A Knowledge Based Approach to Program Analysis

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Jim Baber
Business Division
Cerritos College
jbaber@cerritos.edu

AND

Larry Gentry

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Jim Baber, Business Division, Cerritos College: jbaber@cerritos.edu and Larry Gentry

INTRODUCTION

The fiscal health of today's Major Defense Acquisitions (MDA) remain abysmal for a number of well known and documented reasons such as re-designs, poor estimations, increasing labor rates and higher than expected material costs just to name a few. While cost and schedule continue to exhibit poor performance, Department of Defense (DOD) and components have employed an ever increasing staff of analysts to monitor and report current and future cost/schedule concerns. It has been demonstrated time and again that these analysts continually underestimate cost overruns and miscalculate schedule slippage. The majority of this activity occurs on MDAs with Earned Value (EV) requirements on contract and most are major defense contractors with approved earned value systems.

This gives the appearance that EV as a predictive tool is of little to no value. After all, thirty years of Cost/Schedule Control System Criteria (C/SCSC) and ten years of EV have very little to show in terms of their predictive ability. The authors do not believe EV should be jettisoned. However, organizations charged with oversight of contract performance should begin to question some long held EV industry practices and employ a systematic approach to assessing program performance that will be a better predictor of cost/schedule performance.

The reliance on the cumulative cost performance index (CPI) as well as the other statistical indices has proven to be a dependable failure for cost and schedule forecasting. Additionally, there is an over reliance and drive to combine one or more of these statistical forecasting indices with the results in the DOD database of over 400 programs, which is an attempt to strengthen the use of these indices (Christensen, Cost). This research paper endeavors to demonstrate that to increase the timeliness and reliability of cost and schedule assessments and forecasts requires more than mere formulas, it requires the infusion of timely knowledge from the on-site representatives tasked with contract oversight. The knowledge and insight of these personnel when integrated with comprehensive data analysis will ultimately result in more dependable cost, schedule and performance forecasts.

Congress, DOD, government and private industry program management offices will benefit greatly from integrating knowledge with program EV data. For example, as a program undergoes a redesign or experiences increased labor rates, the on-site representatives will have specific knowledge of the cost and schedule impacts of each of these activities long before they appear on a Contract Performance Report (CPR). It is this foreknowledge that program managers need and want. This paper will question some long held EV industry practices used by analysts to predict costs and introduce a more useful index. Additionally, we will introduce a systematic method for on-site representatives that will enable them to produce more accurate and timely program information.

All cost and program information cited in this research paper is from publicly released information contained in journals, books and Government Accounting Office (GAO) reports.

CURRENT ACQUISITION SITUATION

The current cost, schedule and technical state of many MDAs remain abysmal. More importantly, earned value, the tool for identifying the performance of a program has not been able to predict these variances. This failure is not the fault of earned value, but in the analysis and approach (or lack thereof) of the data. Our approach is to integrate EV data with on-site representative knowledge to create useful information reflective of the current, as well as future, contractor performance status.

This is significant due to the sizeable fiscal commitment of current and planned expenditures for DOD programs. A recent GAO report states that "The Department of Defense (DOD) has more than $1 trillion worth of major defense acquisition programs in development and production." (GAO; Information for Congress) Since 1967 "…DOD instituted a reporting system to summarize program cost, schedule and performance called the [Selected Acquisition Report] SAR." (GAO; Information for Congress) Current SAR information yields poor cost, schedule and technical program performance. The GAO cites that "…in 2003, DOD reported 81 programs; of this number, 49 or (60 percent) had multiple rebaselinings over the life of the program." and "Between the 2004 and 2005 budget requests, DOD rebaselined 7 of 81 major defense acquisition programs." (GAO; Information for Congress)

This same report cited the top four MDAs with multiple rebaselinings. The F/A-22 was the worse offender with fourteen rebaselinings over an eleven year period. A rebaseline is originally initiated by the contractor and approved by the customer. It occurs when the "…baseline does not represent a realistic plan of accomplishing the remaining work and no longer serves as a basis for effective control." (EVMIG). However, with the high frequency of multiple rebaselines many things are clear, one of which is that a rebaseline is merely a signal of continued programmatic issues followed by the high probability of future rebaselines. Continued cost, schedule and performance issues plague virtually every segment of current DOD acquisition such as aircraft, shipbuilding and space systems; each of which has an Earned Value requirement on most if not all of their significant contracts. A brief, but current status of these segments will illustrate the current state of acquisitions.

