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“Plans are nothing; planning is everything.”

- Dwight D. Eisenhower

General Eisenhower recognized that the act of planning (scheduling) is more important than the schedule itself, because when the battle begins, the plans are immediately obsolete. In the spirit of planning, scheduling and adapting, this issue of MN features three interesting and informative articles: ‘Applying Statistical Forecasting of Project Duration to Earned Schedule-Longest Path’, ‘Agile and Schedule Management Guidelines’, and ‘Introduction to Earned Duration’.

In ‘Applying Statistical Forecasting of Project Duration to Earned Schedule-Longest Path’, Mr. Walt Liptke discusses the usage of Earned Schedule (ES) as a more accurate method of forecasting project durations. Although this method has proven to be more accurate, research has shown that as the topology of the network schedule becomes more parallel, the accuracy of the ES forecast worsens. Mr. Liptke discusses how forecast accuracy improvement has been achieved for highly parallel type schedules with the method of Earned Schedule-Longest Path. This paper proposes further advancement to the longest path approach through anomaly rejection and the application of statistical methods.

Continuing the Agile theme from our last newsletter, and emphasis on planning, Ms. Karen Richey and Ms. Jennifer Leotta of the General Accounting Office (GAO) share the GAO’s ‘Schedule Assessment Guide’. This guide further develops the scheduling concepts initially discussed in the GAO Cost Estimating and Assessment Guide. The guide outlines ten scheduling best practices for developing and maintaining high-quality schedules that provide credible forecast dates. In order to address the popular Agile software development approach now employed on many government IT projects, the GAO has developed an Agile appendix. This describes the applicability and benefits of scheduling best practices for Agile projects with various considerations. The appendix also identifies key document differences between Agile and Traditional scheduling.

The third article of the planning scheduling theme is the article ‘Introduction to Earned Duration’ by Mario Vanhoucke, Paulo Andrade, Floriano Salvaterra and Jordy Batselier. The anomalous behavior of the EVM schedule indicators provided the motivation for the development of the Earned Schedule (ES) concept by Walt Lipke (2003; 2009). The basic idea is that project schedule management techniques should be able to evaluate schedule performance in units of time, and not in monetary terms as in the EVM methodology. The Earned Duration (ED) concept (Khamooshi & Golafshani, 2014) was created to address the shortcomings of ES due to the usage of cost-based data as proxies for assessing the schedule performance of projects. Its foundation lies in the exclusive usage of time-based data for the generation of physical progress indicators. The authors have provided a primer for the Earned Schedule and Earned duration approaches with detail algorithms, application of the ‘S curve’ and information tables.
“Data driven analytics and automated technology can do for DoD EVMS compliance what ‘Moneyball’ and ‘Sabermetrics’ have done for the game of baseball”. David Kester, Director EVMS Policy and Strategy, DCMA. In Mr. Kester’s article on ‘Big Data’, he discusses the ‘Call for Change’ within the DCMA, and outlines a response to that call with an initiative that envisions the capability to remotely test a contractor’s EVMS data, thus eliminating the need for multiple DCMA interviews and assessments (and the labor and travel costs associated with numerous people visiting a contractor’s plant). A standard set of data now provides both the DCMA and contractor with an instant diagnosis of the issue and common reference point for discussion. Mr. Kester discusses in detail the impacts to common data sets, ‘New Thinking’ requirements and testing protocols.

Next to ‘Agile’, the most popular word in the EVM community is ‘Tailoring’. The ‘IPMR Tailoring: Data You Can Count On’ article by Mr. Gordon Kranz, Ms. Karen Kostelnik, and Mr. David Nelson of The Office of Performance Assessments and Root Cause Analyses (PARCA) shares PARCA’s tailoring recommendations as a result of the November 2014 Integrated Program Management Workshop. PARCA presented a workshop session on options of tailoring the IPMR. The tailoring scenarios that were presented included: IDIQ reporting, use of Alternate WBS (non-881C), actuals-only reporting, IMS-only reporting, IPMR requirements when DFARS EVM clauses are not applicable, and subcontractor reporting. Presented in an easy to interpret table, the reader can see the recommendations for each scenario.

Also included in this issue are updates from our CPM Tennessee Valley (CPMTV) and Washington DC chapters.

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DATA DRIVEN EVMS COMPLIANCE: AN ANALYTICAL APPROACH THAT WILL TRANSFORM THE WAY WE THINK ABOUT MANAGING

By David Kester, David Cottrell, and Kevin Carney - Defense Contract Management Agency

INTRODUCTION AND BACKGROUND

Since August 1998 the Department of Defense (DoD) has recognized the 32 EIA-748 Earned Value Management System (EVMS) Guidelines as the basis for determining the compliance (or worthiness) of managerial tools used to control billions of dollars of defense acquisitions each year. A compliant EVMS by definition provides for the generation of timely, reliable, and verifiable contract performance data, permitting the government program managers to evaluate a contractor’s progress and likelihood of meeting programmatic and contractual requirements for cost, schedule and technical viability. Earned Value Management (EVM) is founded on the idea that program managers and their teams make the best decisions when they have the best information. EVM is defined by guidelines, where management practices, business processes, systems, and organizational culture meet and mix.

The Defense Contract Management Agency (DCMA) is responsible to ensure that EVMS data for DoD programs is compliant and reliable. Its Defense Federal Acquisition Regulation Supplement (DFARS) EVMS Mission is defined as follows:
1. Influence industry partners to field effective and efficient EVMS that are compliant with the 32 EIA-748 EVMS Guidelines; and
2. Strengthen program management (decision making) by the way we think about (and use) EVMS data.

EVMS Compliance is very much a responsibility shared by contractor and Government alike.
1. The Contract Administration Office (CAO) is responsible for ensuring that the functions described in DFARS 242.302 are completed by the contractor in accordance with the terms and conditions of the contract.
2. DCMA advocates DoD’s implementation of EVMS by executing the roles & responsibilities defined in DFARS 242.302 (S-71).
3. Contractors are expected to assume responsibility for their own behavior; that is, for the consistent application of the EVMS and its currency and relevance.
4. PEO/PMO is responsible to ensure that the desired results are produced in a timely, cost effective manner
   - Manage cost, schedule, and performance within requirements
   - Initiate effective cost, schedule, and performance tradeoffs
   - Continually evaluate progress and predict and mitigate risks

A CALL FOR CHANGE

DCMA’s Director, Lt. Gen. Wendy M. Masiello, believes the time is ripe for the Agency to find internal operational efficiencies. Budget uncertainty translates to no increase in resources and pressures to reduce the administrative burden on DoD contractors as part of the AT&L Superior Supplier Program often points to DCMA processes. The Agency is facing an increasing demand for pricing support and new responsibilities in roles such as Mission Assurance. These factors create a pressing need to take a closer look at our mission, our vision and the strategic goals we set for ourselves.

Fundamental to DCMA’s future success is to better integrate its efforts and analyze its data to provide a unified message that our partners can use to benefit current contracts as well as better shape those in the future. Additionally, consistency in assessing contractor business systems and their compliance is a must. “We are the independent eyes and ears of DoD and its partners, delivering actionable acquisition insight from the factory floor to the front line and around the world.” Lt. Gen. Masiello notes, “Consistency in understanding and decision making will improve our productivity and ensure we behave as One Team with one voice.”

Since the establishment of the DCMA Earned Value Management Divisions in May of 2013, a number of EVMS policies and operating methods have been reconsidered to address inefficiency and inconsistency in the assessment of a contractor’s EVMS. In addition, a first-of-a-kind initiative was launched in 2014 to rethink the way in which contractor EVMS

DATA DRIVEN ANALYTICS AND AUTOMATED TECHNOLOGY CAN DO FOR DOD EVMS COMPLIANCE WHAT MONEYBALL AND SABREMETRICS HAVE DONE FOR THE GAME OF BASEBALL.

- DAVID KESTER

Approval for Public Release, Distribution Unlimited, Feb 21, 2015
validations and follow-on surveillance can be performed in a similar manner using data sets and algorithms to summarize, detect patterns, and draw conclusions. This idea uses a data driven approach to efficiently test the reliability of core management processes from initial implementation and continually thereafter reducing the risk of system failure during sustainment and maintenance.

