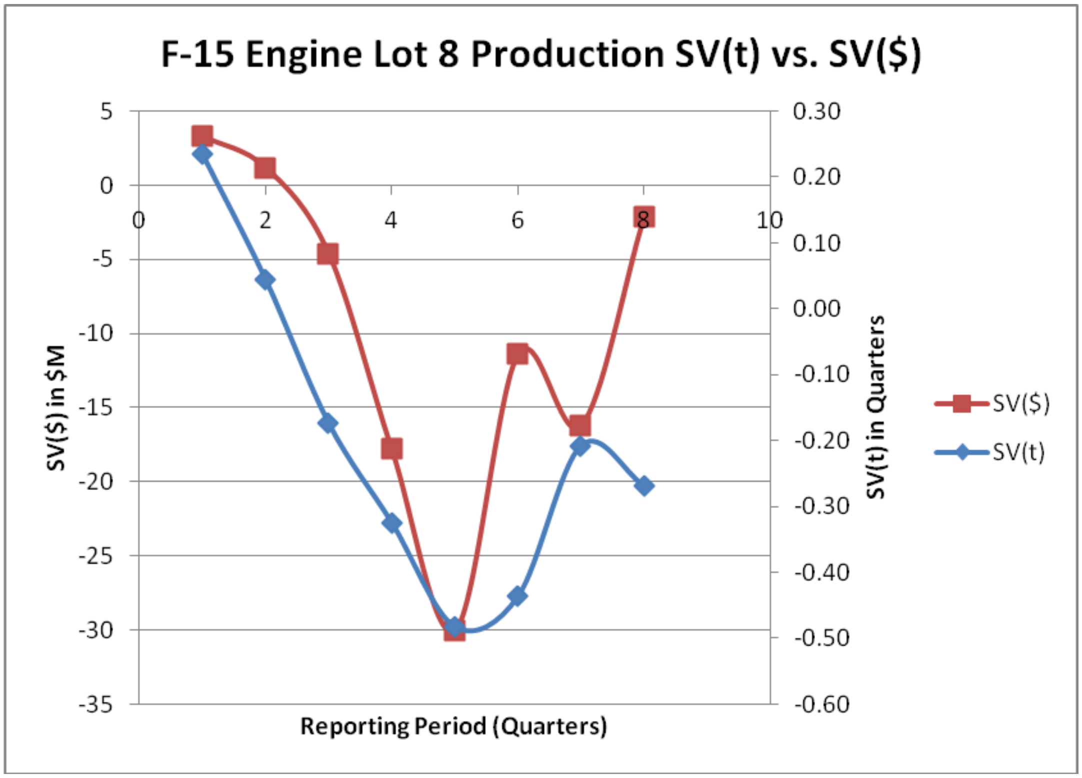

Figure 107: F-15 Engine Lot 8 Production SV(t) vs. SV($)

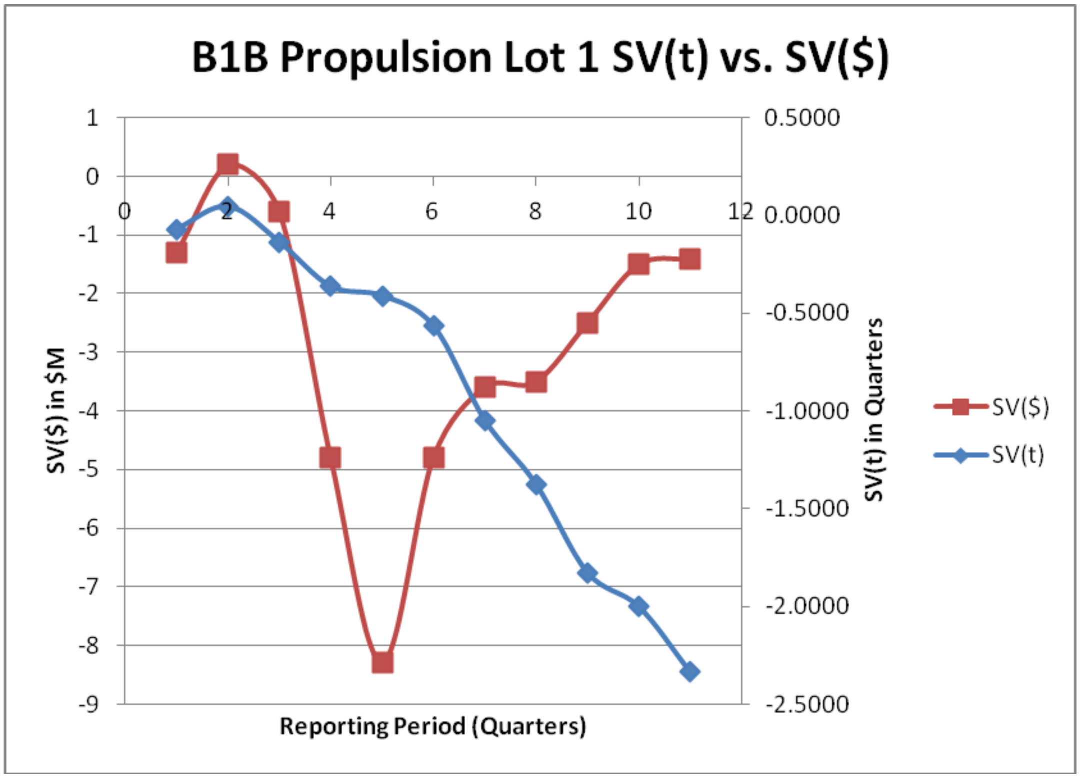

Figure 108: B1B Propulsion Lot 1 SV(t) vs. SV($)

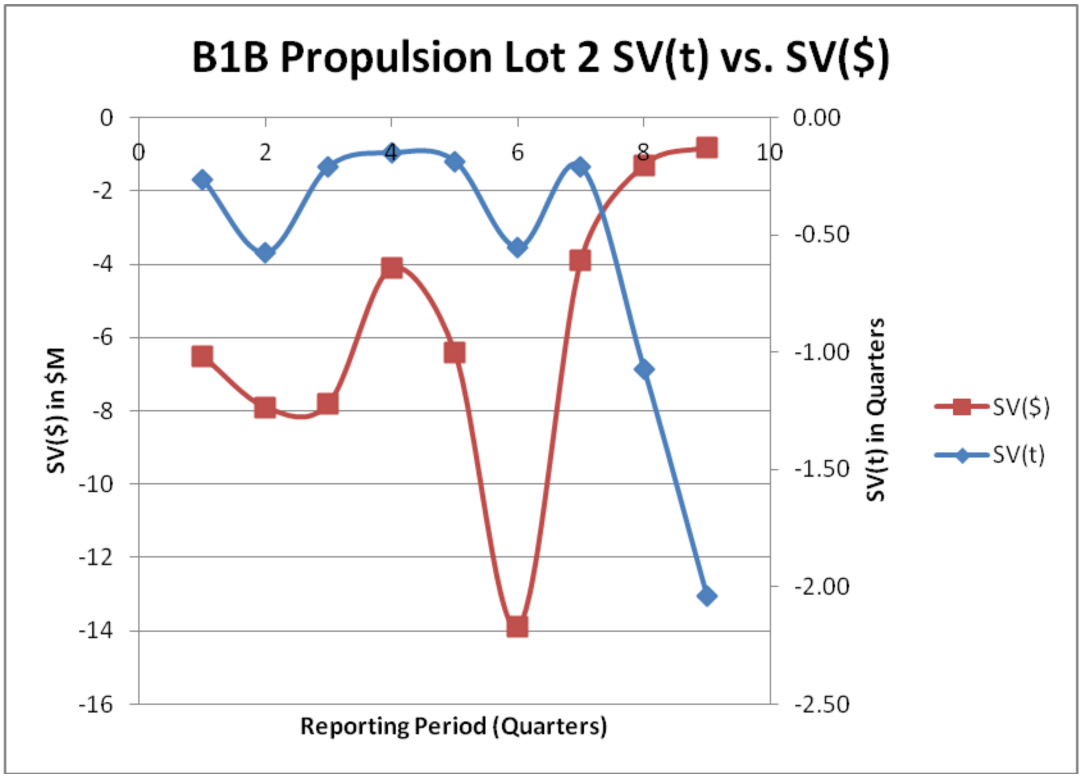

Figure 109: B1B Propulsion Lot 2 SV(t) vs. SV($)

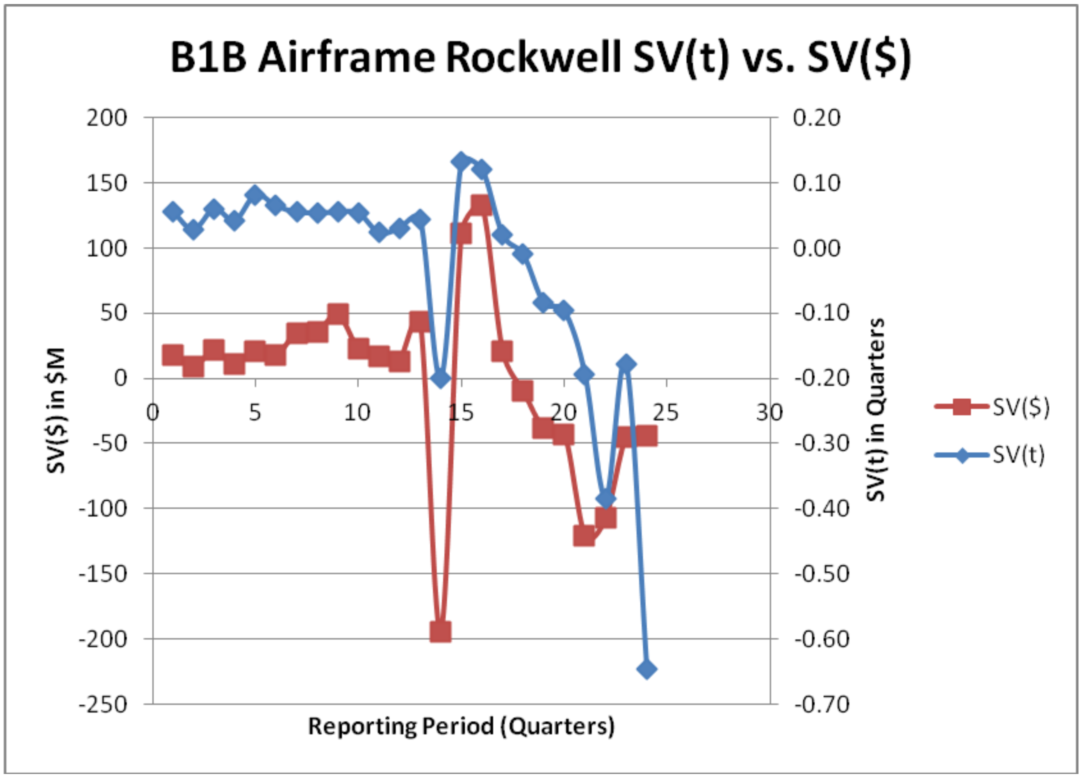

Figure 110: B1B Airframe Rockwell SV(t) vs. SV($)

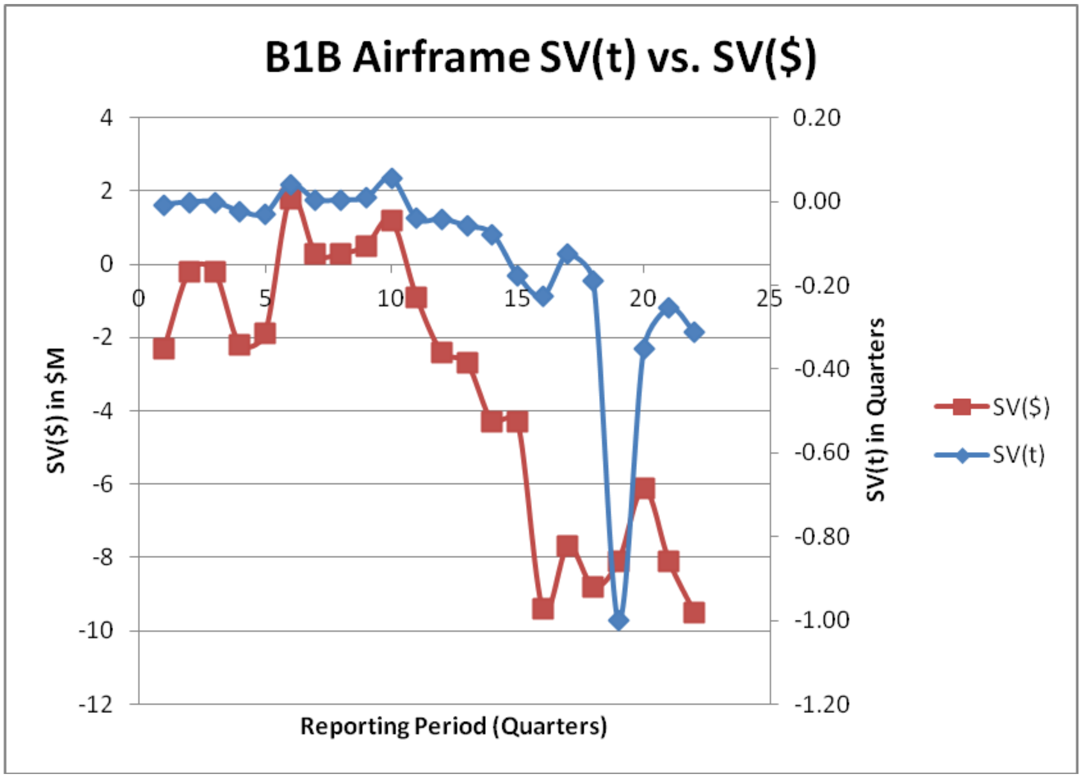

Figure 111: B1B Airframe SV(t) vs. SV($)

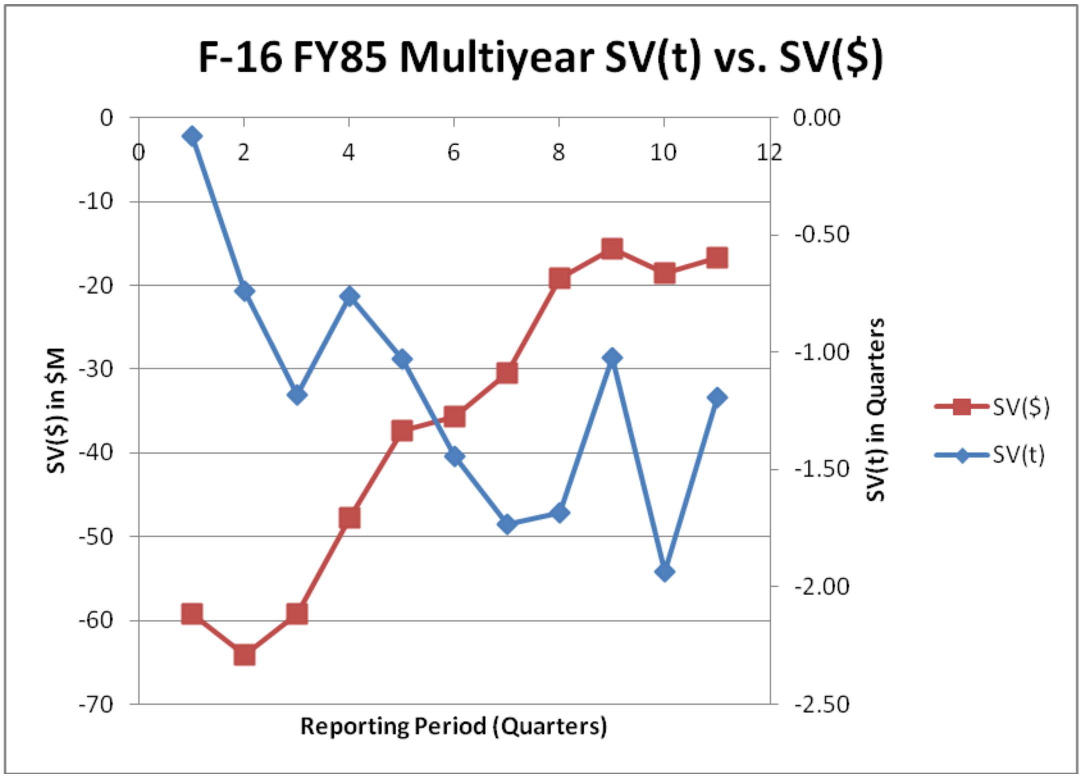

Figure 112: F-16 FY85 Multiyear SV(t) vs. SV($)