Current DOD acquisitions for tactical aircraft such as the F/A-22 Raptor and F-35 Joint Strike Fighter (JSF) are experiencing cost, schedule and technical pressures. The F/A-22 program began in 1986 and the F-35 program began in 1996 (GAO; Status of F/A-22). "The National Defense Authorization Act for Fiscal Year 1998 established a cost limitation of $18.688 billion for F-22 development…" (GAO; F/A-22 Delays). However, the Secretary of Defense recently notified Congress in September 2001 that an additional 557 million would be needed to complete development and that would bring the total developmental cost to $21 billion (GAO; F/A-22 Delays). "The JSF is DOD's most costly aircraft acquisition program." and development costs have increased over 80 percent (GAO; Status of F/A-22).

The original development cost in 1996 was $25 billion; however in 2004 developmental costs are estimated at $45 billion (GAO; Status of F/A-22). The trend for mitigating most of these cost challenges has been through the reduction in order quantities. Both aircraft have been subject to this cost saving strategy. The F/A-22 has been reduced from 750 units to fewer than 180 units and the F-35 has recently been reduced by 535 units (GAO; Status of F/A-22). The future of the F-35 as cited by the GAO has a bleak outlook as they state that the 1996 business case is unexecutable and "…the JSF does not yet have the knowledge to justify future investments." (GAO; Status of F/A-22). Industry standard practices and formulas used to predict these types of cost overruns have failed to provide DOD, Congress and government program management with timely reliable information.

Shipbuilding development and production is in a similar cost and schedule condition as that of aircraft. The February 2005 GAO report on eight ships comprising four classes has estimated that projected cost growth of $3.1 billion has "…proven to be too conservative" (GAO; Improved Management). Unlike aircraft, severely

reducing ship quantities is not a viable option. Two cost areas account for 95% of this growth: Labor at 78% and overhead at 17% (GAO; Improved Management). The labor cost growth is largely a result of rework and a lack of design maturity. For example "…workers were required to rebuild completed areas of the ship to accommodate design changes" (GAO; Improved Management). It was cited by the GAO report that earned value was not used effectively although the shipbuilders had validated EV systems (GAO; Improved Management).

Navy officials believed earned value was to be used as an early warning tool. However, it was also shown that "…the longer the time lapse in receiving the cost performance report, the less valuable the data becomes" (GAO; Improved Management). Additional negative EV related comments by the GAO include: Cost Performance Reports (CPR) submitted on a quarterly basis, poor quality of CPR data, little to no detail regarding root cause analysis and inadequate independent estimate at completion (I-EAC) (GAO; Improved Management). The report acknowledges that cost growth has been a long standing Navy problem and recommends that the Navy needs a higher level of knowledge to produce more realistic results (GAO; Improved Management).

If led and managed properly, the knowledge provided by on-site representatives could provide more realistic predictions rather than waiting for untimely and poor quality EV data that was then subject to a strict formulaic assessment, such as a cumulative CPI, to create unrealistic and consistently understated future cost predictions.

Lastly, space acquisitions share a similar record with both aircraft and shipbuilding in regard to the magnitude of acquisitions and recent cost, schedule and technical performance issues. "DOD expects to spend almost $20 billion dollars to develop and procure satellites and other space systems, including nearly $7 billion on major space systems." Currently reported cost and schedule results are likewise unflattering. Total program cost growth on the six GAO reported programs ranges from 10% to 160% (GAO; Improvements Needed). Unit cost growth has increased on all programs from 3% for a program that began two-years ago to 315% for the Space Based Infrared System High (SBIRS High) that began in 1996. Schedule performance demonstrates equally poor results with the SBIRS High program experiencing a slip of six-years. The GAO concludes by giving the space community an accolade for their positive steps to address these adverse trends. However, they are simultaneously given a caution acknowledging their proposed policy and process changes will be extremely challenging (GAO; Improvements Needed).