The initiative envisions the capability to remotely test a contractor’s EVMS data, thus eliminating the need for multiple DCMA interviews and assessments (and the labor and travel costs associated with numerous people visiting a contractor’s plant). Markers in the data will point the way to emerging issues, allowing a contractor to take preemptive action to remedy data quality issues before they escalate to major deficiencies. Persistent EVMS concerns can then be addressed by a much smaller and more nimble DCMA team with specific expertise tailored to the precise issue. A standard set of data now provides both the DCMA and contractor with an instant diagnosis of the issue and common reference point for discussion. It also pinpoints, or limits the area of concern, thus ensuring that additional resources are not invested in areas where there are not potential deficiencies.

This approach, while still in its infancy, is a game changer and has already proven invaluable in communicating the requirements of the 32 EIA-748 EVMS Guidelines to industry while lowering implementation costs for the DoD and industry. DCMA currently leads a pilot effort to deploy this innovative approach on the F-35 Joint Strike Fighter Program, working with Lockheed Martin Aeronautics (LMA) at its facility in Fort Worth, Texas.

NEW THINKING
For years DoD and industry have debated the finer points of EVMS compliance with no real success. To reach common ground, the DoD is actively working to ensure that industry understands and complies with the 32 EIA-748 EVMS Guidelines by providing greater clarity and consistency in how it goes about its business. In practice, loosely defined EVMS Guidelines have led to inconsistencies in the interpretation of requirements. With the impending release of the EVMS Interpretation Guide, the DoD will rectify this long standing situation by providing more precise definitions and translations. The following strategies underlie the content of this effort:

1. Reduce the burden to demonstrate EIA-748 EVMS Guideline compliance by promoting consistent application of EVMS compliance assessments across the DoD;
2. Emphasize the need to establish clear and measurable technical objectives for planning, tracking, and managing the baseline plan; and
3. Promote the implementation of program-unique management practices consistent with broader EVMS guideline characteristics (i.e., support various ways of being compliant).

DCMA plans to use this increased precision as an underpinning to fundamentally change the method of measuring EVMS compliance. Through the use of recently available technology, DCMA has developed a process to more efficiently collect, correlate, and deliver data and information, and as a result, is repositioning itself in a role as the Department’s EVMS information broker. This inevitable step-change and the enabling technologies behind it will free DCMA technicians | statisticians | analysts to focus on meaningful insights, and result in more clarity and consistency than ever before. Time is of the essence for this change. To quote Marc Benioff, the founder and CEO of Salesforce.com, “Based on the simple fact that there’s just a huge amount more data than ever before, our greatest challenge is making sense of that data. And we need a new generation of tools to be able to organize and view the data. We need a new generation of executives who understand how to manage and lead through data. And we also need a new generation of employees who are able to help us organize and structure our business around that data. When I look at the next set of technologies that we have to build in Salesforce.com, it is all data science based technology”.

THE IMPORTANCE OF CONTEXT IN EIA-748 EVMS GUIDELINE INTERPRETATION
Although the 32 EIA-748 EVMS Guidelines are unambiguous statements of basic program management principles, questions frequently arise as these principles are put into practice. More often than not, the root cause of these questions is an inadequate knowledge of the EIA-748 EVMS Guideline requirements. If more people learned to interpret the EIA-748 EVMS Guidelines in context, quite a few differences would disappear. When both government and industry work together to unfold the meaning of the EIA-748 EVMS Guidelines, agreement is usually the result.

By deconstructing each of the 32 EIA-748 EVMS Guidelines, the practitioner can break the requirements into more manageable segments towards meeting the requirements of DFARS
It is critical to understand that each guideline has a general purpose and well-defined attributes (i.e., qualities and characteristics) which make each guideline distinct from others. Furthermore, test steps can be developed to determine the performance of each of these attributes. While there may be multiple tests for each attribute, each test step provides unique insight into the performance of the EVMS. Unique test metrics can be collected to quantify this performance.

A uniform approach to evaluate the performance of the EVMS in the manner described above safeguards the fairness of EVMS compliance proceedings throughout the DoD. The genuine adoption of these common management attributes across industry sectors reinforces EVMS as a widely accepted best practice for program management. Making a correct EIA-748 EVMS Guideline interpretation can make the difference between creating an authentic connection to a necessary management principle or the implementation of an unwarranted, burdensome and costly routine.

TESTING PROTOCOLS

Many EIA-748 EVMS Guidelines are routinely taken out of their immediate contexts and misinterpreted; Guideline 30 (control of retroactive changes) can be used as a good example of this. EIA-748 EVMS Guideline 30 states:

“Control retroactive changes to records pertaining to work performed that would change previously reported amounts for actual costs, earned value, or budgets. Adjustments should be made only for correction of errors, routine accounting adjustments, effects of customer or management directed changes, or to improve the baseline integrity and accuracy of performance measurement data.”

This is intended for the active performance period and it provides general guidelines for the types of changes, (i.e., correction of errors, routine accounting adjustments, effects of customer or management directed changes, or to improve the baseline integrity and accuracy of performance measurement data).

One of the most important EVMS tests is used to find out if there have been unauthorized retroactive changes to the baseline. In practice, this is done by examining whether a contractor has a change control process that controls retroactive changes to previously reported amounts for actual costs (ACWP), earned value (BCWP), or budgets (BCWS) through a process that includes management approval. Another important test compares the contractor’s current period data on the integrated program management report (IPMR) formats 1 and 3 (which reflect any retroactive changes) to the related explanations on format 5.

This examination helps to ensure that a realistic Performance Measurement Baseline is maintained and there is continuous and consistently credible visibility into past performance. Some contractors might be tempted to eliminate the favorable cost variances from past
performance in order to allocate the remaining (unused) budget to future effort. This tendency is usually based on the contractor not making the distinction between financial funding and EVM budgeting standards. The intention of an EVM budget baseline is to maintain visibility of past performance for the purpose of forecasting future performance. It is important to remember that the BCWP is allowed to change for the correction of errors, and/or accounting adjustments to improve the accuracy of earned value. If other changes are made, then the integrity of the BCWP value becomes suspect. BCWP is the cornerstone of a performance measurement system and it should be based on the accomplishment of discrete tasks that are representative of true progress. The objective is to minimize any subjectivity in the BCWP calculation.

One type of allowable routine accounting adjustment to BCWS stems from negotiating an unpriced change order that results in a differential between the distributed budget of the change and its negotiated value. Please note that the BCWP value should not be impacted by this type of adjustment.

Replanning, or the realignment of scope, schedule, and budget within the Contract Budget Base (CBB), must be limited to preserve a stable baseline upon which performance is measured. Replanning is generally intended for future plans (in the next accounting period, or outside the “freeze” period e.g., current period plus x# months) that significantly vary from the original baseline, but it may also affect budgets in past or current periods within strict controls. Cost, schedule, and technical problems often cause the original plan to become unrealistic; they may require a different engineering or manufacturing approach, or reorganization to increase efficiency of operations. Changes to improve baseline integrity or the accuracy of performance measurement are acceptable, even though they may appear primarily to offset cost overruns or underruns. Examples of acceptable changes to previously reported amounts for actual costs, earned value, or budgets during the active performance period are the following:

- De-performing BCWP when a material item is returned to vendor for repairs;
- De-performing BCWP when rework is required;
- Change in approach due to make or buy decisions;
- Adding budget in the active performance period for risk mitigation activities;
- Where there is BCWS and BCWP but no ACWP on Level-of-Effort (LOE) work packages, set S=P=A (0) and replan the BCWS; and
- Replanning grossly over-budgeted LOE WPs that are masking cost variances as performance measurement information is summarized up the work breakdown structure or the organization breakdown structure.

Conversely, an example of an unacceptable change is when a contractor retroactively reduces a performance value previously reported to equal the actual costs incurred, and then transfers the resulting budget for the effort to other activities that are overrunning. Even though this may be undertaken at the prompting of the program office, this translates to mean a funding underrun (placed against the next emerging issue) rather than a measure of performance. As a result, these changes often have a material impact on reported values and go uncontrolled as negative BCWS, BCWP and ACWP.