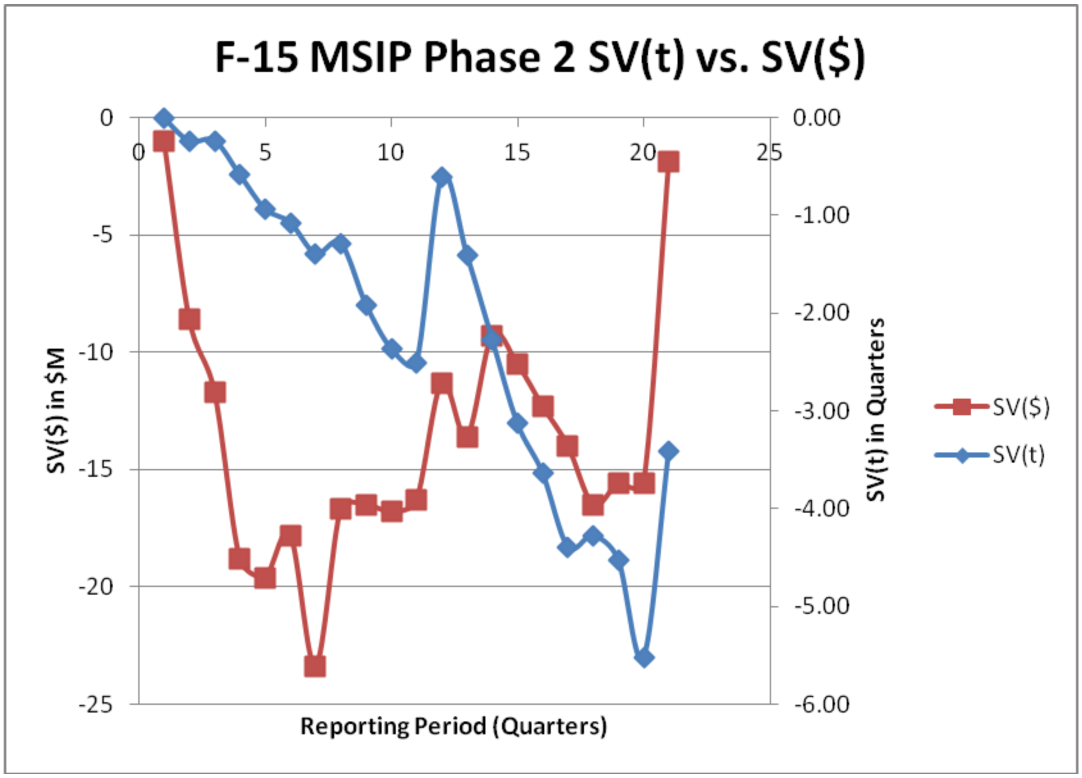

Figure 113: F-15 MSIP Phase 2 SV(t) vs. SV($)

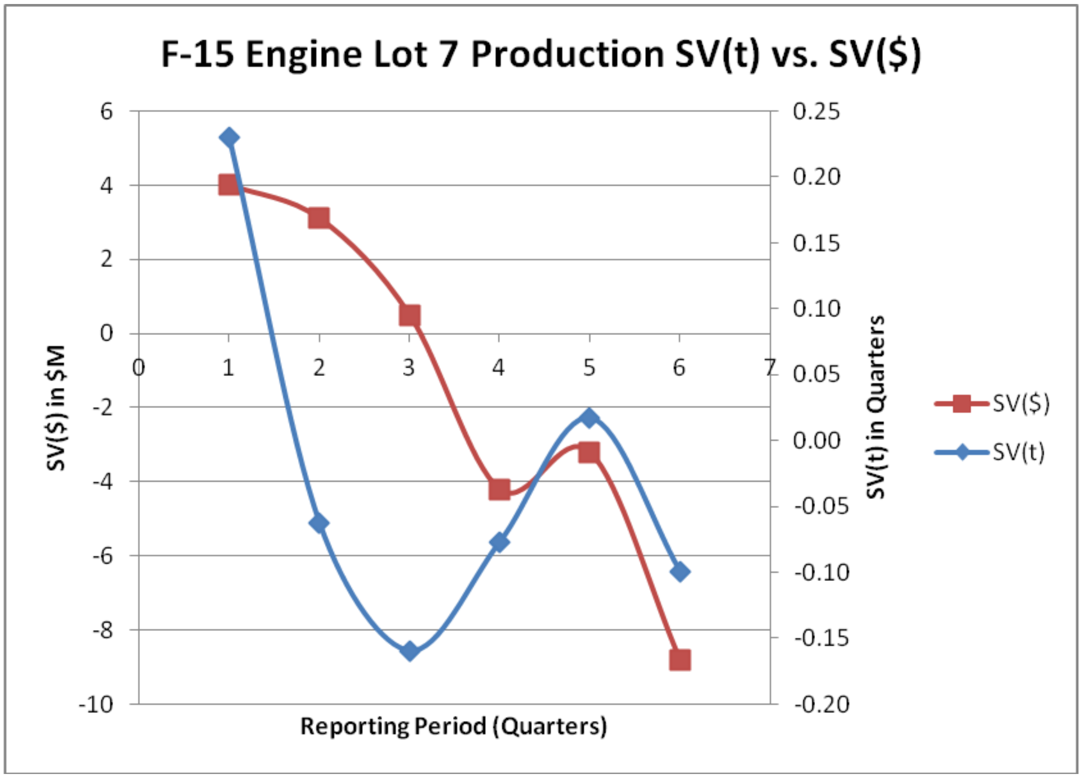

Figure 114: F-15 Engine Lot 7 Production SV(t) vs. SV($)

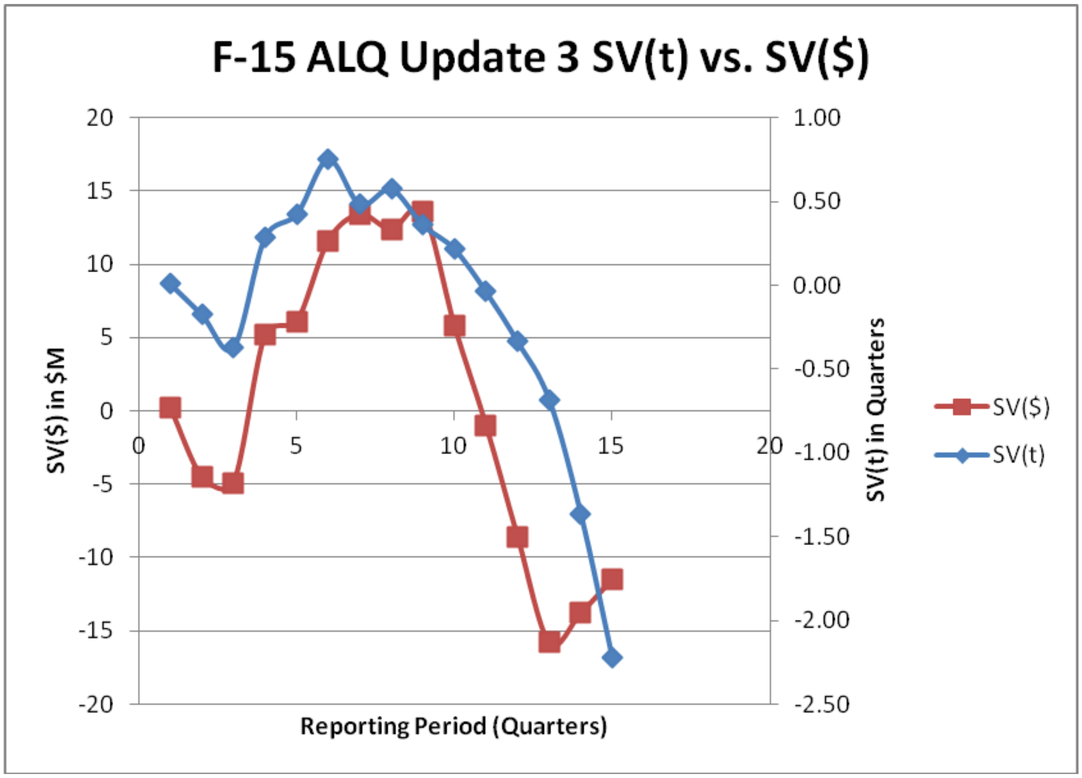

Figure 115: F-15 ALQ Update 3 SV(t) vs. SV($)

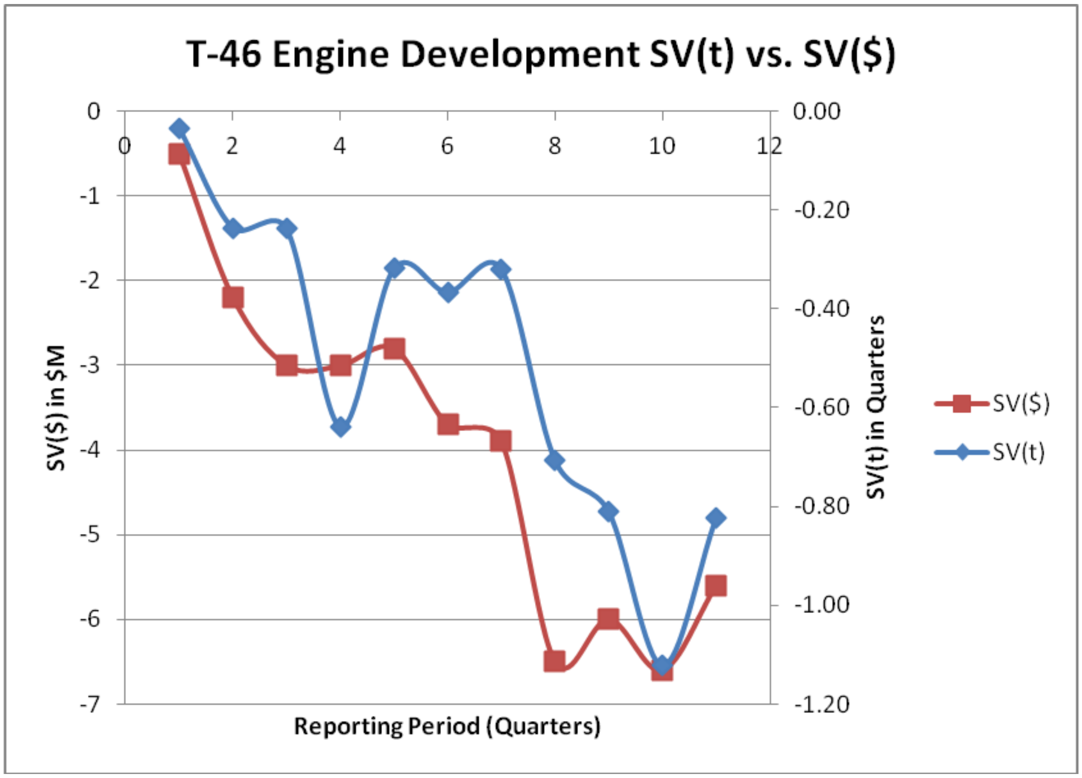

Figure 116: T-46 Engine Development SV(t) vs. SV($)

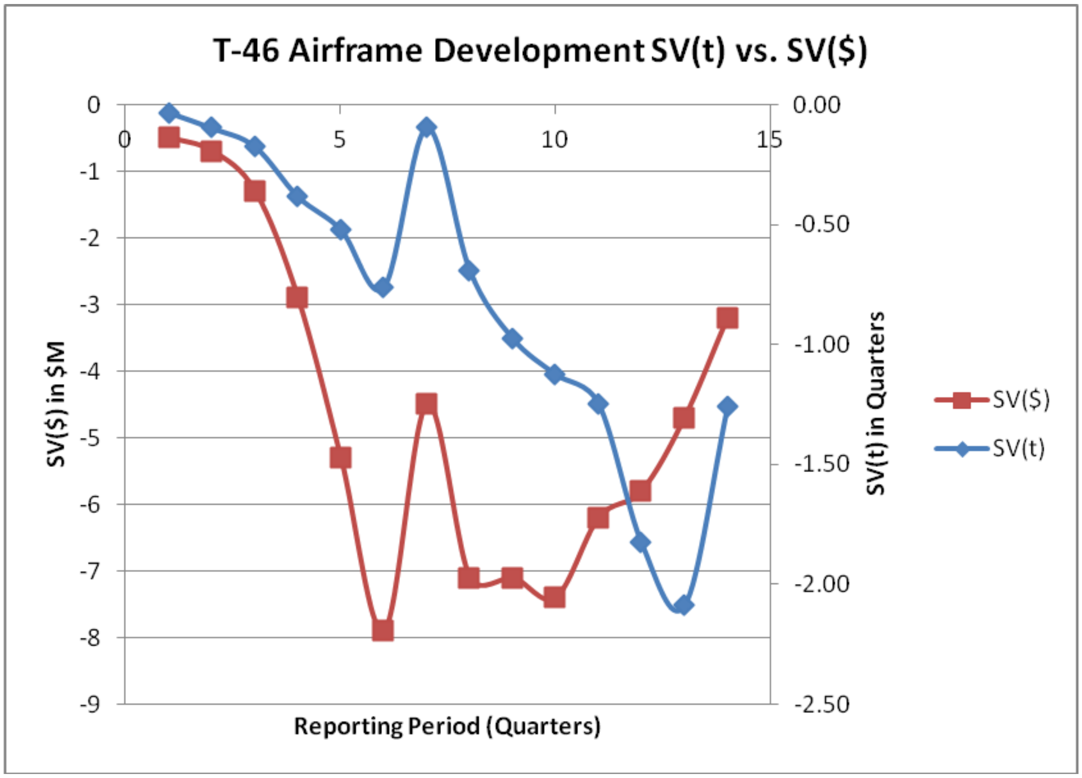

Figure 117: T-46 Airframe Development SV(t) vs. SV($)

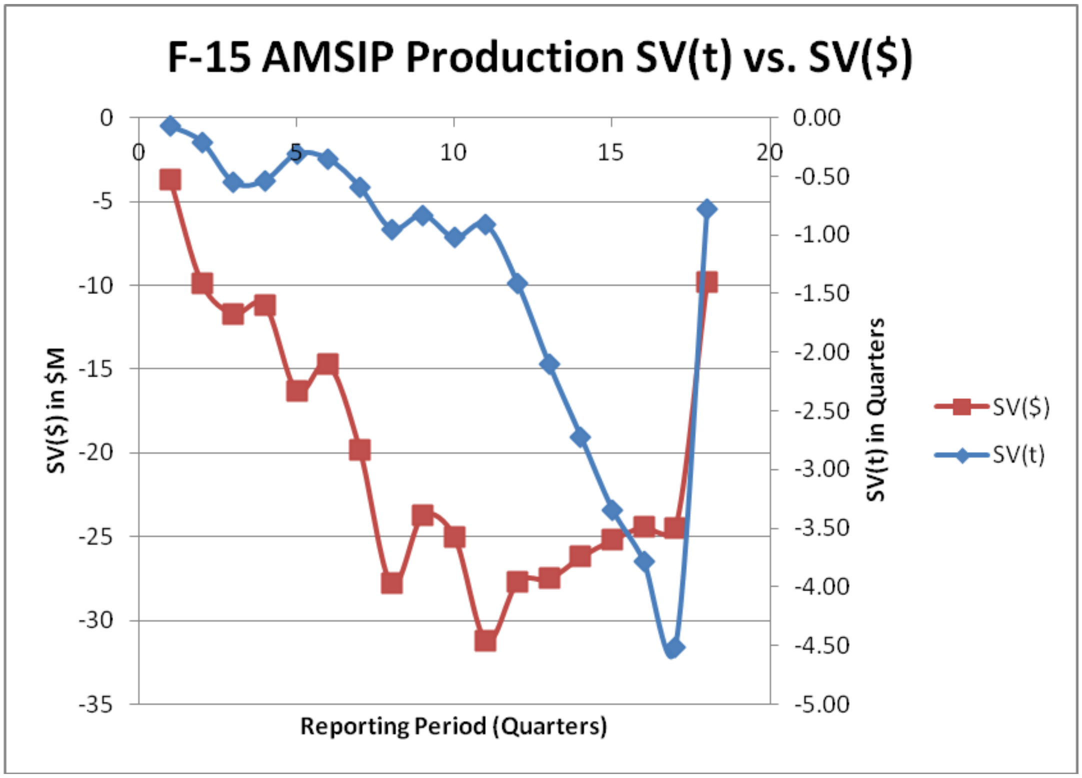

Figure 118: F-15 AMSIP Production SV(t) vs. SV($)