The status of these large DOD acquisition programs is discouraging and gives no clear indication that the trend will begin reversing itself soon. The authors acknowledge, and GAO reports confirm, that there are a multitude of problems that contribute to poor cost, schedule and technical issues. For example the F-35 suffers from design changes, increased weight and greater than anticipated design effort of complex software (GAO; Status of F/A-22). The accuracy of shipbuilding cost analysis has been called into question. Ships currently being manufactured were cost estimated based on data from the 1980's when construction quantities were higher and economies of scale were a positive factor (GAO; Improved Management). Space and satellite programs have been criticized for starting programs too early before capabilities were assured and for attempting to satisfy all user requirements in a single step regardless of the complex challenges and maturation level of technologies (GAO; Improvements Needed).

These issues remain to be addressed and resolved by contractors and senior DOD program management. However, what this paper intends to address is what Congress, DOD and program managers require; and that is the immediate knowledge of potential cost, schedule and technical issues before they are manifest as EV figures in a CPR, which in some cases is sixty days after the fact. A statement made by the GAO in their March 2002 report on the F-22 requests: "We believe that Congress [DOD and program management] should be notified as soon as possible of projected cost increases in the development [and production of any] program" (GAO; F-22

Delays). [emphasis added]. This level of knowledge can only be gained through on-site representatives utilizing proven EV techniques who integrate their real time program knowledge with EV data.
The combination of these two concepts can alert program management of cost, schedule and technical issues before they get surprised by negative trends in EV reports.

CURRENT EV INDUSTRY ACCEPTED PRACTICES

There is no shortage of articles, papers and chapters on the tradeoffs of using various cost and schedule indices (CPI and/or SPI) to predict an I-EAC. Some articles cite the "…CPI as the single most important tracking metric in EVM…" (Fleming; Does Compliance) while others claim that "Only the cumulative CPI data has been found to be viable as a predictive tool…" (Fleming; Earned Value) and conversely others cite "There have been dozens of EAC studies over the past thirty years. …Based on a review of 25 EAC studies, no single EAC formula is always the most accurate."(Christensen, SCI). It is apparent that no single cost or schedule index has been awarded the coveted spot of best predictor; however there remains within the EV community the misdirected need and drive to fill this vacancy.

Given the fact that "There have been dozens of EAC studies over the past thirty years" (Christensen, SCI), it begs the question as to whether the knowledge gained from these studies has been an aid or a determent to DOD acquisition program management. The cost, schedule and technical data cited above on current DOD programs certainly do not positively correlate with increased knowledge and skill in predicting cost and/or schedule conditions. Additionally, it is our position that strict formula based I-EACs are wholly insufficient. However, this does not mean that the cost and schedule indices are not valuable indicators: they are. What is needed is the ability to increase the timeliness and quality of cost and scheduled predictions. This can only occur where on-site personnel integrate current programmatic knowledge and critical thinking with comprehensive EV techniques and analysis. A process for integrating EV analysis with knowledge will be focus of the next section.

Integrating Knowledge and Earned Value for Programs

On-site program management offices need forecasted cost, schedule and technical indicators well before they are manifest in the EV figures via the CPR. Relying on cumulative CPI, composite CPI/SPI or any of the other standard formulas results in forecasts and warnings that are wholly untimely since EV data is essentially a lagging indicator. The on-site organization, as an agent of the buying office, charged with oversight of a defense or private contractor is the only place where knowledge and insight merge to produce timely results. The team charged with oversight needs to employ a systematic approach to integrate EV data with their programmatic knowledge. This can be accomplished through the use of a simple form as shown in appendix 1-The Independent Performance Analysis Report (I-PAR).

The I-PAR integrates EV data and programmatic knowledge which enables the on-site team to make forecasts based on current knowledge as opposed to forecasts based on pure mathematical calculations using data that can be two months old. The integration of current knowledge with EV data will provide Congress, DOD and program managers with the insight that has been lacking. A brief explanation of Appendix 1 will follow to demonstrate the application and use of the I-PAR tool. The following explanation is not intended to be a detailed procedural explanation of the I-PAR. Only high level concepts and ideas will be explained. The authors can be contacted for a more detailed implementation.