Any mass retroactive change as an across-the-board single point adjustment can have drastic effects on the program and its progress reports. A retroactive change to monthly data will not only question the work that was previously thought to have been accomplished, but it will also impact the cumulative trend that was previously reflected.

The contractor’s adjustment method for the effects of a customer-directed change is critical. Changing a control account budget value during a freeze period for customer-directed changes is a legitimate necessity and should be considered as part of a contractor’s internal controls process. Furthermore, the contractor’s work authorization process needs to accommodate such changes prior to the start of work during the active performance period. Otherwise, the authorization process will lag behind, and it could lead to establishment of zero-budget accounts or work packages that would result in negative performance values.

**HOW TO EXAMINE AN EIA-748 EVMS GUIDELINE ATTRIBUTE**

Each EIA-748 EVMS Guideline contains core characteristics (or attributes) that the Government has identified as being essential to fielding a compliant EVMS to adequately support its EVM (management) methodology. To get the information they need from the EVMS, DCMA technicians | statisticians | analysts will perform several tests with the data sample; these include measurements for the materiality and the systemic nature of the issue. Tests are performed against the pre-determined thresholds to screen the data; potential
issues are identified if the data exceeds these thresholds. A digital dashboard will tell the analyst sitting at their desk the status of the contractor’s EVMS. Any measure that falls outside historic norms or deviates from a predetermined threshold is flagged. Within minutes a supervising official will know what issues to focus on and whether additional engagement with the contractor is required.

The future direction for EVMS compliance efforts will be based on these results. DCMA’s level of engagement with the contractors will be carried out through a three-stage process, beginning with a less formal approach. DCMA believes that this will engender a more collaborative approach and get results faster. The stages are:

**Stage 1: Limited Engagement.** When the tests do not exceed thresholds, the results will be shared with the contractor, and DCMA will minimize additional surveillance activities.

**Stage 2: Investigation.** When any test exceeds the thresholds, DCMA will discuss the issue with the contractor, who will investigate whether a breach has occurred. Based on the investigation, the DCMA technician | statistician | analyst may issue advice to clarify/interpret the relevant provisions of the attribute interpretation for the contractor to follow. A summary of the issue raised and the outcome of discussions, including the view taken by the contractor of the issue, will be formally documented.

**Stage 3: Corrective Action.** If the issue continues, the DCMA technician | statistician | analyst will require a more formal investigation by the contractor to include a fish-bone like root cause analysis and corrective action plan. Throughout this process the technician | statistician | analyst will ensure that concerns are promptly considered by the contractor and that any necessary action is taken as swiftly as possible. This is an efficient way to deal with current management practices which may not be consistent with the interpretation, and will significantly reduce the cost of EVMS oversight.

**HOW DOES DCMA’S NEW APPROACH WORK?**

Figure 1 shows the hierarchy utilized in DCMA’s new compliance validation process. DCMA will test for compliance utilizing defined metrics that clearly define expectations for performance. The metrics tie specifically to test steps, which are unique for each EIA-748 EVMS Guideline. The metric numerators will only capture deviations from ideal – so the lower the metric’s value, the better the performance of the EVMS. By utilizing this approach, DCMA will be able to set up thresholds for acceptable performance – or ‘allowable’ deviations. This approach focuses on more significant (or material) deviations – and recognizes that ‘perfection’ may not always be the most affordable solution for the DoD.

### TESTING AND METRICS FOR EVMS GUIDELINE 301

<table>
<thead>
<tr>
<th>TEST STEPS</th>
<th>TEST METRIC NUMERATOR(X)</th>
<th>TEST METRIC DENOMINATOR(Y)</th>
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</thead>
<tbody>
<tr>
<td>ARE RETROACTIVE CHANGES BEING MADE?</td>
<td>X = $ VALUE OF CURRENT BCWS WHERE CURRENT BCWS &lt; 0 (AT LEVEL WHERE BUDGETS ARE ESTABLISHED)</td>
<td>Y = TOTAL CURRENT BCWS</td>
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<tr>
<td></td>
<td>X = $ VALUE OF CURRENT BCWP WHERE CURRENT BCWP &lt; 0 (AT LEVEL WHERE PERFORMANCE IS ASSESSED)</td>
<td>Y = TOTAL CURRENT BCWP</td>
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<td></td>
<td>X = $ VALUE OF CURRENT ACWP WHERE CURRENT ACWP &lt; 0 (AT LEVEL WHERE ACTUALS ARE INCURRED)</td>
<td>Y = TOTAL CURRENT ACWP</td>
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<td></td>
<td>X = $ VALUE OF CUM BCWS WHERE CUM BCWS &lt; 0 (AT LEVEL WHERE BUDGETS ARE ESTABLISHED)</td>
<td>Y = TOTAL CUM BCWS</td>
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<tr>
<td></td>
<td>X = $ VALUE OF CUM BCWP WHERE CUM BCWP &lt; 0 (AT LEVEL WHERE PERFORMANCE IS ASSESSED)</td>
<td>Y = TOTAL CUM BCWP</td>
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<tr>
<td></td>
<td>X = $ VALUE OF CUM ACWP WHERE CUM ACWP &lt; 0 (AT LEVEL WHERE ACTUALS ARE INCURRED)</td>
<td>Y = TOTAL CUM ACWP</td>
</tr>
<tr>
<td>ARE THERE CHANGES TO OPEN WORK PACKAGES?</td>
<td>X = $ VALUE OF BAC FOR CA’S WHERE CUM ACWP &gt; 0 AND CURRENT MONTH BAC DOES NOT EQUAL PREVIOUS MONTH BAC EXCLUDING OVERHEAD AND ALLOCATION ROLL-UP ACCOUNTS</td>
<td>Y = $ VALUE OF TOTAL BAC EXCLUDING OVERHEAD AND ALLOCATION ROLL-UP ACCOUNTS</td>
</tr>
<tr>
<td>DO CPR FORMATS 1 AND 3 REFLECT RETROACTIVE CHANGES AND DOES FORMAT 5 HAVE RELATED EXPLANATIONS?</td>
<td>X = $ OF RETROACTIVE CHANGES NOT EXPLAINED IN FORMAT 5</td>
<td>Y = TOTAL $ VALUE OF RETROACTIVE CHANGES IN FORMAT 3</td>
</tr>
</tbody>
</table>

1. EVMS Guideline Attribute Testing and Metrics is subject to change.
HOW IS A DATA-DRIVEN TEST CARRIED OUT?
The contractor provides a sample of raw data to DCMA for specific artifacts on a periodic basis. DCMA will calculate the individual EVMS metrics, and will make metric results available to the contractor. If there are any anomalies, DCMA will react only to those metric values that are outside of the defined threshold values.

EIA-748 EVMS Guideline tests are done on a sample data set taken directly from the contractor’s EVMS. Figure 2 lists the results of the diagnostic tests performed on a sample of a contractor’s EVMS data for EIA-748 EVMS Guideline 6. This sample test employs a red color scheme to indicate the exact guidelines and attributes needing immediate attention. The ‘red’ data, or data which is outside of accepted threshold level, will trigger additional testing to track and subsequently determine whether the EVMS has a deficiency. Importantly, data-driven testing can reveal vital information about the cause of a deficiency and its symptoms (diagnosis) and is invaluable in monitoring the effects of any corrective actions. The expectation is that by documenting, classifying, and sequencing the 73 attributes of a compliant EVMS, the DCMA technician | statistician | analyst will be able to find the underlying causes of core management process issues. Like genome sequencing where scientists and doctors map out a person’s entire genetic code, or genome, by sequencing all 21,000 (or so) genes is an important step towards understanding it. Over time, analysis of these results using new technologies is expected to uncover newer and better diagnostic tests and remedies. Prescribed rules, weighting criteria, mathematical equations, and probability formulas will be used to make predictions that we can learn from in order to identify and change inefficient behaviors. Anomalies from past trends can be identified to help spot new trends that are emerging that could result in non-compliance if left unattended.

More significantly, however, these metrics will be made available for industry’s internal use and corporate governance, so there will not be any surprises or mystery outcomes of a DCMA EVMS compliance event. Preparation for these events by the contractor will be minimal; instead, it will encourage each contractor to focus their internal control efforts in a manner that will give them a better return on their scarce resources.