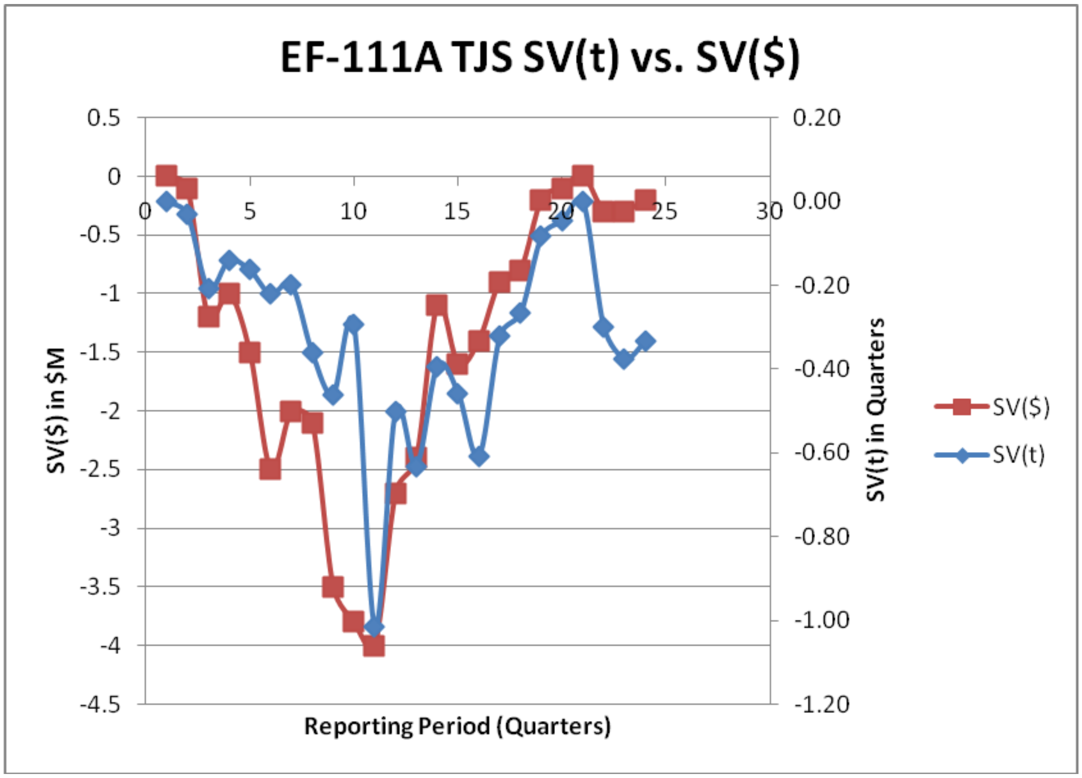

Figure 119: EF-111A TJS SV(t) vs. SV($)

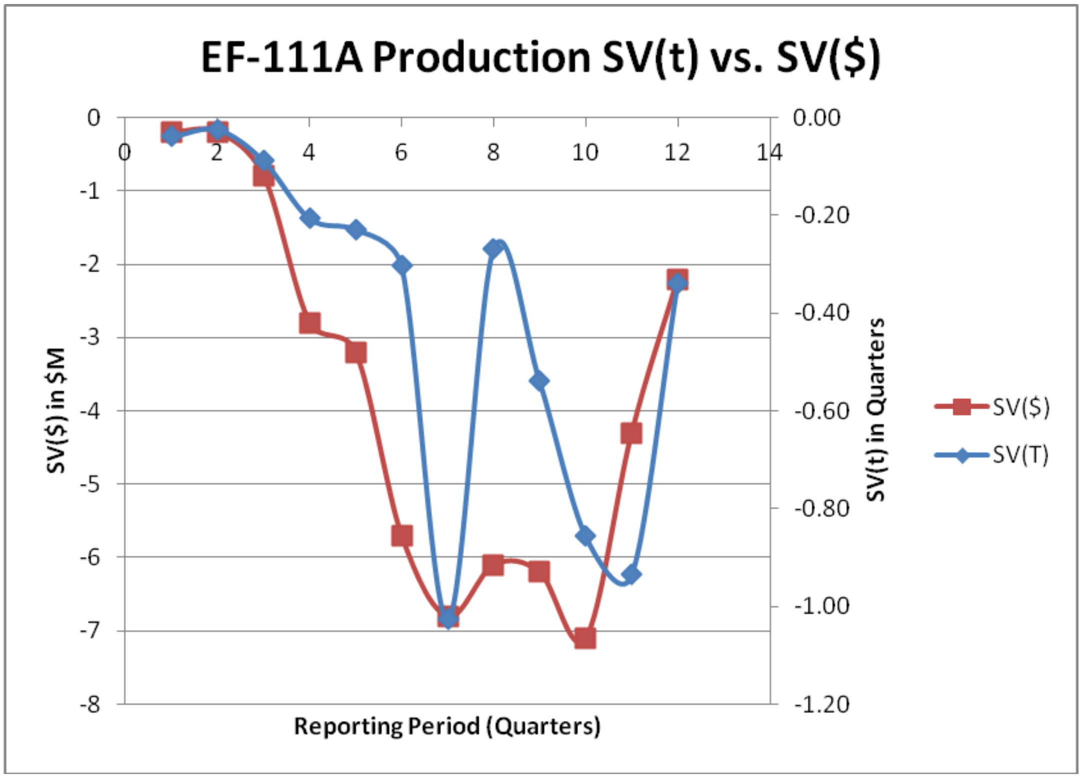

Figure 120: EF-111A Production SV(t) vs. SV($)

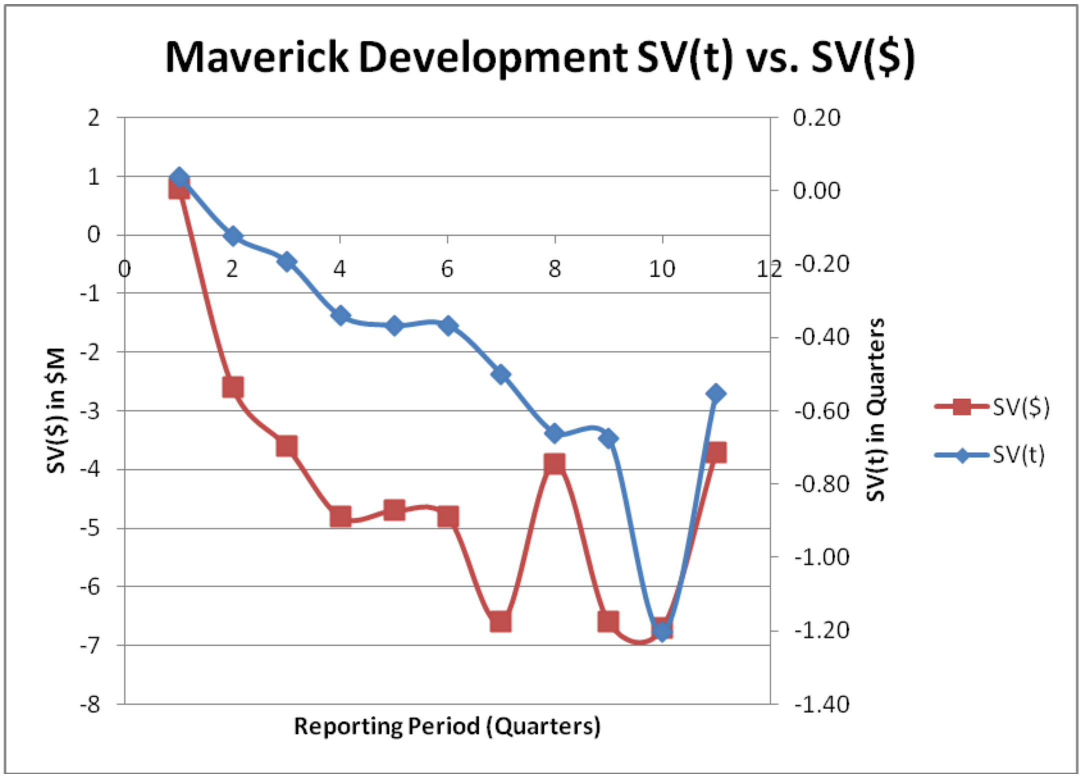

Figure 121: Maverick Development SV(t) vs. SV($)

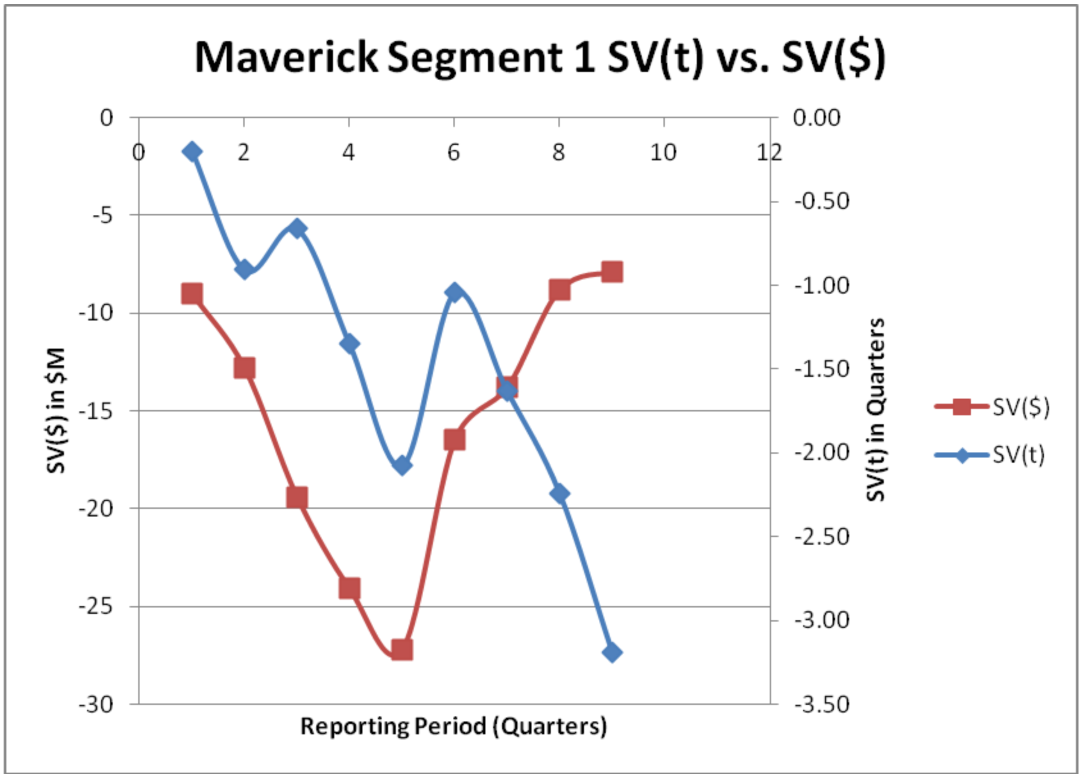

Figure 122: Maverick Segment 1 SV(t) vs. SV($)

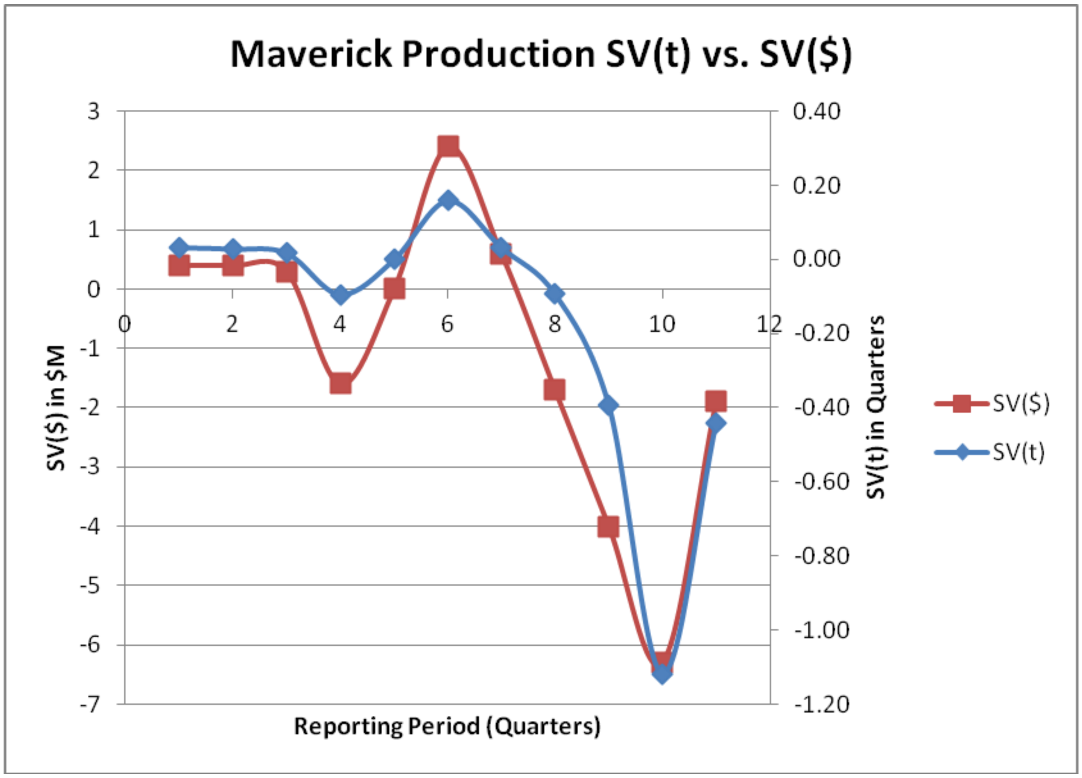

Figure 123: Maverick Production SV(t) vs. SV($)

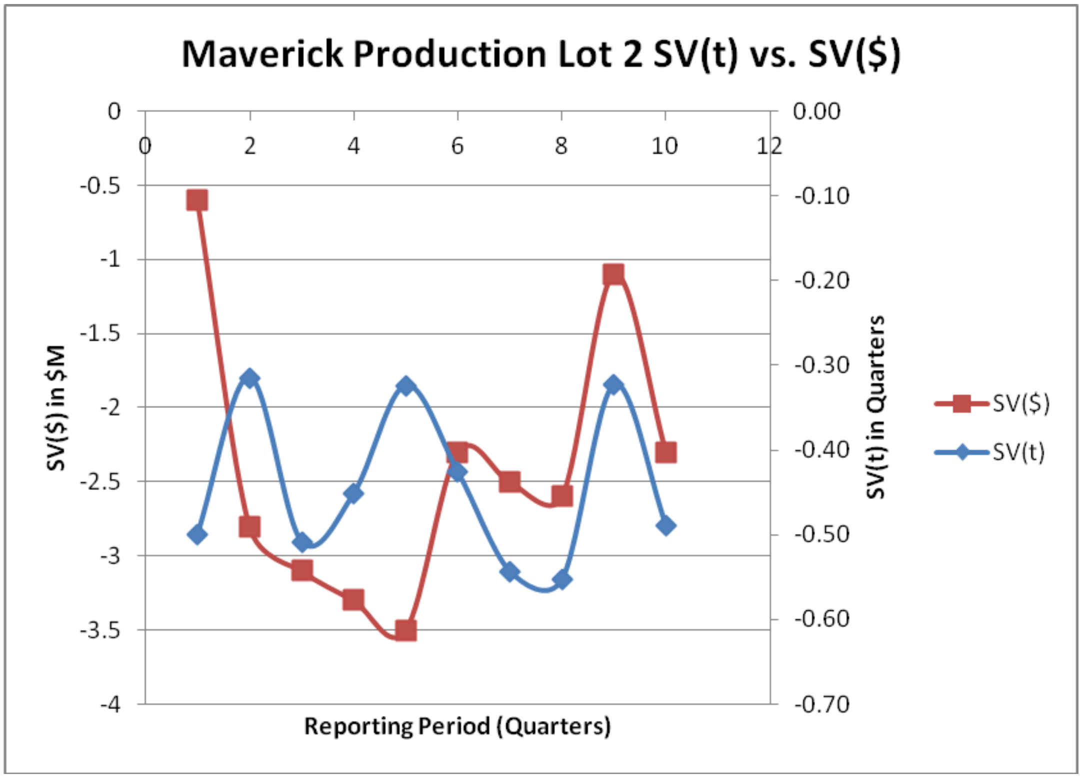

Figure 124: Maverick Production Lot 2 SV(t) vs. SV($)