The I-PAR is intended for use by the team of on-site representatives charged with reporting contractor performance activity to a buying or program office. The I-PAR is only created for those Work Break Down structures (WBS) at the Control Account Manager (CAM) level that have been identified through a well defined and comprehensive risk management process as high or moderate risk. Additionally, it demands that on-site management define and distribute all CAM level WBS to team members. There is typically only one contact

designated to complete each I-PAR. However, not all team members will be assigned WBS responsibility. Some team members provide broad support spanning multiple WBS i.e. quality assurance.
Therefore, the team needs to develop a process that integrates their input into the I-PAR. Once this and other team procedures are in place and understood, then the I-PAR can be deployed. The supervisor and EV analyst receive the monthly team I-PARs in preparation for a monthly status report and development of a program I-EAC. The knowledge based I-EAC is a collaborative effort between the team supervisor and EV analyst. The team's I-PAR input will influence the magnitude of the I-EAC.

An explanation of the four related sections of the I-PAR (Appendix 1) will describe the inputs required and how the team uses those inputs when producing independent knowledge based predictions. This is likewise not intended to be a detailed procedural explanation.

The first two sections of the I-PAR (Figure 1) contain general descriptive information of the WBS such as critical path designation as well as current and cumulative control account data. The EV data contained in this section provide the genesis of analysis and typically forms the basis of future inquiries as relationships between key financial indicators are analyzed. This section of the I-PAR is the quickest to populate, however, it is the analysis and critical thinking that provides the program benefit and forms the basis of knowledge the analyst will use in the remaining two sections.

FIGURE 1

Current Performance Data

Bcws Cur	Bcwp Cur	Acwp Cur	Sv Cur	Cv Cur	Cpi Cur	Spi Cur

On Critical Path Yes___ No___

Cumulative Performance Data

Bcws Cum	Bcwp Cum	Acwp Cum	Spi Cum	Cpi Cum	Cpi Cur3	CV Cum	SV Cum

Bac	VAC	Eac	Tcpi Eac	Tcpi Bac

The second section (Figure 2) is an independent assessment of the WBS that will be completed when contract defined cost and/or schedule thresholds have been breached. This section is an assessment of the contractors root cause explanations for cost and schedule variances. The analyst will summarize the significant cost/schedule drivers given by the CAM, but will also add their assessment of the cost/schedule drivers and why they agree or disagree with the CAM.

FIGURE 2

Corrective Action

Cost Variance Due to:

Schedule Variance Due to:

Programmatic Impact:
Cost:
Schedule:

Lastly, the analyst will quantify the cost/schedule impact in terms of dollars and time to this particular WBS as well as the program. The intent of this section is to analyze and assess actions that are proposed to be taken to correct negative trends. This section is not intended to simply reiterate presented information. The benefits from this assessment are contained in the candid assessment of the proposed corrective actions. The realistic or unrealistic corrective actions proposed can be immediately evaluated and expressed in terms of cost and schedule impacts, long before their effect is expressed in published EV reports.

This last section of the I-PAR (Figure 3) results in the culmination of all the program knowledge gained from the previous three sections. The cells (current month, next & past) will be filled in with the appropriate month. The current and past cells will be appropriately colored using the thresholds defined in

FIGURE 3

Cost and Schedule Forecasts

	CV	Reason	SV	Reason
Next 3	$xx to $xx		T_1 to T_2	
Next 2	$xx to $xx		T_1 to T_2	
Next 1	$xx to $xx		T_1 to T_2	
Current Month	Actuals		Actuals	
Past 1	Actuals		Actuals	
Past 2	Actuals		Actuals	
Past 3	Actuals		Actuals	

the contract and will contain actual cost and schedule expenditures.