RESULTS FROM THE LMA PILOT
In the past year LMA’s efforts to identify and correct emerging EVMS deficiencies following the DCMA data-driven approach have yielded significant results. Not only does the company retain DoD DFARS 252.234-7002 EVMS compliance credentials, it is working to fundamentally change the way it thinks about EVM and how it manages work in the future.

2. The number of EVMS Guideline Attributes is subject to change.
The JSF Program Office’s (JPO) and LMA’s commitment to using reliable EVMS data for day-to-day decision making on the largest single global defense program has solidified the long-term stability of the program and increased the purchasing power of the Department. Having the Program Office actively participate and contribute to the pilot has been instrumental to its success. LMA estimates that the new data driven approach can save costs each year by making EVMS surveillance activities proportionate to the risk identified through testing. For this reason, the implementation of the DCMA data-driven approach clearly advances the Department’s Better Buying Program (BBP 2.0) initiatives to incentivize productivity and innovation while eliminating unproductive processes and bureaucracy.

Furthermore, LMA has recognized, through a combination of rethinking its floor operations and adopting a data-driven approach, the cost for its aircraft assembly scheduling process (1 of 9 major EVMS processes) has been significantly reduced. The JPO customer has also realized an overall reduction in LMA charges against contract reporting requirements.

**MANAGEMENT IS A PRACTICE LIKE MEDICINE AND LAW; RESULTS ARE NOT IN THEORY BUT IN WHAT HAPPENS.**

**- PETER F. DRUCKER**

**NEXT STEPS**

Due to the success of the DCMA data-driven approach at LMA, efforts are currently underway to replicate this approach at several other contractor locations. One natural outgrowth is an effort to replicate the approach at LMA F-35 Joint Strike Fighter critical subcontractor locations. Other potential efforts include the Navy Shipyards, where a good test case can be made to try to resolve longstanding EVMS issues. Through ongoing collaborative efforts with the Navy and the various Agencies that form the DoD Intelligence Community, DCMA is nearing its ultimate goal to take the current complexities of EVMS compliance from Tax Law to Turbo Tax© for a smarter and more sustainable future.

**ABOUT THE AUTHORS**

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Readers can ask questions or provide comments to this article by emailing david.kester@dcma.mil.
SM&A is a premier program lifecycle consulting firm, with over 30 years of experience. We help companies successfully pursue, win and perform complex programs:

- Earned value management (EVM), planning, scheduling, and cost management
- Program management office (PMO) support and systems engineering
ABSTRACT

The management of project baseline schedules has evolved significantly since the development of the Gantt chart in the early 20th century (Gantt, 1919). In the next few decennia, the Program Evaluation and Review Technique/Critical Path Method and the Precedence Diagram Method (Fondahl, 1987), and more recently, the Critical Chain Project Management technique (Goldratt, 2002) saw the light.

The evolution of microcomputers and their software simplified the usage of these techniques in project management. Furthermore, the concept of “earned value” emerged early in the 20th century and was largely based on the principle of “earned time”, which was popularized by Frank and Lilian Gilbreth (Solanki, 2009). In the 1960s, the Department of Defense of the US government used it to create the PERT/COST technique (Hamilton, 1964), which later evolved into the Cost/Schedule Control System Criteria or C/SCSC (Christensen, 1990). In the late 1970s, the latter technique culminated in the Earned Value Management (EVM) method (Fleming & Koppelman, 2010). EVM rose to prominence in 1991 when the US Navy Avenger II program was canceled because of performance issues in its cost/schedule objectives that had been detected by EVM (Stevenson, 2001).

EVM, as a project management methodology, achieved enormous success on cost management, but almost none in schedule management. This was due to the idiosyncrasies of its schedule indicators, as they fail in the final portion of the schedule for late projects (see Figure 3), which generated disbelief in EVM’s applicability for schedule management. Therefore, EVM has been used almost exclusively for cost management for many years. However, the Earned Schedule (ES) technique, created in 2003 by Walt Lipke (Lipke, Schedule is Different, 2003), changed the way of computing schedule indicators in order to eliminate their shortcomings. In academic studies by Vanhoucke (2010; 2011; 2014), it has been shown that the ES method outperforms the traditional methods of EVM. However, although the new indicators indeed perform better, the use of cost data in their calculation causes the obtained information to not always be reliable. Therefore, prof. dr. Homayoun Khamooshi and Hamed Golafshani recently published a paper describing a new approach for project schedule performance management (Khamooshi & Golafshani, 2014). The new technique, Earned Duration Management (EDM), eliminates the use of cost data in the schedule context.

THE EVM S-CURVE AND ITS USE IN ES

Before proceeding to the conceptualization and application of the new EDM approach, a review of the foundations supporting its introduction is provided. More concretely, the EVM S-curve and its use in ES are described.

S-CURVE CONCEPT

Consider a project A that aims at building up a wall of 2000 bricks, planned to last 10 days, and performed by a bricklayer who works on average four hours a day. This project is represented by just one activity that extends from day 1 to day 10. Suppose that the bricklayer costs $20 per hour, which results in a project budget of $800. Under these conditions, the bricklayer must lay 200 bricks per day and has to be paid $80 daily. Table 1 summarizes the planned evolution of project A’s cost during the 10-day lifetime.

<table>
<thead>
<tr>
<th>Time (Days)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned Value</td>
<td>$80</td>
<td>$160</td>
<td>$240</td>
<td>$320</td>
<td>$400</td>
<td>$480</td>
<td>$560</td>
<td>$640</td>
<td>$720</td>
<td>$800</td>
</tr>
</tbody>
</table>

Table 1: Evolution of planned costs for project A
Furthermore, the chart in Figure 1 visualizes the table values.

![Figure 1: Evolution of planned costs for project A](image)

The displayed curve, which is a straight line in our simple example, is known in project management jargon as the “S-curve” (Dinsmore & Silveira Neto, 2004). It is a graph that traditionally displays the relationship between two variables, namely time and cost (or effort in some cases). For larger projects, the same construction process would yield a curve with a small inclination at the beginning (i.e. allocation of personnel and materials are still rather limited at the start of the project), an increasing slope during the middle periods where there is greater activity and generally a higher rate of cost growth, and again a smaller rise in its final phase reflecting the decreasing rate of effort and spending (i.e. only a few closing activities remain at the end of the project). In our example, the agreement with the bricklayer was that he would be paid based on the number of hours that he dedicated to the project. Assume that the project has started and is now at its fifth day. The records of the hypothetical progress monitoring are shown in Table 2.

<table>
<thead>
<tr>
<th>Time (Days)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>9</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Planned Value</td>
<td>$80</td>
<td>$160</td>
<td>$240</td>
<td>$320</td>
<td>$400</td>
<td>$480</td>
<td>$560</td>
<td>$640</td>
<td>$720</td>
<td>$800</td>
</tr>
<tr>
<td>Actual Cost</td>
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<td>$184</td>
<td>$296</td>
<td>$392</td>
<td>$536</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earned Value</td>
<td>$80</td>
<td>$120</td>
<td>$160</td>
<td>$224</td>
<td>$256</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Actual progress of project A at day 5

It can be seen that the actual cost (AC) was equal to the planned value (PV) only at the end of the first day of project execution. Over the next four days, there was an occurrence of bad weather, delays in delivery, and mistakes in the number of delivered bricks. This forced the bricklayer to dedicate an unforeseen amount of hours on actions different from the plan, every day of the project. For this reason, the AC was always higher than the PV. However, the monetary value of the progress made (work completed) at a certain point in time, known as the Earned Value (EV), remained below the PV.

The measurement of work performed (i.e. EV) at a certain day was based on the number of bricks laid that day multiplied by the cost per brick of $0.40 ($80/200). The $120 value on the second day reflects that, by the end of this day, project execution achieved only half of what was planned for that day. On the third day, the execution kept running late in relation to what was planned, and instead of having fulfilled the PV of $240, the EV was just $160, which had been planned for the end of the second day. At the end of the fifth day, the EV ($256) was only slightly higher than the PV for day 3.
The graph of Figure 2 corresponds to the values of Table 2.