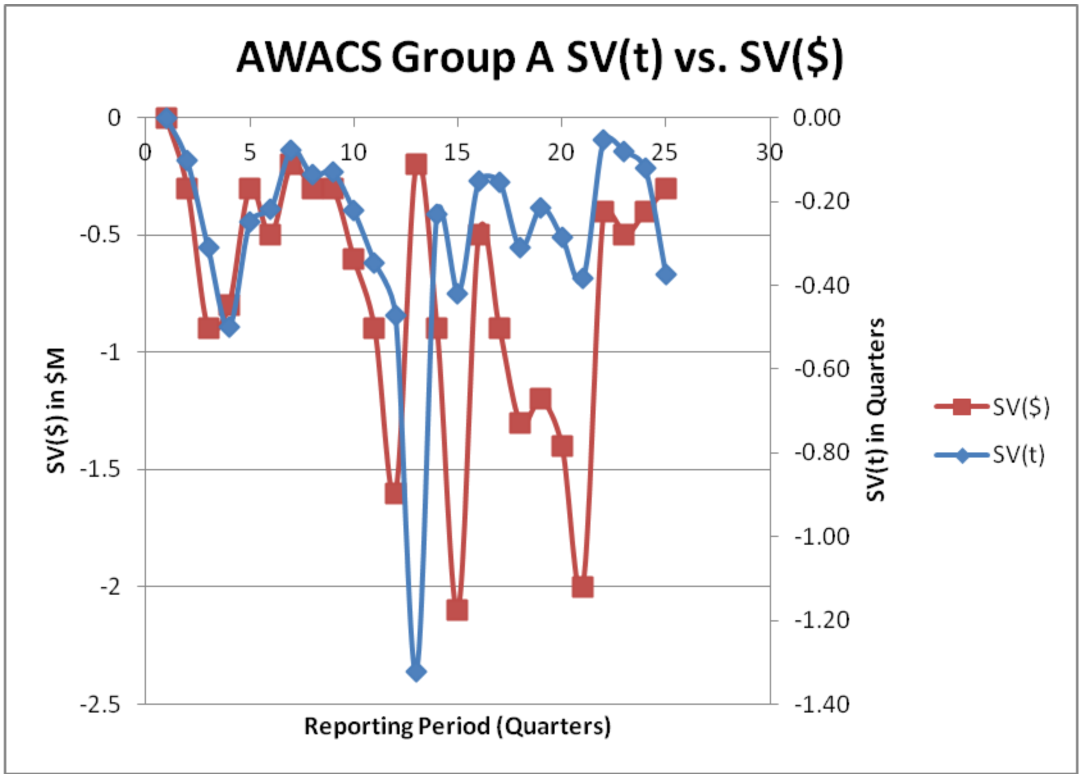

Figure 125: AWACS Group A SV(t) vs. SV($)

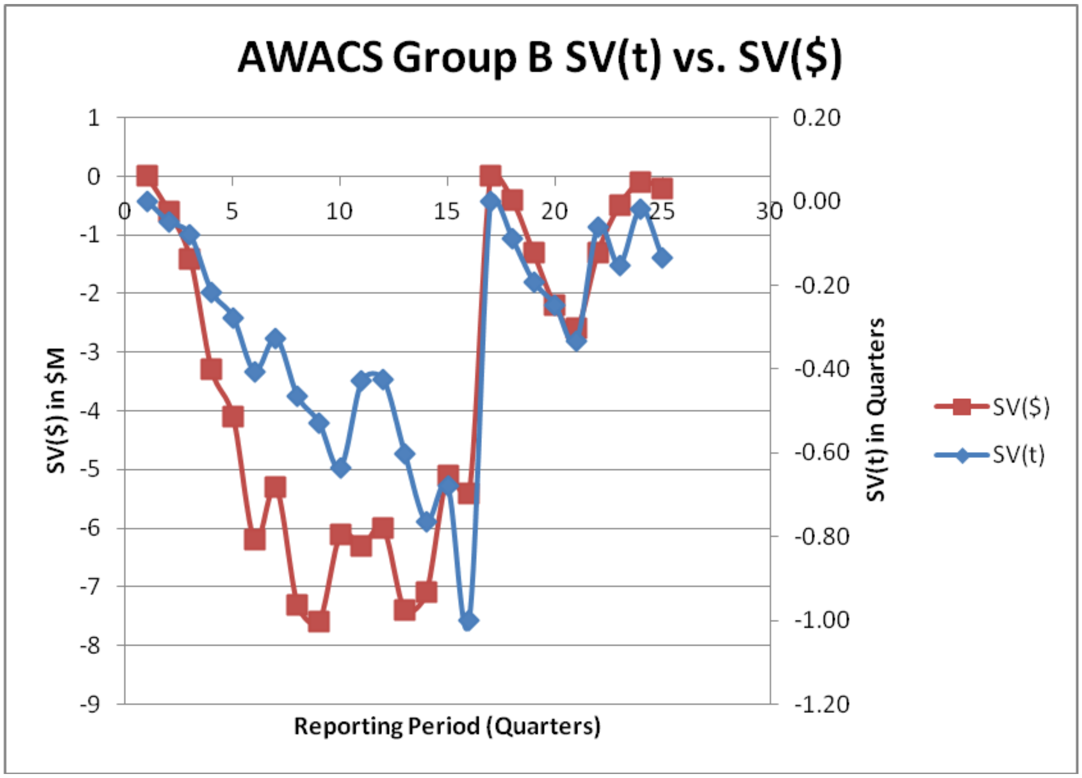

Figure 126: AWACS Group B SV(t) vs. SV($)

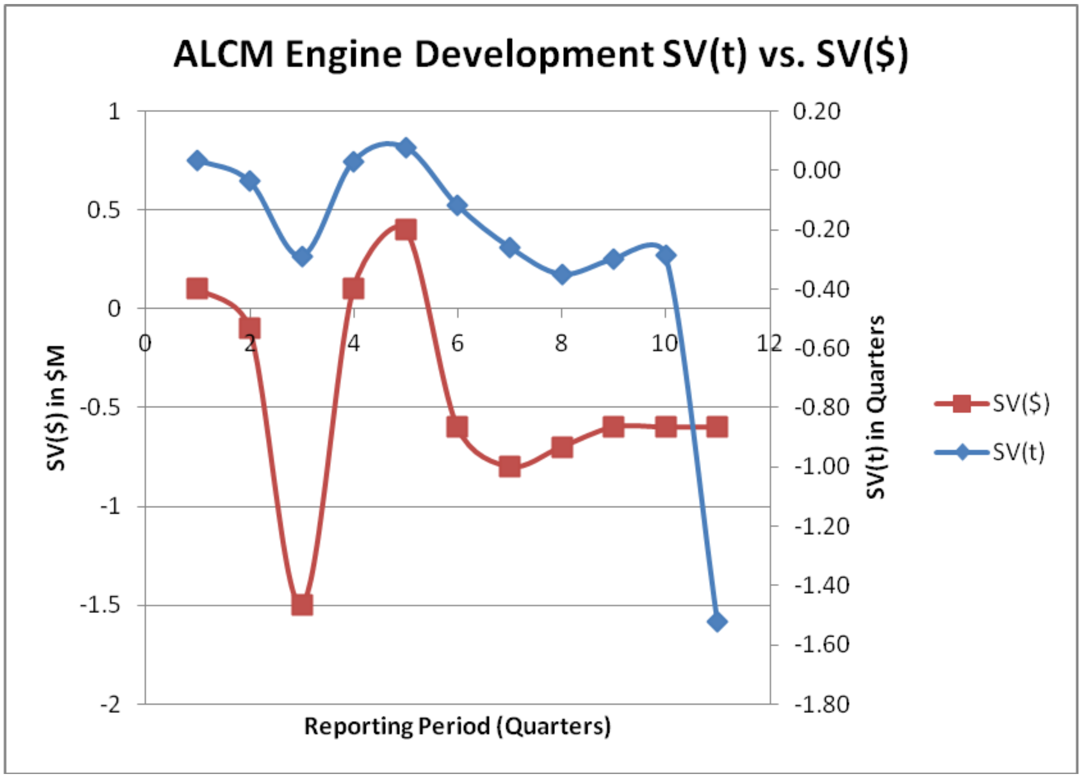

Figure 127: ALCM Engine Development SV(t) vs. SV($)

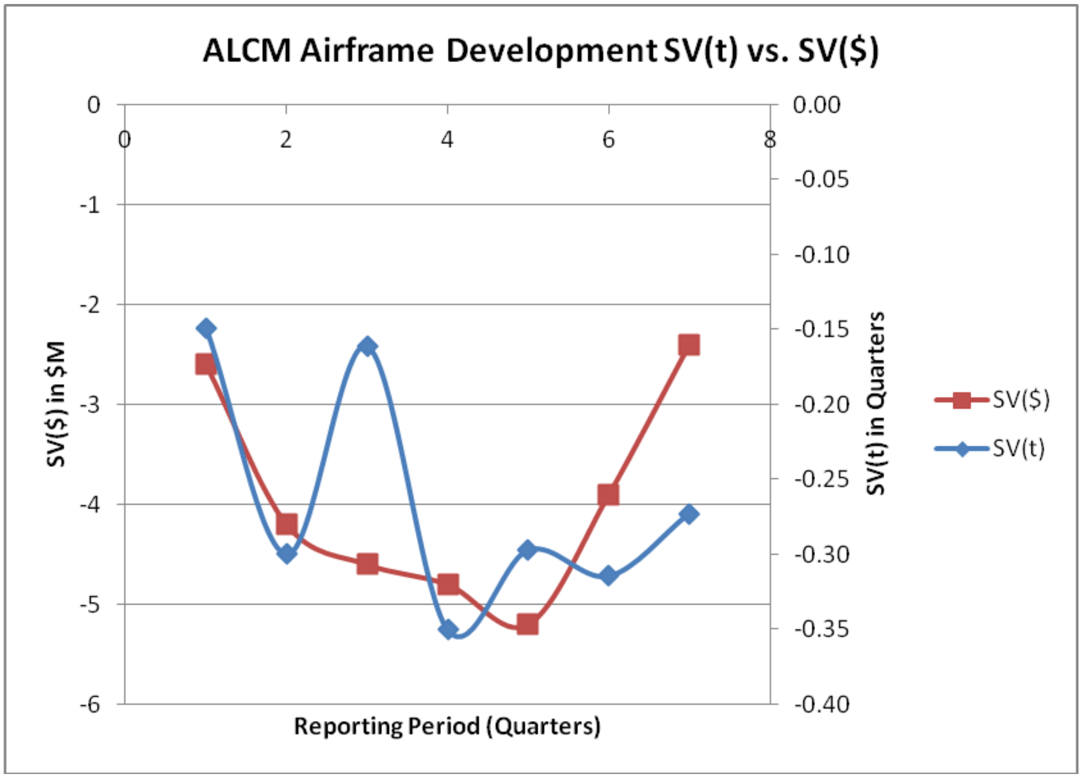

Figure 128: ALCM Airframe Development

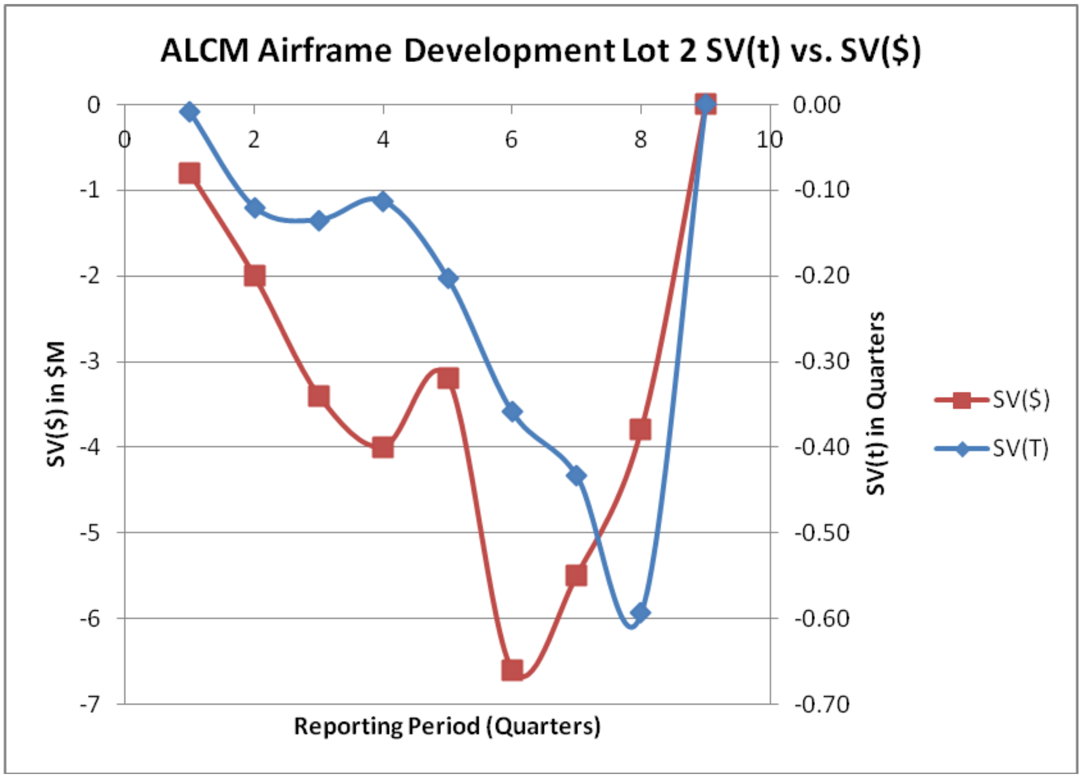

Figure 129: ALCM Airframe Development Lot 2 SV(t) vs. SV($)

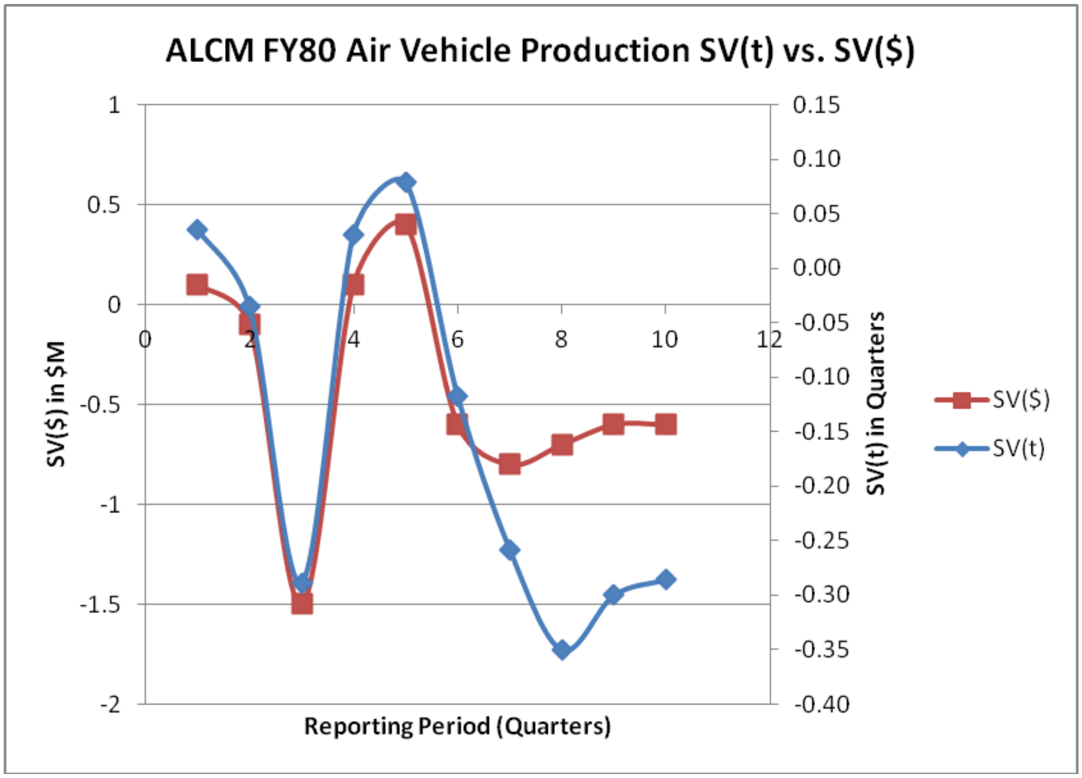

Figure 130: ALCM FY80 Air Vehicle Production SV(t) vs. SV($)