The WBS analyst will then, with their knowledge gained, predict (Next 1, 2, 3) a 30, 60, and 90 day cost and schedule impacts to this WBS. Cost and schedule predictions are expressed in ranges of a most likely to worse case. Each cost and schedule prediction is supported and explained and may refer to other sections of the I-PAR. It is at this point that the integration of EV information and current program knowledge converge to provide timely program information unobtainable anywhere else. Additionally, the use of EV data and current program knowledge enables the analyst to create knowledge based assessments and predictions that are not available if a strict formula based approach were used.

The on-site program supervisor and EV analyst collaborate in their review of all I-PARs. The EV analyst determines which EV statistical formulae serves as the best foundation for an I-EAC and then justifies and documents the increase or decrease with the knowledge from the I-PAR forms. The supervisor consolidates all I-PARs and embeds these files in Microsoft Word on an executive summary. The monthly status report is thus reduced to a few pages, but includes (as embedded files) the detailed explanation and backup for staff analysis.

The Problem with Cumulative CPI

An integral part of predicting future cost and schedule performance on the I-PAR, alluded to in the prior section, is the ability to understand current performance. This is the problem with the cumulative CPI. The cumulative CPI does not provide any meaningful indication of current contract performance. Therefore; if the cumulative CPI is used as the sole indicator for future performance it is and has proven to be a poor predictor of future cost performance. The authors understand that established EV industry literature has gone to great lengths to study large databases of past DOD contracts. This was done in an attempt to make correlations of contract CPI and SPI at various contract completion percentages to learn when and where to use statistical formula estimates on current contracts to create accurate predictions on current active contracts. The results of these studies remain insightful, but still do not provide the insight necessary by those performing oversight when 30, 60 and 90 day predictions of cost and schedule are required.

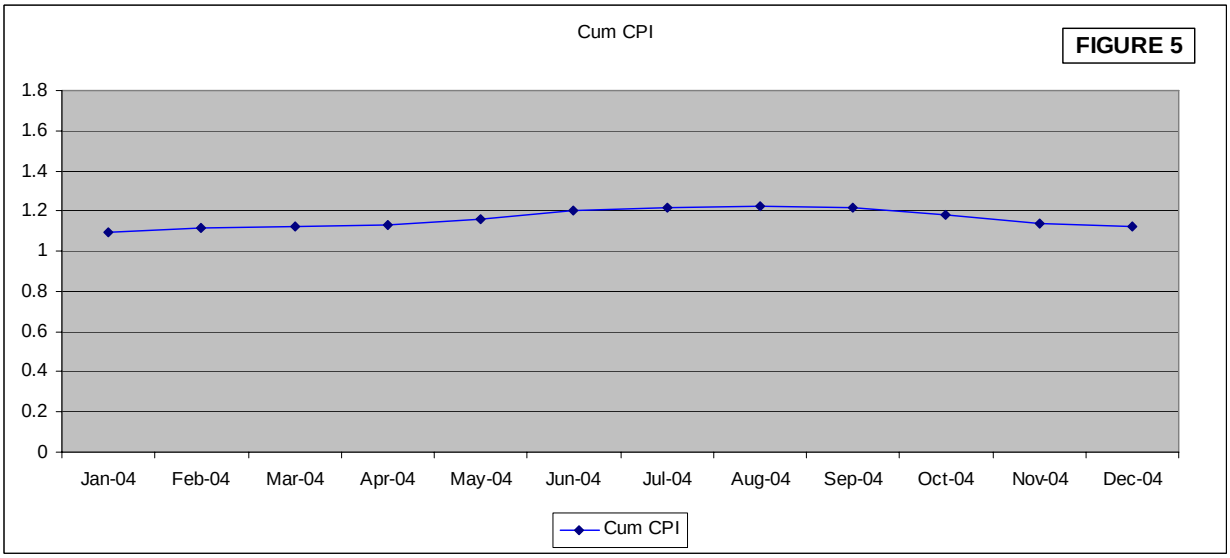
The cumulative CPI is not useful because it is overly skewed. Typically as contract work progresses it becomes more complex. The less complex work is usually performed and earned early. The early CPI is typically represented with an index greater than 1.0. As work progresses and becomes more complex (current CPI typically less than 1.0), the cumulative CPI trend scarcely reflects the trend of the current work. The answer to this dilemma is to create a 3-month rolling current CPI and lay this trend line on top of the cumulative CPI trend. The departure and difference between these two trends is sometimes very dramatic and extremely beneficial. The 3-month rolling current CPI will trend only recent performance by removing the cumulative effect of the early less complex work and provide insight on the status of present performance. Merely trending the current monthly CPI will yield somewhat similar results, but the benefit of a 3-month rolling current CPI is a smoothing effect on the trend line. Before illustrating this concept, full credit for the 3-month rolling current CPI as well as some of the ideas underlying the I-PAR must be given to Colonel Mark Borkowski who was influential in explaining this concept.