The vertical line on the fifth day indicates the time that the project manager delivered his status report. The green line represents the PV, which is the same as shown in Figure 1. The red line corresponds to the AC accumulated at the end of each period (i.e. each day). The blue line is the result of project progress measurement, which is expressed in terms of the value actually earned (i.e. EV) at a certain point in time. One may notice that at the end of day 5, the project cost exceeded the value that was planned at this point, whereas the progress measured was lower than planned. Through this simple example, we have introduced the basis of what is known as EVM in project management.

Furthermore, the fifth period in the example, at which the current measurement was made, is referred to as the Actual Time (AT) and represents the elapsed time from the beginning of the project. Summarizing the other key metrics, the cumulative budgeted value at the end of a period is identified as the PV of that period. In the case above, the PV is $400 by the end of the fifth period. The EV, corresponding to what was actually accomplished by the end of day 5, is $256. The AC accrued by the end of the fifth period is $536. Furthermore, the total amount budgeted for project A, $800, is called Budget at Completion (BAC).

The EVM key metrics can also be used to obtain measures of project performance. For example, the difference between EV and AC at a specific point of measurement is known as the Cost Variance (CV). The difference between EV and PV receives the name of Schedule Variance (SV). However, while the SV indicates duration, its measurement unit is expressed in monetary terms. This has been the subject of many EVM criticisms in the project management community. Furthermore, the ratio of EV to AC is the Cost Performance Index (CPI) and the quotient of EV to PV is the Schedule Performance Index (SPI). Summarizing, the EVM performance measures are:

- Cost Variance: \[ CV = EV - AC \]
- Schedule Variance: \[ SV = EV - PV \]
- Cost Performance Index: \[ CPI = EV/AC \]
- Schedule Performance Index: \[ SPI = EV/PV \]

It is well known that the EVM schedule indicators are flawed. This statement is easily demonstrated by the analysis of the SPI behavior at the end of a late project. At that point, the EV reaches its maximum value of BAC, and consequently, the SPI becomes 1, indicating that the project ended right on time. Figure 3 graphically illustrates this aberration in EVM behavior. Consequently, the EVM schedule indicators always inform the project manager that the project ended at its planned time, even if the project is completed with a delay. Lipke (2009) stated that the anomalous behavior of the EVM schedule performance indicators starts when the project reaches 65% of its completion. These results have also been obtained in simulation studies performed by Vandevoorde and Vanhoucke (2006), Vanhoucke and Vandevoorde (2007) and Vanhoucke (2010).
EARNED SCHEDULE CONCEPT

The anomalous behavior of the EVM schedule indicators provided the motivation for the development of the Earned Schedule (ES) concept by Walt Lipke (2003; 2009). The basic idea is that project schedule management techniques should be able to evaluate schedule performance in units of time (Figure 5), and not in monetary terms as in the EVM methodology (Figure 4).

Lipke’s ES technique provides a solution to this problem and resolves the existing inconsistencies for SPI and SV. The ES value can be graphically determined by finding the point where the horizontal projection of the EV at a given time meets the PV curve. The projection of this point on the time axis (horizontal coordinate) then defines the ES. This procedure is visualized in Figure 6.
In order to explain the process of calculating the numerical value of ES, we zoom in on the area within the blue circle in Figure 6 and thus produce Figure 7. Note that this zoom is conceptual and should therefore not be regarded as an exact representation of the situation in Figure 6. As the point found on the PV curve can reflect any time instant, one must select the integer time value immediately to the left of the projection of the point on the horizontal axis and then calculate the fraction of time to be added to the integer in order to obtain the ES value.

The algebraic calculation of ES is based on the similarity of triangles from basic geometry (see upper right corner of Figure 7). We now refer to Figure 7. First, we define the range \([t, t+1]\) as the consecutive integer times between which the projection of the PV curve point on the horizontal axis is situated. The range of PVs \((PV_t, PV_{t+1})\) that contains the projection of the EV on the vertical cost axis forms the vertical side \((PV_{t+1} - PV_t)\) of the larger triangle and is called “B”. The difference between the EV and the PV at time t defines the vertical side of the smaller triangle and is referred to as “b”. The horizontal side of the bigger triangle is equal to 1 UC (Unit of Calendar) because \((t+1) - t = 1(UC)\) and is called “A”. The difference in time between the value of ES and the time t is the horizontal side of the smaller triangle and is indicated by “a”. Since the distance “d” (in time units) between the point actually found on the PV curve and the point on the larger triangle hypotenuse is much smaller than the value of ES to be calculated \((d \ll ES)\) it can be stated that:

\[
\frac{a}{A} \frac{b}{B} = \frac{ES - t}{(t+1) - t} = \frac{EV - PV_t}{PV_{t+1} - PV_t}
\]

Here, \(t\) is the largest integer time period that is smaller than ES. The \(t\) and \(t+1\) subscripts for PV indicate that it concerns the PV values at those particular time periods. The factor \(x 1(UC)\) accomplishes the conversion of the dimensionless fraction to time units.

Figure 8 shows the application of the ES calculation for project A at the fifth day.
From the above equation, the formula for calculating ES can be derived:

$$ES = t + \frac{EV - PV_t}{PV_{t+1} - PV_t} \times 1(UC)$$

Here, $t$ is the largest integer time period that is smaller than ES. The $t$ and $t+1$ subscripts for PV indicate that it concerns the PV values at those particular time periods. The factor $\times 1(UC)$ accomplishes the conversion of the dimensionless fraction to time units.

Figure 8 shows the application of the ES calculation for project A at the fifth day.

From the graph in Figure 8, one can observe that after five elapsed days from the start of the project, the ES is just a little over three days. In other words, the project is nearly two days late. On the other hand, EVM informs us that the project, on its fifth day, is late by $144$ (i.e. the difference between EV and PV at day 5 according to Table 2). Logically, the expression in time units provides a clearer view on the occurred delay than that in monetary terms. The ES concept also eliminates the anomalous behavior of the EVM schedule indicators, as the horizontal projection of EV onto the PV curve can only equal BAC at the end of the project. Furthermore, the Schedule Variance is expressed in units of time (for example, days). Studies by Vandevoorde and Vanhoucke (2006) and Vanhoucke and Vandevoorde (2007) showed that the performance measures of Schedule Variance and Schedule Performance Index based on ES, which are denoted by $SV_{\text{ES}}$ and $SPI_{\text{ES}}$, are the best indicators for project schedule assessment when using EVM data. Moreover, Batselier and Vanhoucke (2015b) came to similar conclusions based on their real-life project database (Batselier & Vanhoucke, 2015a). Note that this empirical database can be consulted freely at www.or-as.be/research/database.

**EARNED SCHEDULE DIFFICULTIES**

One of the criticisms on ES is that it still utilizes cost values (PV, EV, BAC) as proxies for time values. This criticism might have created difficulties on understanding the concept and has hindered the dissemination of ES use in many projects. Nevertheless, the criticism is justified, as the ES outcomes indeed depend on the cost values from project planning. This means that, after all, the ES-based schedule performance indicators can still exhibit a significant dependence on these monetary values. Furthermore, projects with planned outages (e.g. vacation, planned waiting time, concrete curing time) may produce ES values and indicators that are clearly out of context. The website www.earnedschedule.com offers an additional solution in the form of an Excel spreadsheet for these specific cases.

We now provide a demonstration of the problem that can arise from the use of ES on projects that are not suitable for analysis by this technique. Figure 9 shows the schedule for a notional project with four activities. The first two activities were executed according to plan. The third activity, which is on the critical path, was not yet initiated at the status date (i.e. March 13, 2015, represented by the vertical dashed red line).
Table 3 and the associated graph of Figure 10 were generated based on the Gantt chart of Figure 9. The table shows the PV and EV for each activity and for the entire project. The PV and EV curves are displayed in Figure 10. The figure also exhibits the values for ES (approximated) and SPI\(_{t}\) (calculated).

Here, an important point of concern is that activities #3 and #4, which both lie on the critical path, have not even started at the status date, whereas activity #3 should in fact be nearly completed. Yet, according to the SPI\(_{t}\), schedule performance is around 97%. Considering the significant lengths of these two critical activities and the current progress of activity #3, this level of performance does not accurately reflect reality.