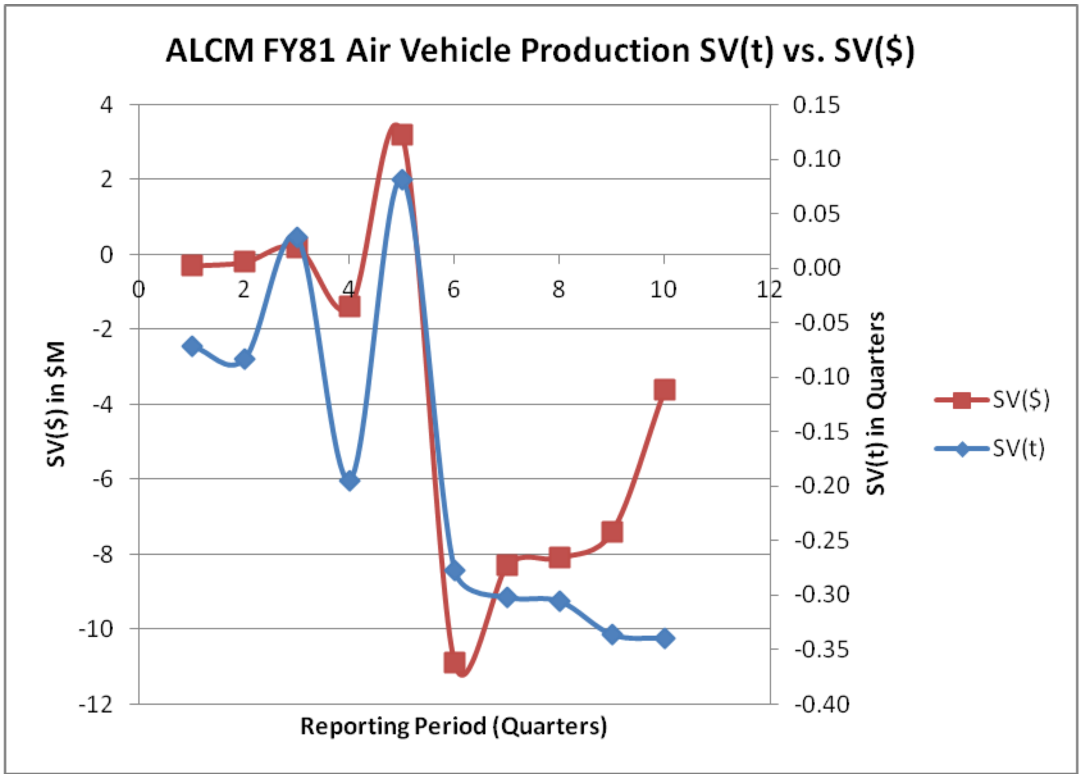

Figure 131: ALCM FY81 Air Vehicle Production SV(t) vs. SV($)

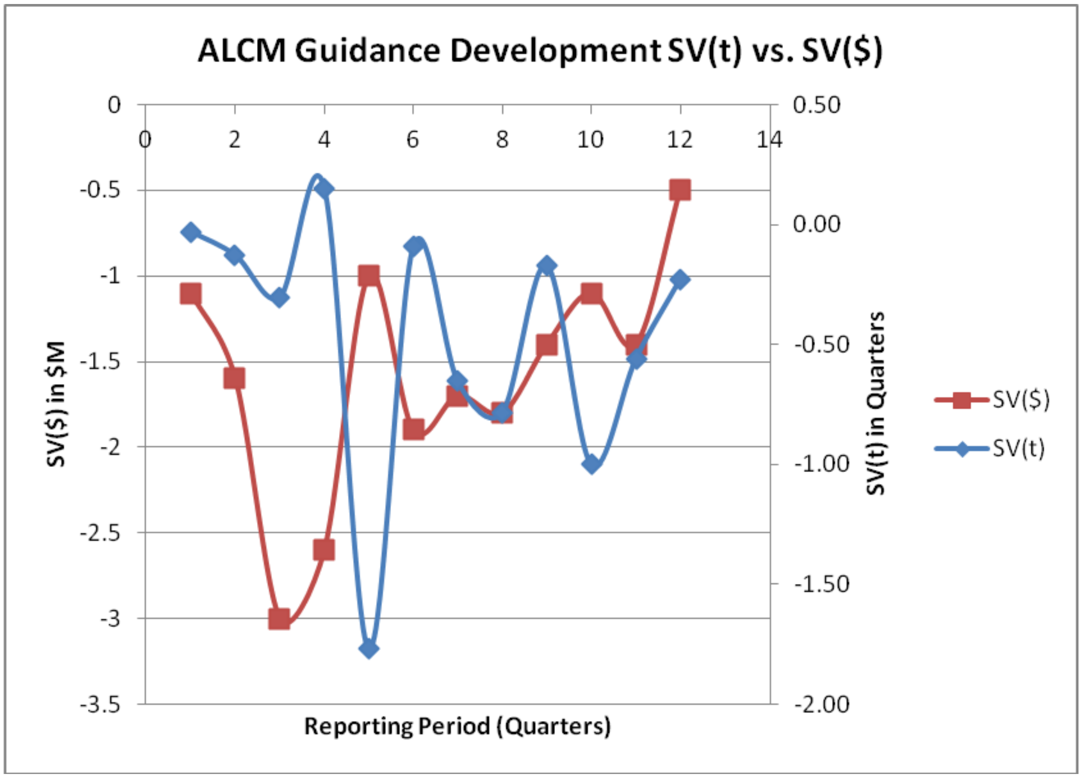

Figure 132: ALCM Guidance Development SV(t) vs. SV($)

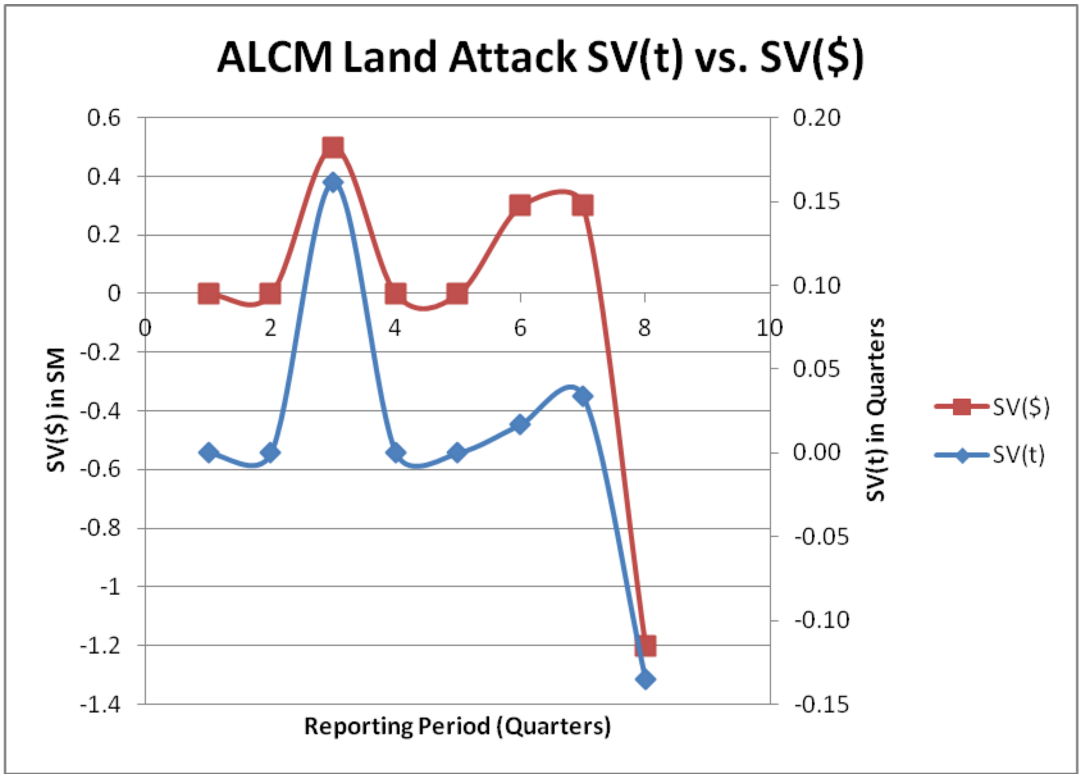

Figure 133: ALCM Land Attack SV(t) vs. SV($)

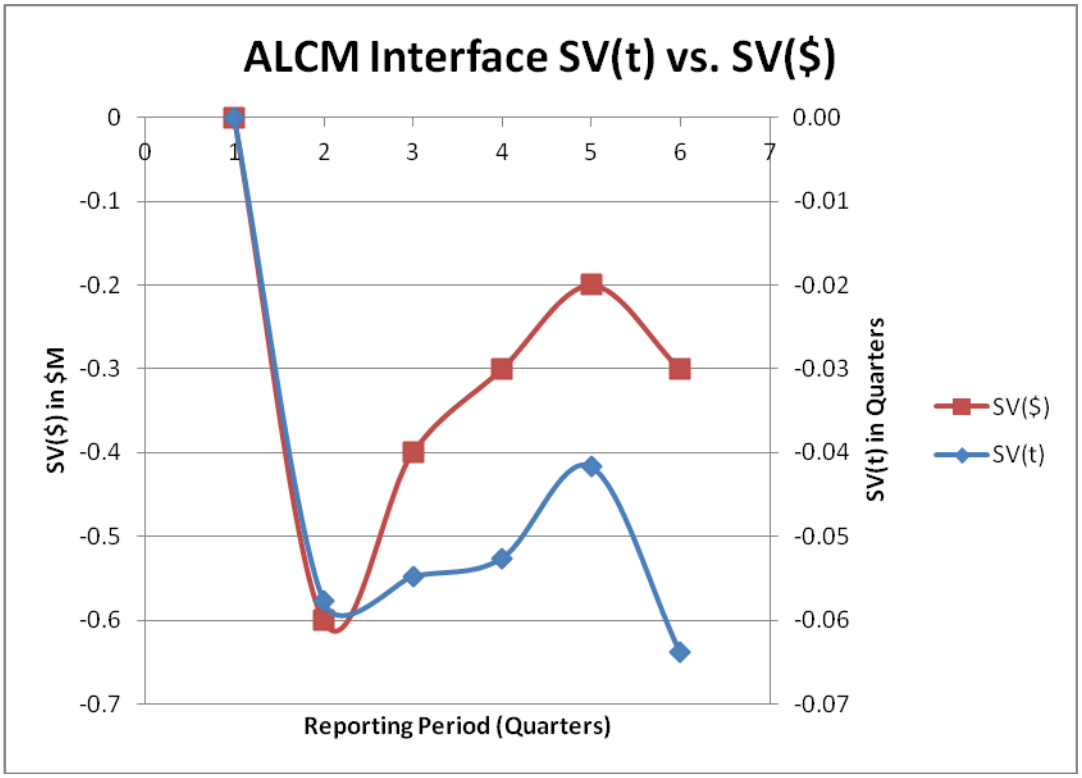

Figure 134: ALCM Interface SV(t) vs. SV($)

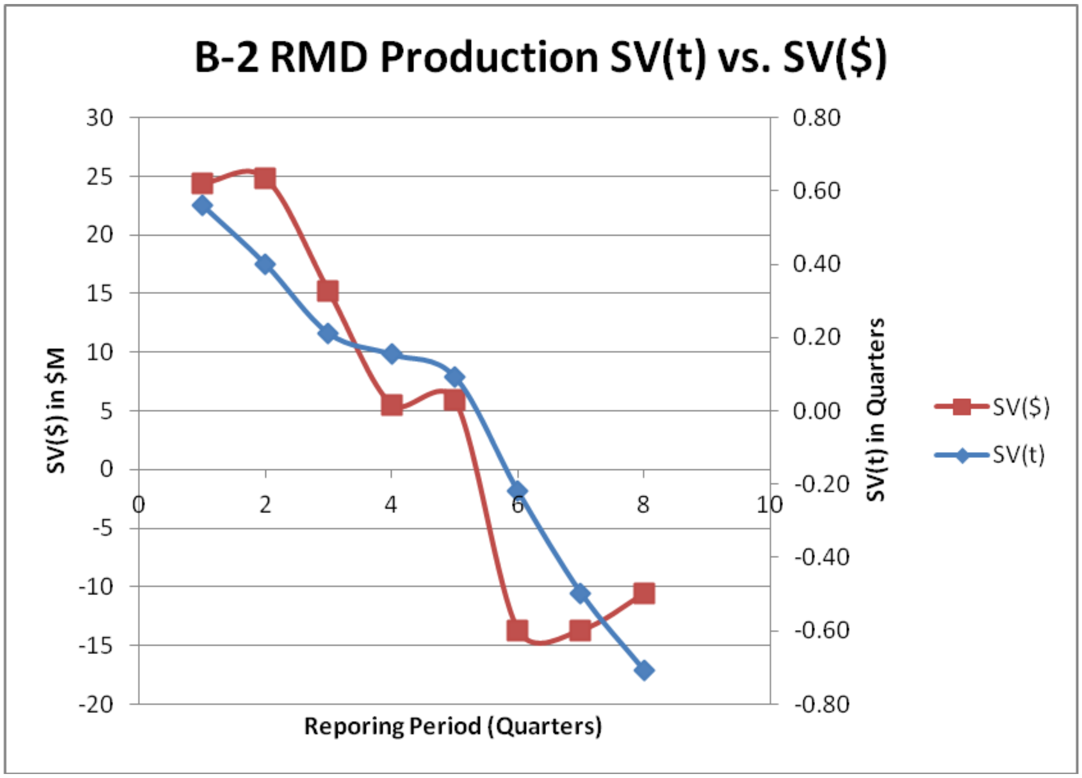

Figure 135: B-2 RMD Production SV(t) vs. SV($)

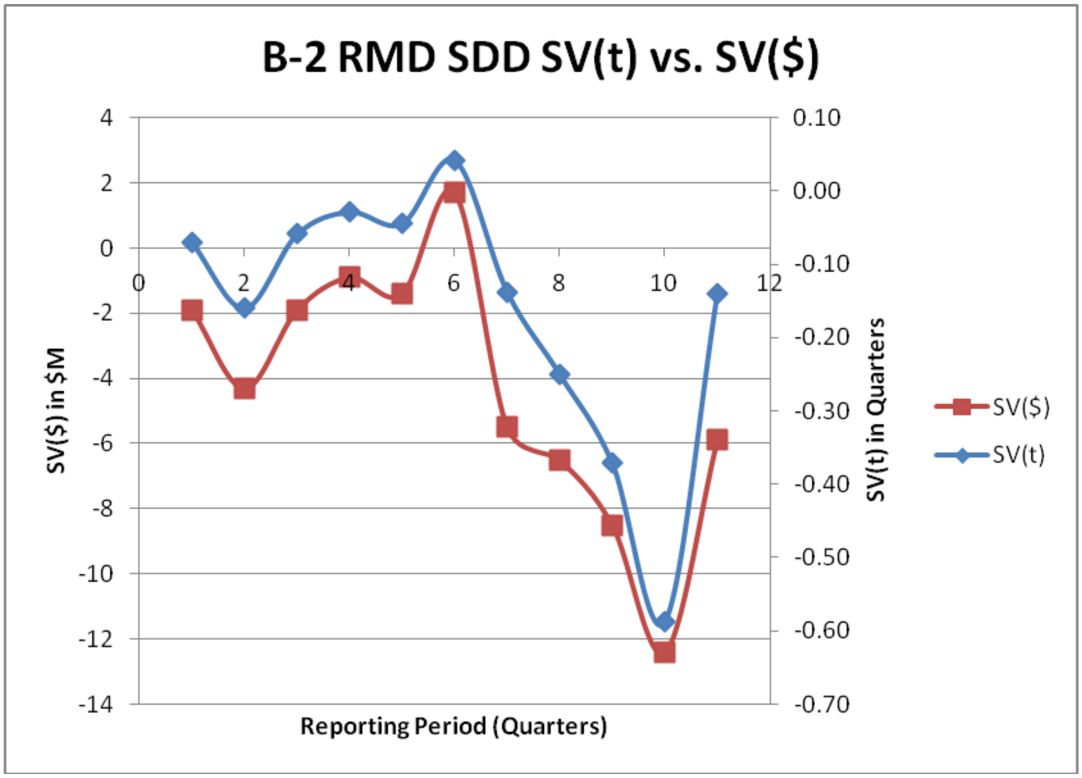

Figure 136: B-2 RMD SDD SV(t) vs. SV($)