FIGURE 4

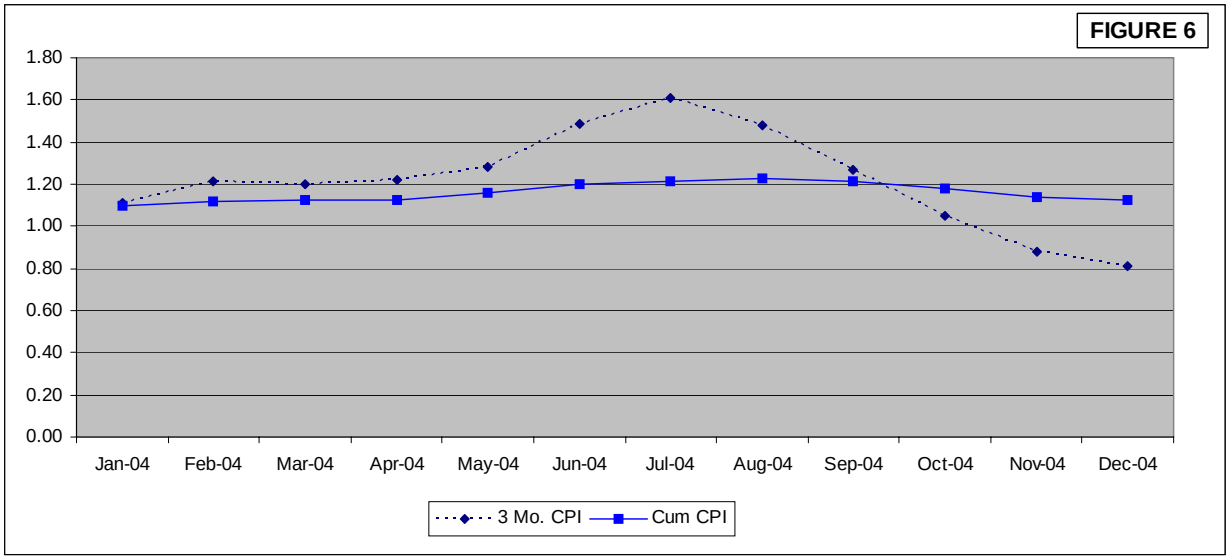
Current	Aug	Sep	Oct	Nov
BCWP	26	20	21	24
ACWP	20	18	26	30
3 Mo. CPI	1.47	1.26	1.05	0.88

The 3-month rolling current CPI is a standard CPI calculation, but it is composed of the current month BCWP and ACWP summed with the same data from the previous two months. For example in figure 4 the 3-month rolling current CPI for November is the sum of BCWP from September, October and November that is then divided by the sum of the ACWP from the same period. For example Figure 5 below is a trend of cumulative CPI data representing typical CAM cost

performance. Most CAMs reviewing a CPI hovering around this level of 1.0 would pay little to no attention to this work effort.



However when overlaying the 3-month rolling current CPI trend on the cumulative CPI trend, a much different picture emerges as show in Figure 6 below. Notice the graphing scales in Figure 5 and 6 are identical. The



difference is that a 3-month current rolling CPI was calculated. It can now be understood that for the past five months performance has been degrading and there is no indication that the current performance has reached its lower limit. An additional benefit of calculating the 3-month current rolling CPI at each CAM level is that with a little effort and through the wonders of Microsoft Excel macros, a program level I-EAC can be calculated using this index. The 3-month rolling current CPI is an invaluable indicator for current performance and provides significant input for completion of the I-PAR when 30, 60 and 90 predictions are necessary. Additionally, this indicator can be used to forecast total program cost and provide a future cost based forecast based on current performance. This index as well as a current 6-month CPI is now a standard feature in C/S Solutions, Inc. wInsight version 6.3.