**EARNED DURATION CONCEPT**

The Earned Duration (ED) concept (Khamooshi & Golafshani, 2014) was created to address the shortcomings of ES due to the usage of cost-based data as proxies for assessing the schedule performance of projects. Its foundation lies in the exclusive usage of time-based data for the generation of physical progress indicators. Thus, schedule performance indicators become free from any dependency on planned cost values, and therefore, are no longer influenced by them. For the presentation of the EDM methodology, it is important to come to an initial understanding of the concepts of activity duration, project duration and total duration under the new paradigm. These concepts were used to generate the Actual and Earned numbers shown in Table 4 for a notional project that contains three activities.
From close examination of Table 4, one can understand the duration “accounting” process for the planned and actual progress of the activities at each working day. The planned numbers result from assigning one time unit to each day of each activity and adding up all those numbers for a certain working day (column) to reach the Total Planned Duration (TPD) numbers (daily and cumulative) at the bottom. By definition, each planned day of an activity has a weight of one, regardless of the effort, resources or costs involved in its execution. Also, the Actual Duration of an activity \( i \) (AD\(_i\)) is the number of working days it actually took to complete it. To calculate the value of the daily ED for each activity effectively carried out in a working day, one must divide the Planned Duration of the activity (PDi) by its AD\(_i\). For example, activity 1 had a PD\(_1\) of 4 working days and was completed in 8 days (AD\(_1\) = 8). This means that the activity effectively contributes to the project’s ED with \( 4/8 = 0.5 \) days for each day of its execution. For activity 2, which was planned to last 4 days (PD\(_2\) = 4) and was conducted in 6 days (AD\(_2\) = 6), each day of this activity’s execution contributes to the project’s total daily ED with \( 4/6 = 0.67 \) working days. For activity 3, the said contribution is \( 1.60 \) days per day of its execution. The sum of the daily EDs of a certain activity \( i \) defines the Earned Duration of that activity (ED\(_i\)). Note that, in the above discussion, we considered the PD, AD, and ED, at project completion (maximum values). However, these metrics can be calculated at any time instance (working day) during the project for schedule performance evaluation purposes (see later). For example, the sum of the daily EDs of a certain activity \( i \), up to a specific point in time, defines the ED\(_i\) of that activity at that time, which is not necessarily the maximum value.

Furthermore, it is worth noticing that, similar to EVM’s BAC, EDM exhibits a Total Duration at Completion (TDC). While the BAC is the sum of all planned activity costs (i.e. PV sum), the TDC is the sum of all planned activity durations (i.e. PD sum). Achieving the TDC would indicate the completion of the project. The two EDM project progress graphs are now presented in Figure 11.
From Figure 11, the similarity between the ED and ES graphs becomes obvious. "Total Duration" (units of time) replaces "$" (costs) on the vertical axis, while Total Earned Duration (TED) substitutes EV and Total Planned Duration (TPD) does the same for PV. The formulas for the new metrics are provided in Table 5. The table also explicitly shows the correspondence between EDM and EVM/ES metrics.

<table>
<thead>
<tr>
<th>EDM Acronym</th>
<th>Description</th>
<th>Equation</th>
<th>EVM Acronym</th>
<th>Description</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED</td>
<td>Earned Duration</td>
<td>See above</td>
<td>ES</td>
<td>Earned Schedule</td>
<td>See above</td>
</tr>
<tr>
<td>AD</td>
<td>Actual Duration</td>
<td>N.A.</td>
<td>AT</td>
<td>Actual Time</td>
<td>N.A.</td>
</tr>
<tr>
<td>TED</td>
<td>Total Earned Duration</td>
<td>$\sum_{i=1}^{n} BD_i$</td>
<td>EV</td>
<td>Earned Value</td>
<td>$\sum_{i=1}^{n} EV_i$</td>
</tr>
<tr>
<td>TPD</td>
<td>Total Planned Duration</td>
<td>$\sum_{i=1}^{n} PD_i$</td>
<td>PV</td>
<td>Planned Value</td>
<td>$\sum_{i=1}^{n} PV_i$</td>
</tr>
<tr>
<td>TAD</td>
<td>Total Actual Duration</td>
<td>$\sum_{i=1}^{n} AD_i$</td>
<td>AC</td>
<td>Actual Cost</td>
<td>$\sum_{i=1}^{n} AC_i$</td>
</tr>
<tr>
<td>DPI</td>
<td>Duration Performance Index</td>
<td>$\frac{ED_i}{AD}$</td>
<td>SPI</td>
<td>Schedule Performance Index (ES)</td>
<td>$\frac{ES_i}{AD}$</td>
</tr>
<tr>
<td>EDI</td>
<td>Earned Duration Index</td>
<td>$\frac{TED}{TPD}$</td>
<td>SPI</td>
<td>Schedule Performance Index</td>
<td>$\frac{EV}{PV}$</td>
</tr>
<tr>
<td>TDV</td>
<td>Total Duration Variance</td>
<td>$TED - TPD$</td>
<td>SV</td>
<td>Schedule Variance</td>
<td>$EV - PV$</td>
</tr>
</tbody>
</table>

Table 5: Summary of EDM and EVM/ES metrics

The i subscript in the equation columns of Table 5 are meant to represent the numbering of project activities (with a maximum number of n). Also note that the Actual Duration (AD) represents the same metric as the AT used for ES calculations (but it is different from ADi, the actual duration of an activity i). However, the former denomination seems to be more appropriate in the EDM context. Because of the mentioned similarity between the ED and ES concepts, the ES calculation principles can also be applied for EDM, that is, with the necessary adjustments. We refer to Figure 12.

According to Figure 12, the equation for ED is:

$$ED = t + \frac{TED - TPD_t}{TPD_{t+1} - TPD_t} \times 1(UC)$$

Here, t has the same meaning as in the ES equation, and all other metrics are described above.

The ED schedule performance measures are also exhibited in Table 5, together with those based on EVM/ES. Again, it is easy to see the similarity between the equations for both sets of indicators.
ES AND ED ANALYSIS ON A NOTIONAL PROJECT

The Gantt chart of Figure 13 presents the data of a notional project executed in Microsoft Project. This project was developed with the intention of exacerbating some of the potential differences in results when applying EDM and EVM/ES to the same project schedule. The schedule covers the entire interval from project start to finish. The most important feature in this diagram is that activity #7 had its start delayed for 23 days and was only completed two days before the status date (on November 7, 2014). All other activities were performed perfectly according to plan.

![Figure 13: Gantt chart of a notional project](image)

The following analysis assumes that the costs are linearly distributed over time for each activity in both planning and execution phase.

Based on the Gantt chart of Figure 13 and the cost distribution assumptions, the values for the relevant EVM/ES and EDM metrics and indicators are calculated. The results are presented in Table 6 and visualized in Figure 14.

<table>
<thead>
<tr>
<th>Time (Days)</th>
<th>PV ($)</th>
<th>AC ($)</th>
<th>EV ($)</th>
<th>SPI</th>
<th>ES (days)</th>
<th>SPI (t)</th>
<th>TPD (days)</th>
<th>TED (days)</th>
<th>ED (days)</th>
<th>DPI</th>
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Table 6: EVM/ES and EDM metrics for a notional project
Figure 14 also provides a basis for comparison of the performance indexes SPI (from EVM), SPI(t) (from ES), and DPI (from EDM) along the 50 days of project execution. The red circles in this graph mark six points of interest (PoI) for the analysis. Furthermore, we will restrict the analysis to the comparison of ES and ED performance indexes, since EVM’s SPI exhibits almost no change over the entire project and the performance of the indicator has been shown to be inferior to that of SPI(t), in multiple studies (Batselier & Vanhoucke, 2015b; Vandevoorde & Vanhoucke, 2006; Vanhoucke & Vandevoorde, 2007).