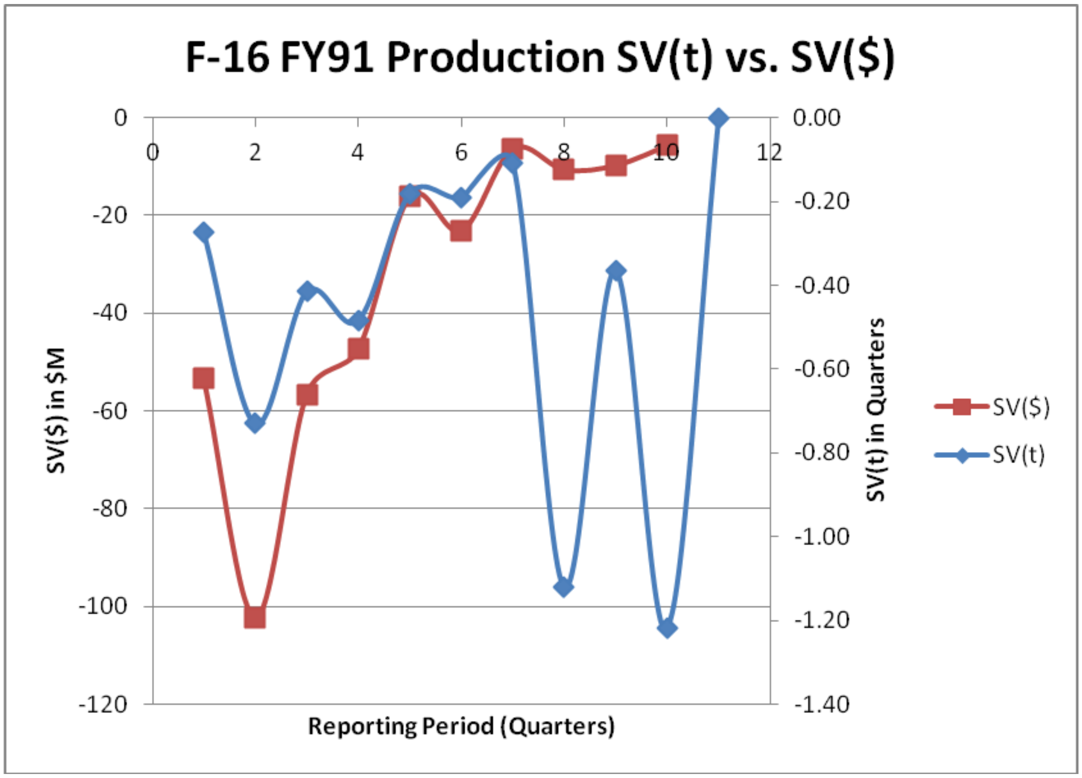

Figure 137: F-16 FY91 Production SV(t) vs. SV($)

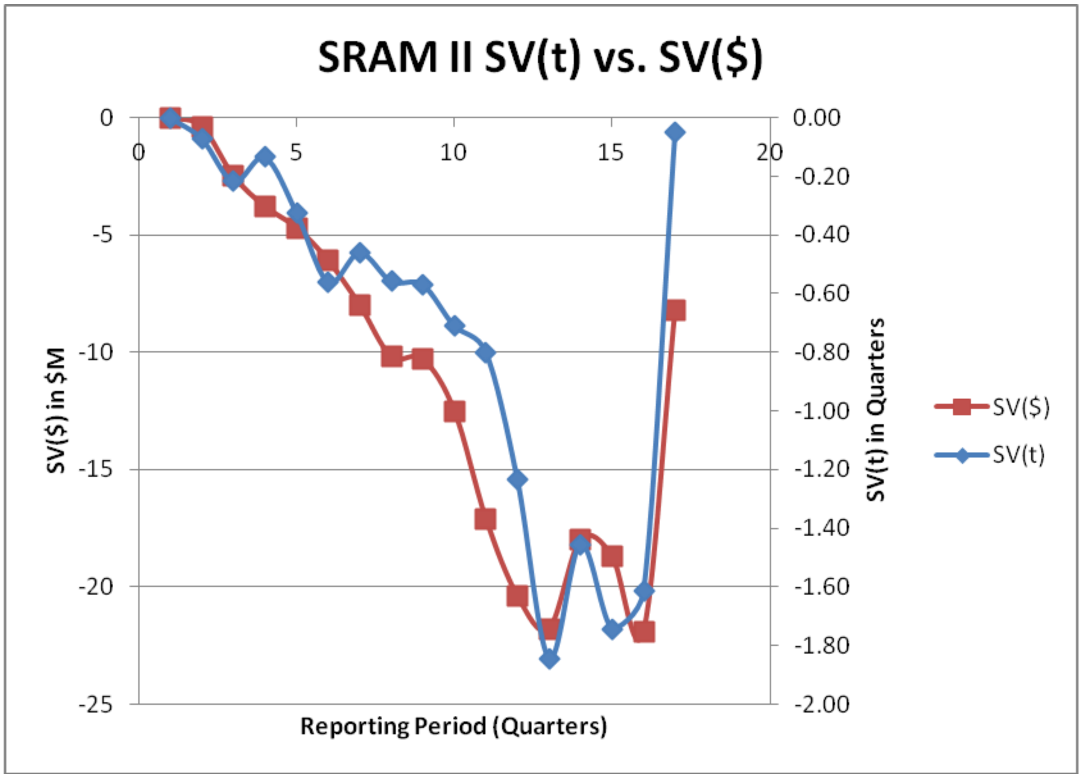

Figure 138: SRAM II SV(t) vs. SV($)

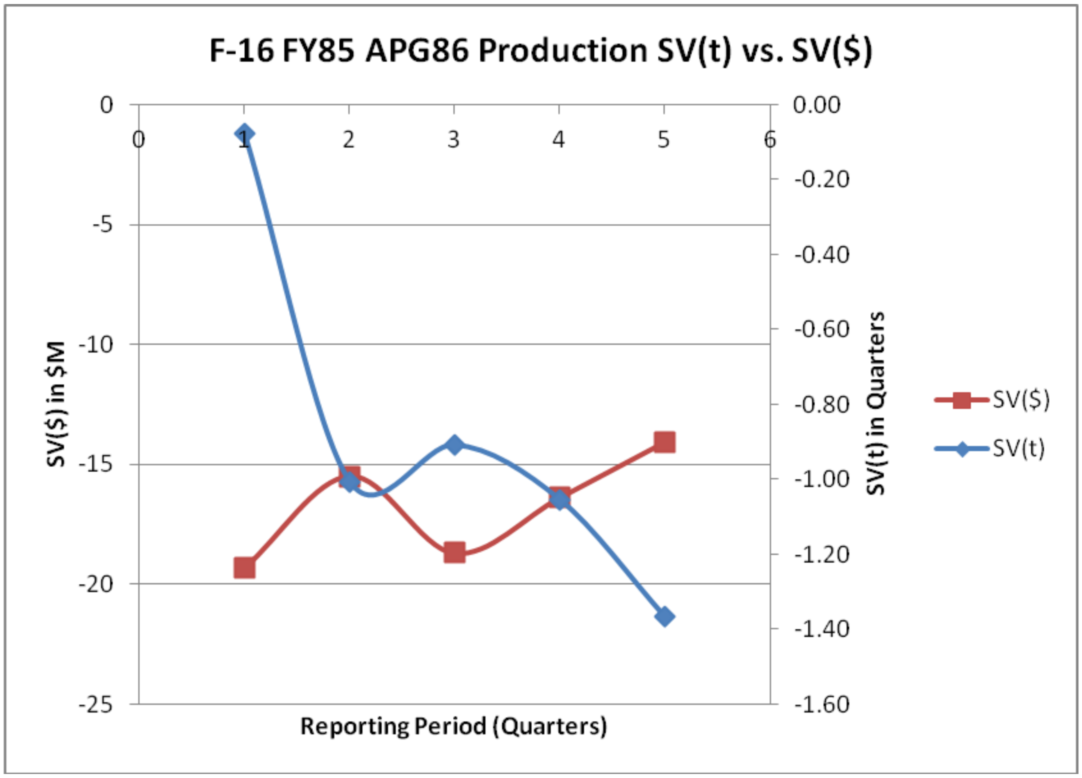

Figure 139: F-16 APG86 Production SV(t) vs. SV($)

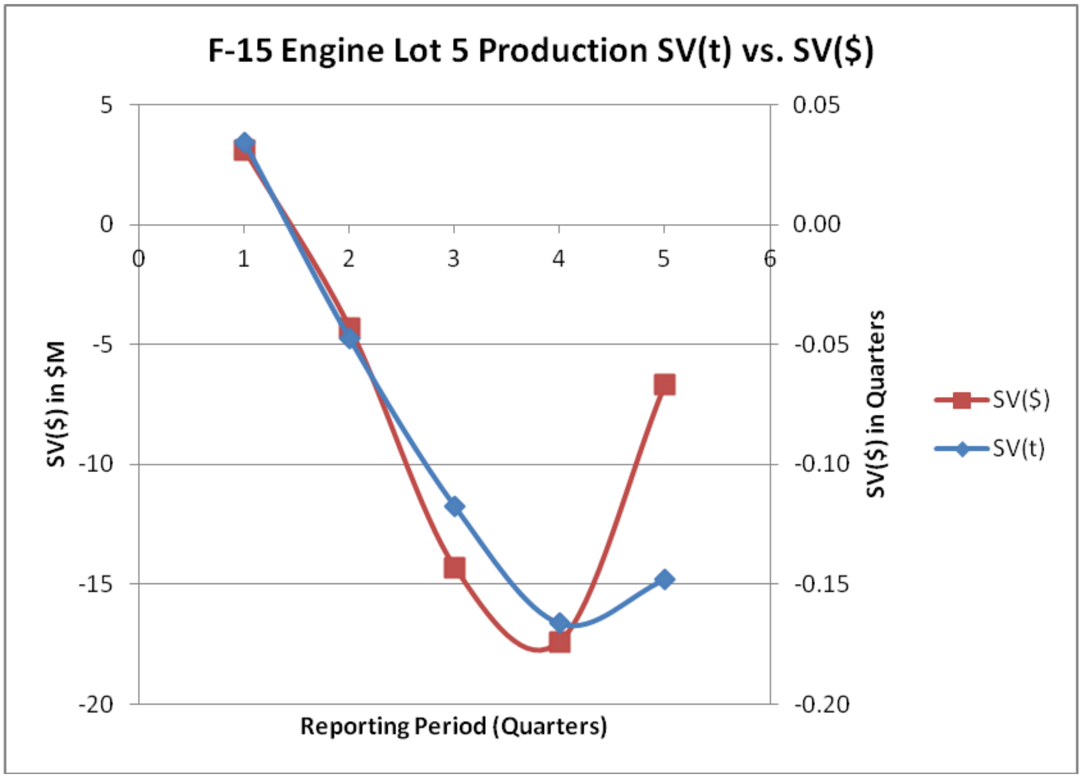

Figure 140: F-15 Engine Lot 5 Production SV(t) vs. SV($)

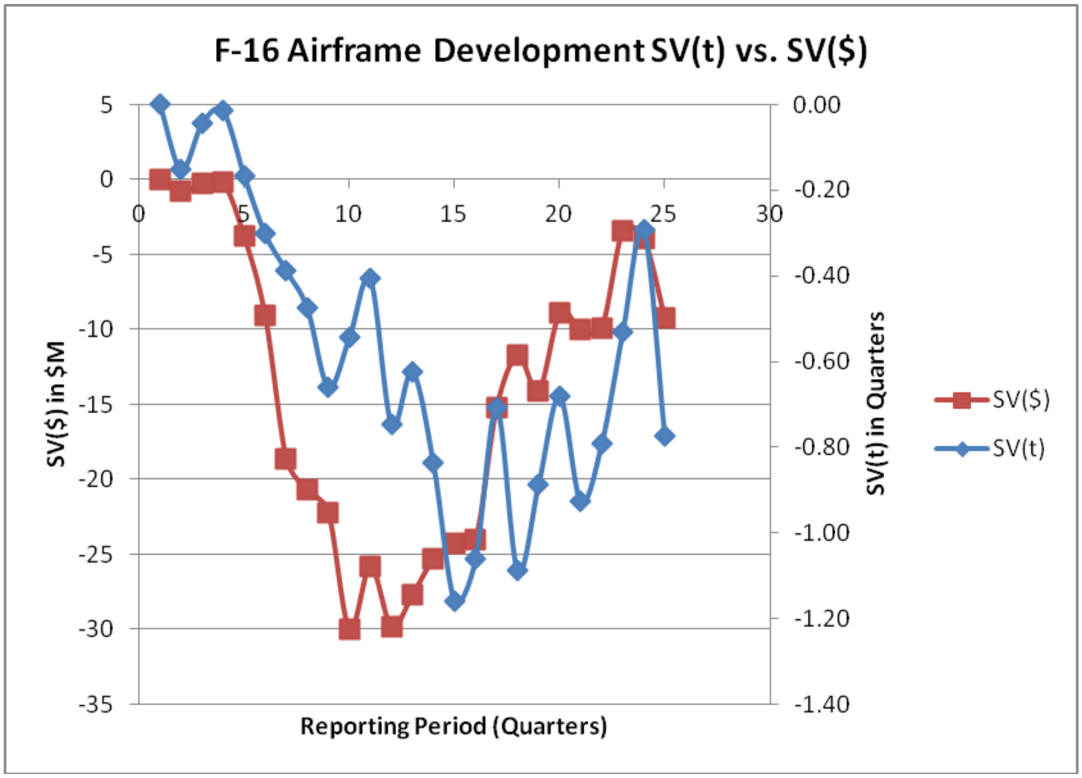

Figure 141: F-16 Airframe Development SV(t) vs. SV($)