Management and Implementation

Lastly, the I-PAR like any business initiate requires strong management, committed leadership and steadfastness. The absence of strong leadership will wreak havoc on any initiative regardless of how sound, researched or proven it was prior to implementation. The road of past business and management initiatives is littered with failed initiatives, many of which can be directly attributed to managers and leaders. One fairly recent example comes to mind: Reengineering.

In 1993 Michael Hammer and James Champy published a book titled Reengineering the Corporation. The concept of reengineering was simple. “It meant abandoning long-established procedures and looking afresh at the work required to create a company’s product or service and deliver value to the customer” (Hammer 31). Reengineering swept government and private industry as initiatives proliferated the business landscape. So what happened? James Champy states: “Reengineering is in trouble. It’s not easy for me to make this admission” (Champy 1). “Some managers, misled by wishful thinking, believe that merely repeating the key words *Reengineering the Corporation* is enough to bring transformation…” (Champy 6). Reengineering was facing trouble, not because Reengineering was a flawed concept, but because of management. Hence the sequel to Reengineering the Corporation is Reengineering Management. Likewise, the I-PAR requires competent, engaged and committed management or this concept will go the way of a plethora of past initiatives.

Conclusion

The current cost, schedule and technical state of large DOD programs remains abysmal. The GAO has stated that “We believe that Congress [DOD and program management] should be notified as soon as possible of projected cost increases in the development [and production of any] program” (GAO; F-22 Delays) [emphasis added]. There is a strong tendency in current EV literature to place an overdependence on using the cumulative CPI as a whole or part of an equation to predict future program performance. While this indicator is beneficial, it does not provide an adequate assessment of current cost trends, which then can be used to predict future cost performance. The I-PAR and the 3-month rolling current CPI can provide the missing information that Congress, DOD and program management are seeking. However, this success depends on the commitment and dedication of skilled and competent management or it will become one more piece of refuse on the littered business initiative highway.

APPENDIX 1

WBS XXX-Name
MM/DD/YYY Variance Summary

Current Performance Data

Bcws Cur	Bcwp Cur	Acwp Cur	Sv Cur	Cv Cur	Cpi Cur	Spi Cur

On Critical Path Yes___ No___

Cumulative Performance Data

Bcws Cum	Bcwp Cum	Acwp Cum	Spi Cum	Cpi Cum	Cpi Cur3	CV Cum	SV Cum

Bac	VAC	Eac	Tcpi Eac	Tcpi Bac

Cost and Schedule Forecasts

	CV	Reason	SV	Reason
Next 3	$xx to $xx		T_1 to T_2	
Next 2	$xx to $xx		T_1 to T_2	
Next 1	$xx to $xx		T_1 to T_2	
Current Month	Actuals		Actuals	
Past 1	Actuals		Actuals	
Past 2	Actuals		Actuals	
Past 3	Actuals		Actuals	

Corrective Action

Cost Variance Due to:

Schedule Variance Due to:

Programmatic Impact:
Cost:
Schedule:

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About the Authors

Jim Baber is currently an earned value management specialist with the Defense Contract Management Agency (DCMA). He has over 15 years experience in the aerospace and defense industry. He is also an adjunct professor of business at Cerritos College in Norwalk California. He is actively engaged in curriculum development at the local and state level. He is a member of the Cerritos College Business Division curriculum advisory committee and a member of a Business Education Statewide Advisory Committee. He holds a graduate degree in Organizational Management from Antioch University.

Larry Gentry is currently a program integration specialist for DCMA. He has 4 years engineering and earned value experience with the Department of Defense. He has 10 years experience with the Federal Aviation Administration (FAA) and over 20 years experience in Aerospace and commercial industries. He holds an Electrical Engineering degree from UCLA and a graduate degree in business from Pepperdine University.