The first PoI (1) occurs on day 10 of the project, where activity #7 started to be delayed. The cost rate for this activity is $10/day. At this point, the ES performance index SPI(t) initiates a downward slope that lasts for about three days and reaches the minimum value of 0.98, which is not a substantial change. However, the ED performance index DPI readily identifies the problem and begins to fall with strong inclination and reaches 0.88 after three days. The project manager (PM) that receives the information from the SPI(t) may simply conclude that there is no indication of any problem with the project schedule. On the other hand, should the PM receive the DPI, he/she would probably decide that schedule problems are imminent. The DPI thus seems to respond quickly to problems in the schedule, even within a few days. Moreover, during the following days, the negative trend of DPI continues, signifying a progressive delay in the project execution. The PM will thus be urged to address the schedule problem. Interestingly, the SPI(t) practically gets back to 1 after day 13, leaving the PM ignorant of the schedule problem.

The second PoI (2) takes place on day 23, when the SPI(t) starts to record the delay of activity #7. That is, it took 13 days after the beginning of the delay for the SPI(t) to really start showing the schedule risk. One explanation for this lateness in reporting is related to the relatively low daily cost rate ($10/day) of activity #7 as compared to that of activity #4 ($1,000/day) and activity #3 ($100/day). As such, the contribution of activity #7 to the project SPI(t) is effectively masked. The authors’ experience as project managers shows that differences in daily cost rates across activities of magnitudes from 10 to 100 actually occur quite often in real-life. An inspection of a sample of seven projects from the empirical project database of Batselier and Vanhoucke (2015a) confirmed that a factor 10 is frequent and that a factor 100 occurs occasionally (activities with a cost rate of $0.00/day are obviously excluded). Back to Figure 14, the DPI continues to exhibit very low values (i.e. between 0.70 and 0.75) during a large portion of the project. It, therefore, keeps indicating poor schedule performance.

The third PoI (3) is related to the period from day 23 to day 25, in which the DPI reflects a schedule performance improvement due to the start of activity #5 as it was planned. At the same time, the SPI(t) records nothing. At day 23, activity #4, which has a high relative value ($1,000/day), stops influencing the SPI(t) calculation. Thereafter, the 13 days of delay of activity #7 (total of $130) begin to show up in the SPI(t) calculation, which results in a downward trend of the index value. Nevertheless, activity #5’s execution according to plan ($50/day) during the same period causes very little change to the SPI(t) curve. It should also be emphasized that after the day 23-25 period, the DPI returns to its downward trend, which reflects the continued delay of activity #7’s start.
The fourth PoI (4) is on day 34 when the delayed activity #7 eventually commences. Observe that on this day, the DPI interrupts its downward trend and begins recording the execution of this activity, while the SPI\(_{(t)}\) continues its downward trend until day 40. Once again, the DPI immediately registers that there is a project status change with respect to schedule, whereas the SPI\(_{(t)}\) postpones this information for the PM. The DPI directly begins registering schedule recovery because it is not affected by the costs of the activities. The fifth PoI (5) is situated on day 40, at which the SPI\(_{(t)}\) begins recording the inversion of the project schedule trend and starts displaying a recovery of the schedule performance. It should be noticed that it took 6 days from the eventual start of the delayed activity #7 for SPI\(_{(t)}\) to begin indicating the recovery of the project in terms of duration.

Finally, the last PoI (6), day 48, represents the point when all project activities get back on track and the project is on course for a timely finish. All activities are completed here, except for activity #6, which is progressing as planned. At this point, both SPI\(_{(t)}\) and DPI reach the value of 1, meaning that project execution is, at last, according to plan.

**CONCLUSIONS AND RECOMMENDATIONS**

In spite of all the attention and effort dedicated to the issue of managing a project schedule, up to the beginning of this century, the main schedule evaluation technique still consisted of comparing the status of each activity against its planned progress. PMs traditionally resorted to the dissection of the project’s Work Breakdown Structure (WBS), the Gantt chart timetable, and the network diagram. Then, upon finding discrepancies, they performed lengthy discussions on the problem and on how it could best be reported to upper management. This process was commonly tedious and very time- and resource-consuming, and yet, it frequently lacked the ability to convey the project schedule status message in a way that executives could clearly and swiftly understand the problem and approve the solution proposed. The same kind of problem was faced in the area of project cost management, but there, much success was achieved with the development and practice of EVM.

The ES technique, based on the EVM methodology, has been deemed the best alternative to simplify the management of project schedule. However, as demonstrated in this paper, the fact that it uses cost data as proxies for time values makes it the subject of possible improvements. By means of notional examples, we have demonstrated the strengths of the EDM technique of Khamooshi and Golafshani (2014) as an alternative to ES. These are: the high responsiveness to changes in activity execution; the simplicity of data collection (most data are promptly available from EVM data); the independency from activity costs; the similarity to known ES calculations; and the natural understandability of the obtained results.

It is the authors’ belief that EDM is bound to replicate the EVM success in project cost management for the project schedule environment. However, the authors also understand the difficulties involved with the absorption and comprehension of the new concepts introduced by EDM. One of the authors had extensive dialogues on the subject with professionals in the field and perceived that the new concepts, especially total duration, are rather difficult to assimilate.

There is a definite need for demonstrating the power of EDM; by extensive research and experimentation, as well as through the development of an educational methodology, presentations, tutorials and software tools to assist in the acceptance and dissemination of the new technique.

EDM has yet to be scrutinized by extensive research to validate its seemingly promising potential. Some academic research on the subject is already being performed (Batselier & Vanhoucke, 2015c). With the current article, the authors also hope to foster PMs that like to explore new techniques to be the first to test EDM in practice, and thus, contribute to the knowledge advancement in project schedule management.
References


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**Dues:**  
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**Payment:**  
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Project duration forecasting has been enhanced with the introduction and application of the techniques derived from Earned Schedule (ES). The computed forecast results from ES have been shown to be better than any other Earned Value Management based method using both real and simulated performance data. Even so, research has shown that as the topology of the network schedule becomes more parallel, the accuracy of the ES forecast worsens. Recently, forecast accuracy improvement has been achieved for highly parallel type schedules with the method of Earned Schedule-Longest Path. This paper proposes further advancement to the longest path approach through anomaly rejection and the application of statistical methods.

Introduction
To assist the reader’s understanding beyond his/her knowledge of Earned Value Management (EVM), three areas will necessarily be discussed: Earned Schedule (ES), Longest Path (LP), and Statistical Forecasting. Some may not need the review. However, for those readers not well-versed in the publications on these topics, the introduction, summarizing several papers, should be helpful [Lipke, 2003; Lipke, 2010; Lipke, 2012-2].

Earned Schedule. The concept is illustrated in figure 1. ES is the measure of time indicating the completed portion of Planned Duration from the EVM performance measurement baseline (PMB). The measure facilitates the ability to assess the schedule performance efficiency; i.e., the time-based schedule performance index, SPI(t). The index is equal to ES divided by AT, the actual time duration from the project start to the status point. The derived schedule efficiency, SPI(t), in turn, enables the forecasting of project duration through the simple formula [Henderson, 2004]:

\[ \text{IEAC}(t) = \frac{\text{PD}}{\text{SPI}(t)} \]

where
- IEAC(t) = Independent Estimate at Completion (time units)
- PD = Planned Duration

![Figure 1. Earned Schedule Concept](image)
The forecasting capability of the formula has been shown to be reasonably good. It has been verified by simulation [Vandevoorde and Vanhoucke, 2007] and application to real project data [Henderson, 2003]. As well, the capability has been verified elsewhere, thereby establishing a compelling argument for applying ES forecasting when EVM is employed for project control [Lipke, 2009; Lipke, 2014]. However, recent research has demonstrated that the topology of the schedule has impact on the “goodness” of the forecast. The ES forecasts are more accurate for schedules which are more serial and less so when parallel [Vanhoucke, 2009].

**Longest Path.** To improve forecasting for projects having very parallel network schedule topologies, the concept of Longest Path was created. The fundamental idea of LP is that ES forecasting is most accurate from a schedule topology that is completely serial, as shown by Vanhoucke’s research cited previously.

Thus, the method requires identifying all of the serial paths in the schedule network leading to project completion. For each path a PMB is created. The longest duration forecast is then determined by applying ES forecasting to each serial path. For the current status point, the longest duration computed from among the paths remaining to be executed is proposed to be the best forecast, and is labeled “LP.”