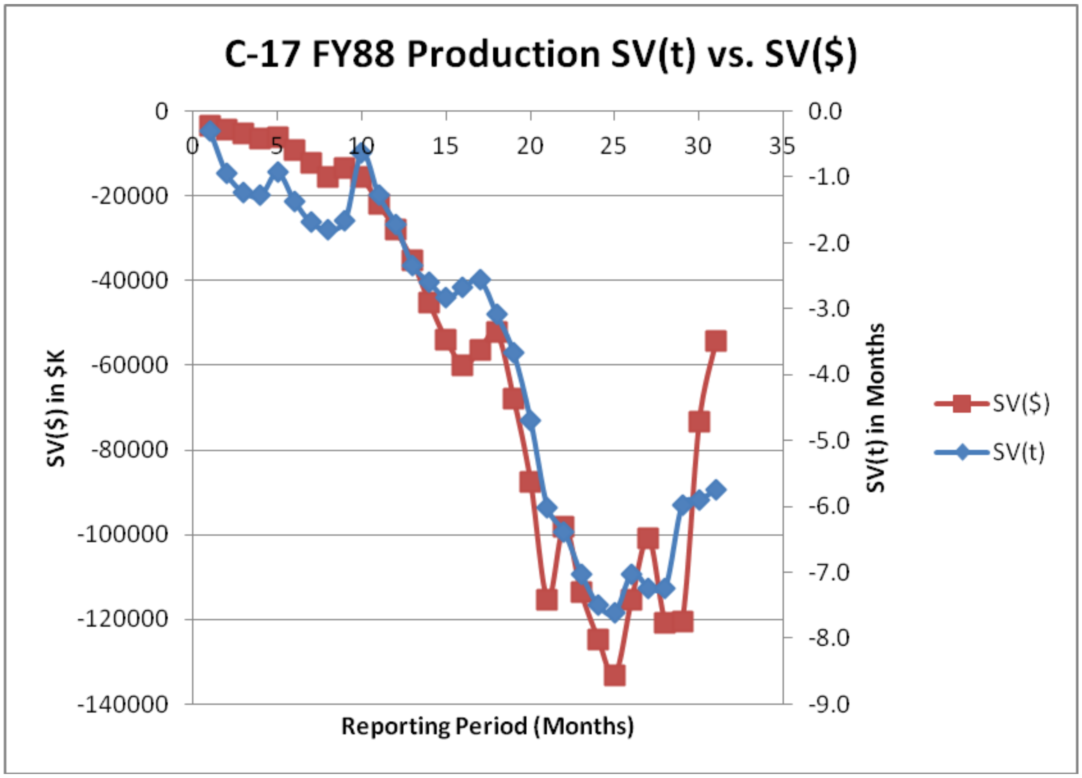

Figure 142: C-17 FY88 Production SV(t) vs. SV($)

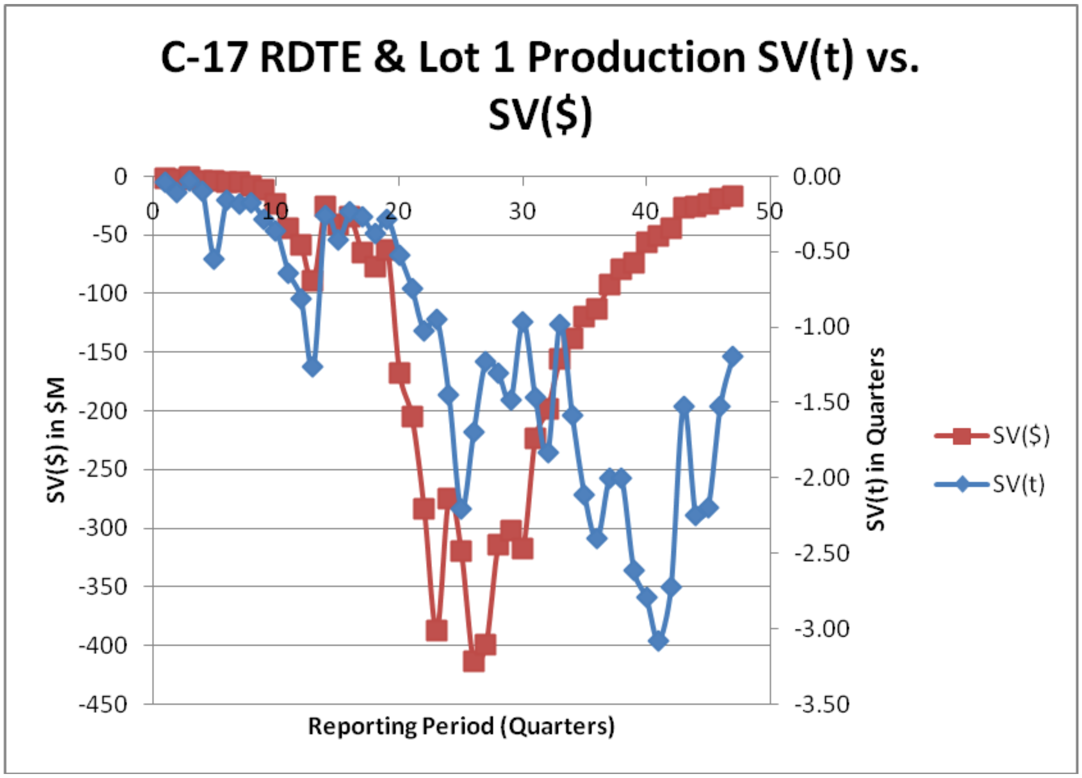

Figure 143: C-17 RDTE & Lot 1 Production SV(t) vs. SV($)

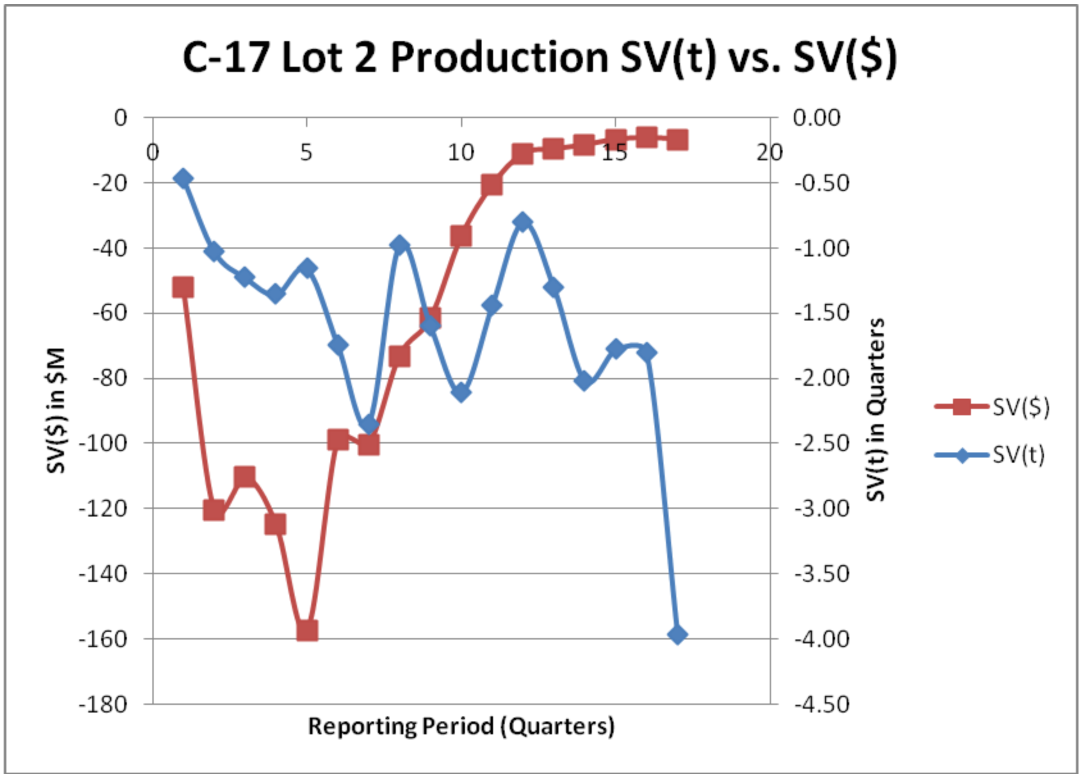

Figure 144: C-17 Lot 2 Production SV(t) vs. SV($)

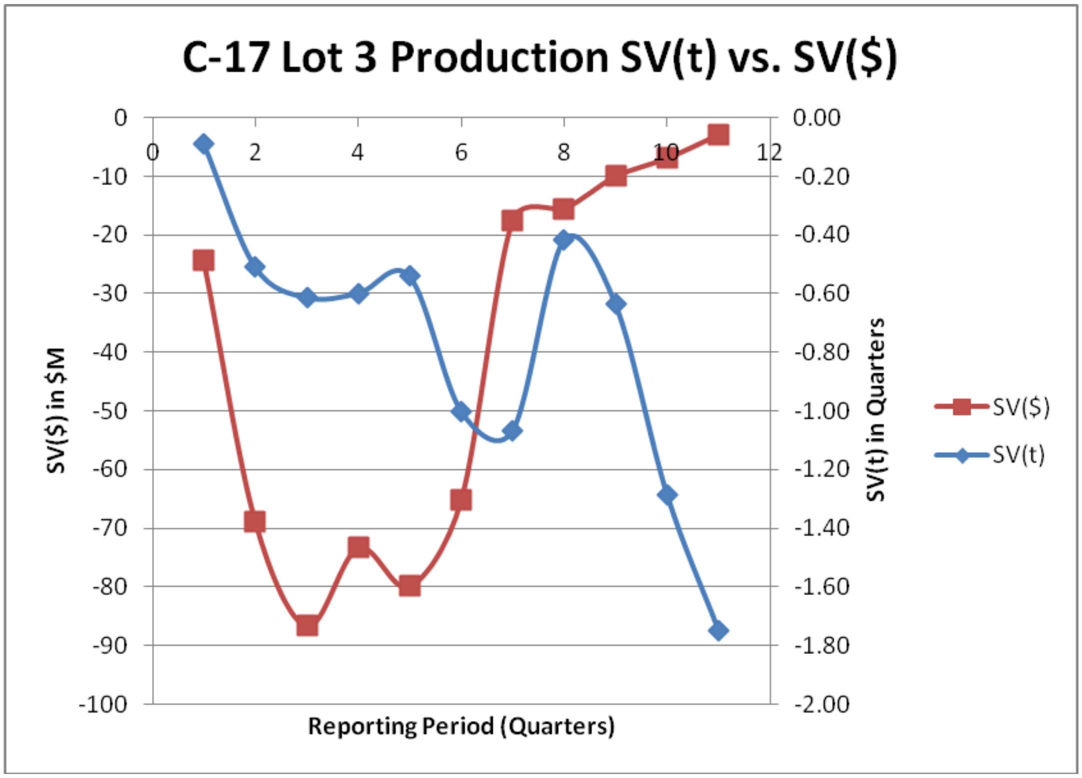

Figure 145: C-17 Lot 3 Production SV(t) vs. SV($)

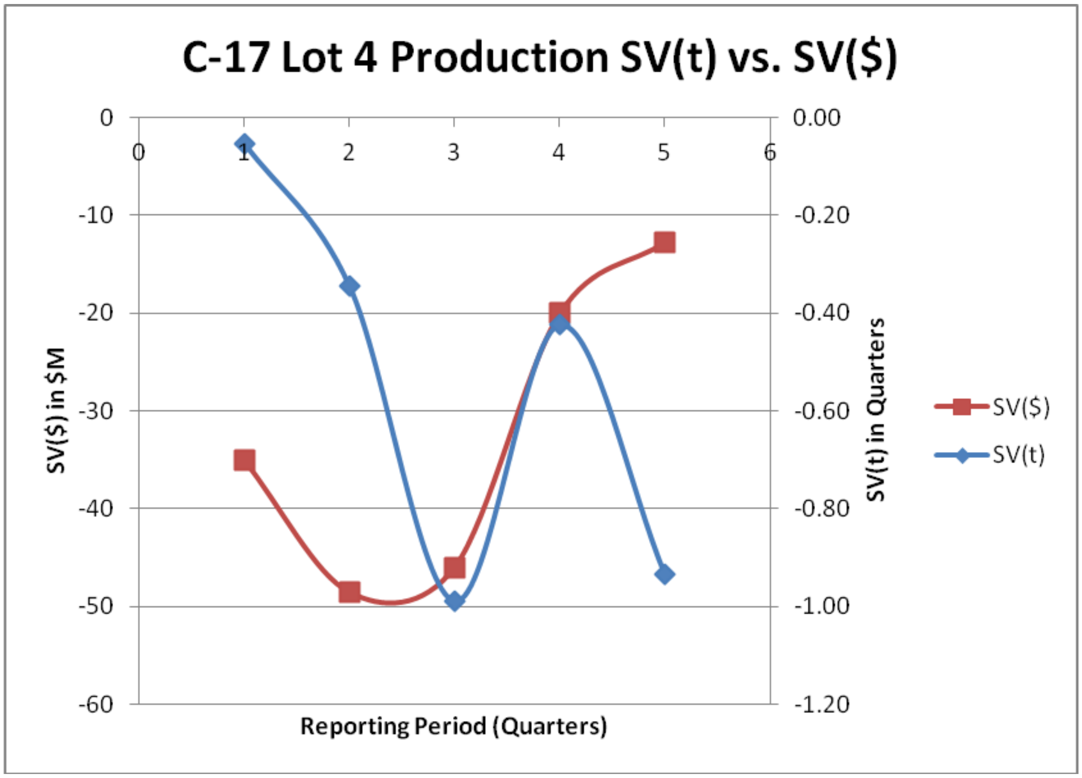

Figure 146: C-17 Lot 4 Production SV(t) vs. SV($)

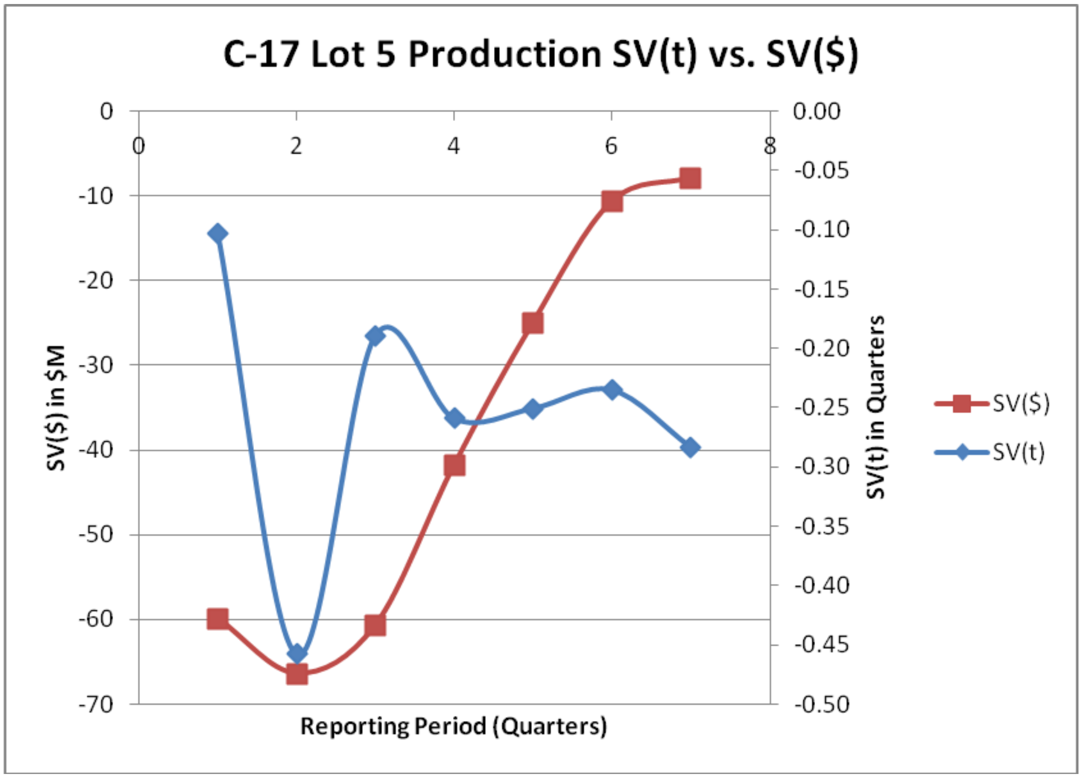

Figure 147: C-17 Lot 5 Production SV(t) vs. SV($)

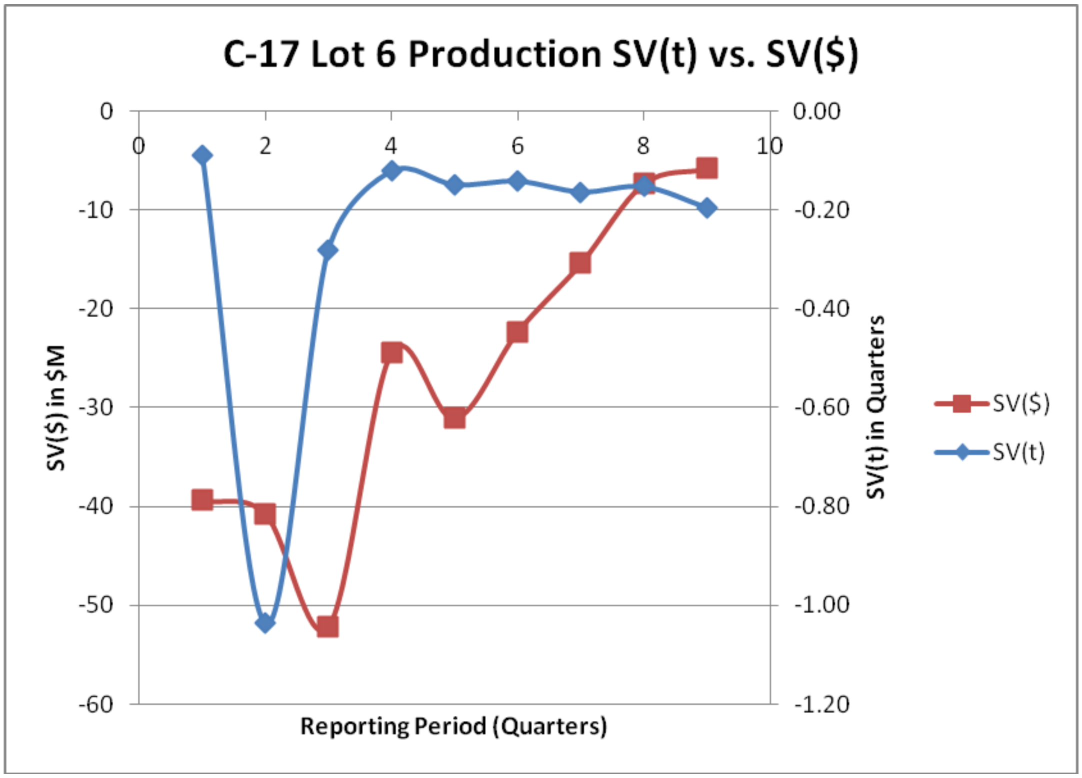

Figure 148: C-17 Lot 6 Production SV(t) vs. SV($)

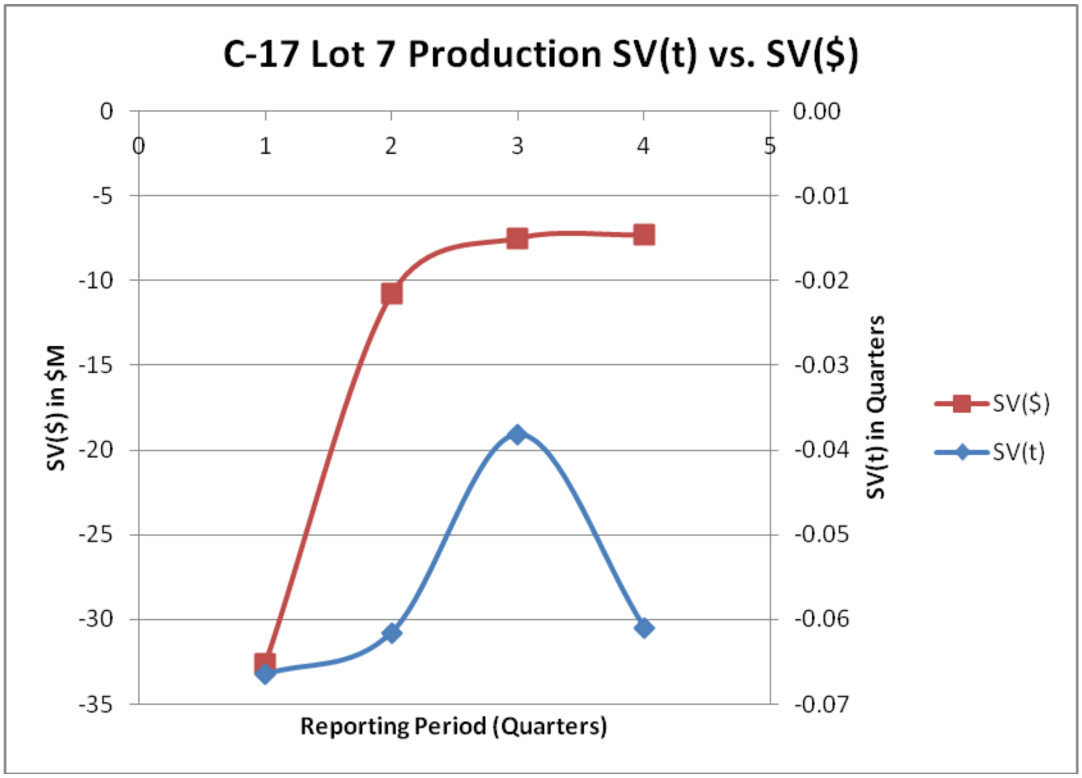

Figure 149: C-17 Lot 7 Production SV(t) vs. SV($)

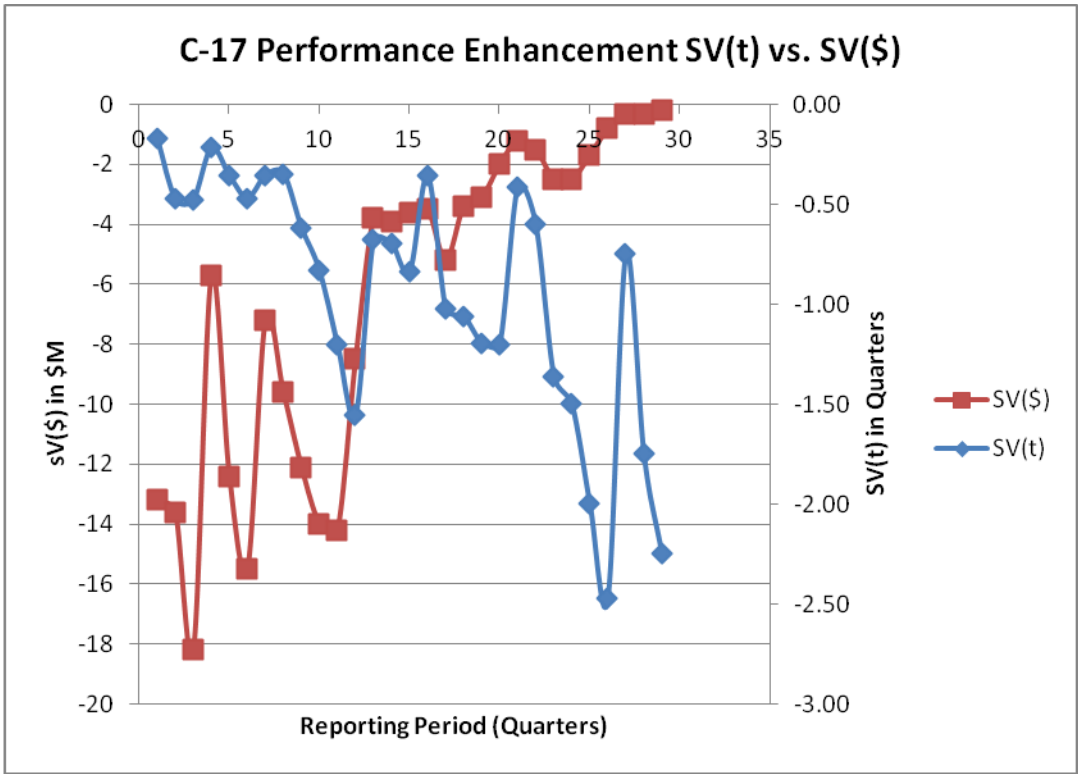

Figure 150: C-17 Performance Enhancement SV(t) vs. SV($)

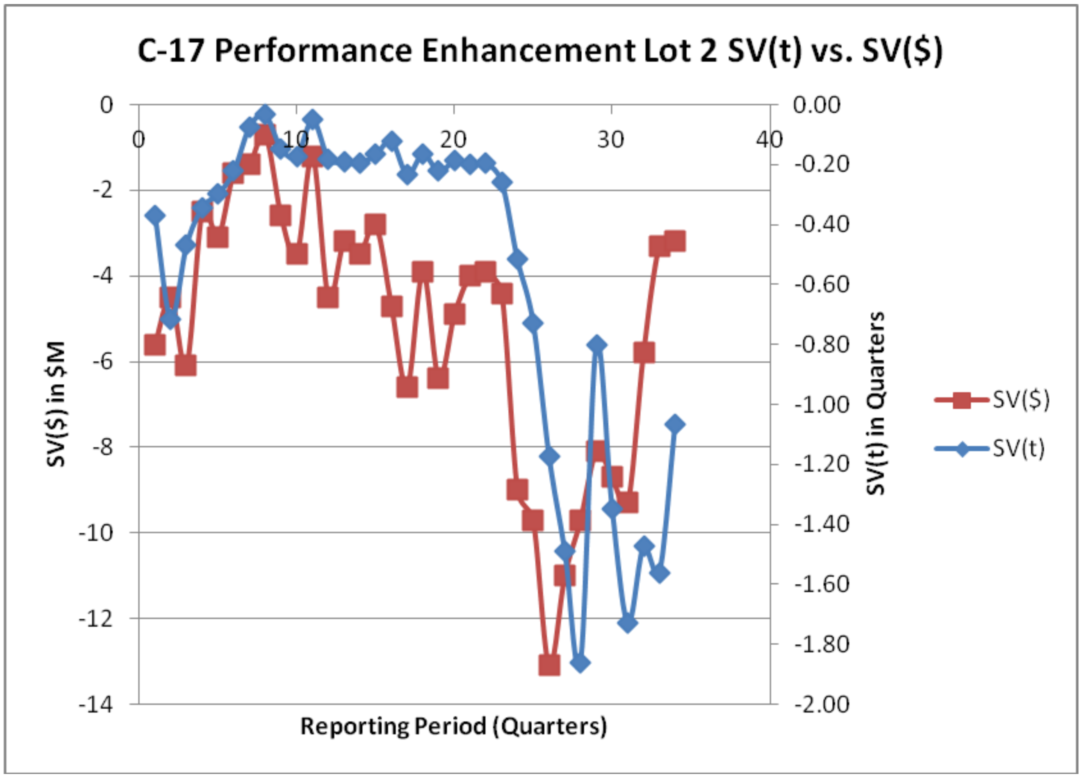

Figure 151: C-17 Performance Enhancement Lot 2 SV(t) vs. SV($)

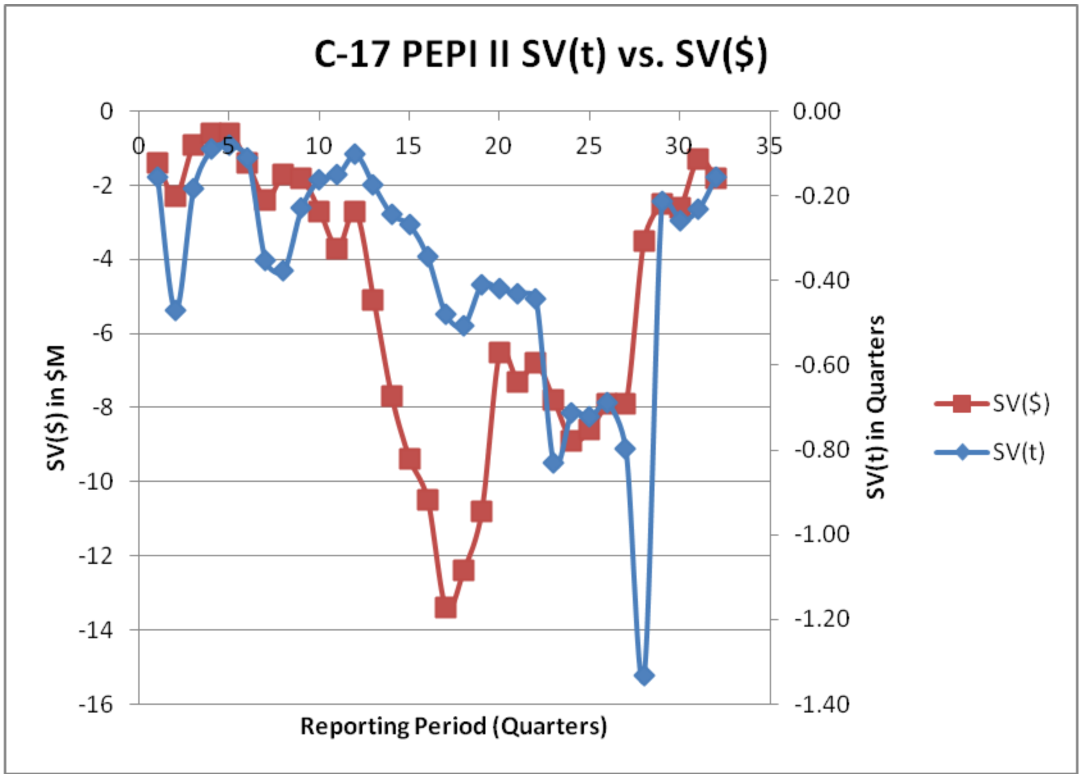

Figure 152: C-17 PEPI II SV(t) vs. SV($)

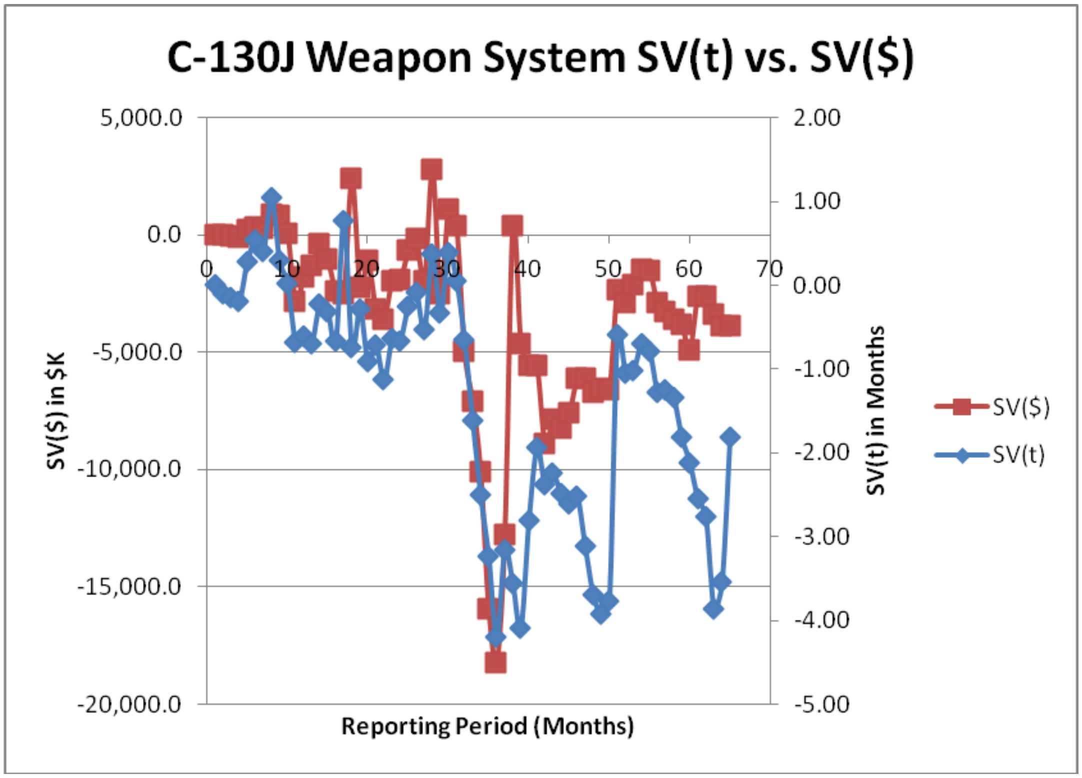

Figure 153: C-130J Weapon System SV(t) vs. SV($)

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14. ABSTRACT
Earned Schedule, since it was introduced by Walt Lipke in 2003, has been studied extensively in a variety of different fields and on programs of all sizes. However, Earned Schedule's viability as an extension of Earned Value Management (EVM) in Major Defense Acquisition Programs (MDAP) has yet to be effectively answered. The first aspect of this research explores the breadth of Earned Schedule's adoption by the System Program Offices (SPO) of the United States Air Force. The second phase of this research explores whether Earned Schedule is a more accurate and timely schedule predictor than the EVM technique currently employed by the United States Department of Defense (DoD). A series of five descriptive statistical tests were conducted on the Earned Value data for 64 Acquisition Category (ACAT) I MDAP's. This research finds Earned Schedule to be a more timely and accurate predictor than Earned Value Management.

15. SUBJECT TERMS
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