The method has been shown, using notional data, to provide schedule forecasting improvement. Certainly, more research is needed to validate the findings. Nevertheless, at present, the idea appears to provide a solution, albeit complex, to improving ES forecasting for highly parallel project schedules.

**Statistical Forecasting.** The use of statistical methods for inferring outcomes is a longstanding proven mathematical approach. The statistical forecasting method for duration is relatively simple in concept and, from the statistical hypothesis testing of real data, has been demonstrated to perform rather well [Lipke et al, 2009].

The statistical method of duration forecasting is derived from the ES equation, $IEAC(t) = PD / SPI(t)$, where using the cumulative value of SPI(t) yields the nominal forecast. The associated high and low Confidence Limits are computed from the variation of the periodic values of ln SPI(t):

$$\text{CL} = \ln \text{SPI(t)}_C \pm Z \times \sigma_m \times AFS$$

where

- $\text{CL} =$ Confidence Limit
- $\ln \text{SPI(t)}_C =$ logarithm of the cumulative value of SPI(t)
- $Z =$ the prescribed Confidence Level (usually 90 percent)$^3$
- $\sigma_m =$ $\sigma / \sqrt{n}$, the standard deviation of the sample means
- $\sigma =$ the standard deviation of the logarithm of the periodic values of SPI(t)$^4$
- $n =$ the number of periodic values
- $AFS =$ $\sqrt{(PD - ES) / (PD - ES/n)}$, the adjustment for finite population$^5$

The results obtained from the CL computations are natural logarithms of the cumulative index. In turn, the limit values are used to calculate the estimates of the Confidence Limits for the forecast duration. For example, the high forecast, $IEAC(t)_H$, is calculated using the low CL value, $CL(-)$, as follows:

$$IEAC(t)_H = PD / e^{CL(-)}$$

where

- $IEAC(t)_H =$ PD / $e^{CL(-)}$
- $CL(-) =$ $\ln \text{SPI(t)}_C - Z \times \sigma_m \times AFS$
- $e =$ the base number for natural logarithms

1. Hypothesis testing is a statistical method for determining the likelihood of the validity of a claim. More information is available from [Wagner, 1992]

2. Information about Confidence Limits may be found in [Crowe et al, 1960]. Confidence Limits are sometimes misunderstood to be thresholds for management action. The limits, instead, describe the region containing the “true” value of the parameter for the prescribed probability, i.e. Confidence Level.

3. $Z$ is a measure of deviation from the mean. Use of the $t$ statistic is recommended when the sample size is less than 30 [Crowe et al, 1960].

4. The logarithm of SPI(t)C is used as the mean value in the computation.

5. The finite population adjustment description may be found in the reference [Lipke, 2009]

6. The use of natural logarithms is attributed to studies of the distribution of the periodic values of CPI and SPI(t) [Lipke, 2002; Lipke, 2012-1].
NOTIONAL DATA / LP ANALYSIS
The notional data used for discussion is shown in table 1. For the example, the project, having 10 tasks, is planned to be completed in 10 periods. The total project and its six paths to completion are depicted with their respective PV and EV values, both periodic and cumulative. The performance path identifiers, such as 1-4-8-10, are the various sequences of the individual task numbers.

To further enhance understanding of table 1 a brief explanation of the symbol “XX” is needed. When used in the PV row, the XX indicates no work was planned for the period, i.e. “Down Time.” In the EV row, the interpretation is the execution was delayed for that period, “Stop Work.” For example, performance was not planned to begin for path 2-4-8-10 until period 3, as shown in the PVP row. For performance path 2-5-9, it is observed that although execution was planned to begin in period 3, it did not commence until period 4. This is shown with XX in the EVP row for periods 1 through 3.

Two paths, 2-5-9 and 6-9 indicate completion two periods past the planned duration of 10 periods. Thus, we know from inspection of the table that execution of the planned critical path (1-4-8-10) did not complete the project and that the longest path must have changed during project execution.

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</table>

Table 1. Path Performance

Table 2 contains the computed forecasts for all paths and the total project. For the various paths the longest duration forecast for each status period is identified in the chart by the lime color. Clearly, it is seen that the current LP was identical to the planned CP for only one performance period, period 2. Path 7-10 includes the current LP for periods 4 through 7, while from period 8 through project completion, period 12, longest duration forecasts occur in path 6-9.
Table 2. Longest Path Forecasts

<table>
<thead>
<tr>
<th>Performance Path</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>7</th>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4-8-10</td>
<td>13.50</td>
<td>9.23</td>
<td>7.82</td>
<td>6.00</td>
<td>11.00</td>
<td>9.96</td>
<td>9.76</td>
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<td>10.00</td>
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<tr>
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<td>11.33</td>
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<td>Total Project</td>
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<td>9.75</td>
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<td>10.03</td>
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<td>11.81</td>
<td>11.11</td>
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</tbody>
</table>

ES for Longest Path. The remaining LP observation, period 3, indicates the longest duration forecast is from path 2-4-8-10 (colored red) and not the lime color cell of path 3-8-10. The value in red is regarded as an anomaly because the representative value of ES for the LP of period 3 decreases from its value at period 2.

For the longest path, the representative ES must increase from one period to the next. This requirement may be understood from the subsequent discussion. However, it raises some fundamental questions. Having a representative value for ES, identified as ES(L), is somewhat confounding. Why is ES(L) different from the ES value used to compute the forecast? To begin the explanation, ES(L) is computed from the path forecast values as follows:

$$ES(L) = PD \times AT / IEAC(t)$$

In contrast, the forecast IEAC(t) is computed from two portions of the path. One is from the executable portion and the other is the number of periods prior to beginning execution. Thus, ES from path execution is different from ES(L); ES represents the executable portion of the path, whereas ES(L) represents the PD of the project.

We now understand that ES(L) is not the same as ES for a path, but why must it increase for successive periods? To respond, let’s first assume EV increases from one period to the next. Very simply, from the definition of ES, we can deduce that ES must increase with increasing EV. This analysis applies to both the total project and to the various network paths to project completion.

A more complex situation is EV increases in successive periods for the project, while a path has no accomplishment for the effort made. Referring to table 1, it is seen that this situation occurs for three paths at period 6: 1-4-8-10, 2-4-8-10, and 3-8-10. For this condition, the forecasts will likely increase for both the paths and the project. However, the ES(L) for the paths will decrease. Thus, these paths are excluded from the selection of LP. When EV increases in successive periods for the project, the LP is identified from paths having increasing EV. Because EV increases, ES and ES(L) must increase.

Now, assume for a path that a Stop Work occurs and EV does not increase from the previous period. For this condition ES remains at its value for the previous period. However, even though ES remains the same, the forecast must increase by one period. Because both the forecast and AT increase, ES(L) will increase, as well. This can be deduced by examining the ratio, AT/IEAC(t), from the ES(L) formula. The impact of Stop Work is adding one period to numerator and denominator of the ratio, (AT + 1)/(IEAC(t) + 1). Until the project completes, the value of IEAC(t) will be larger than AT. It then follows, the ratio for the Stop Work period will, likewise, be a larger value than its predecessor; therefore, ES(L) will increase.

From the preceding discussion the following has been established:

Due to the requirement for ES(L) to increase, the selection of LP for a period is conditional. LP is chosen as the longest forecast having a positive change in ES(L).

The discussion to this point covers the possibilities of project performance, with one exception. Disregarding Stop Work, it is possible, although highly improbable, for a project to have no EV for a performance period. For this situation, the LP is indeterminate and the period is excluded from forecasting.
Table 3. ES(L) Values

<table>
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<tr>
<th>Performance Path</th>
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**ES(L)-LP Forecasting.** From the following brief discussion, the reader should realize a clear understanding as to how LP was selected for period 3. Using the formula for ES(L), table 2 is transformed into table 3. The ES(L) values of table 3 provide the means to identify the positive change needed for LP selection. From the table, it is observed that the ES(L) value for period 3 of path 2-4-8-10 is less than the value for period 2 of path 1-4-8-10 (1.05 < 1.48), thus identifying the anomalous forecast. The next lowest value of ES(L) at period 3 is then chosen to satisfy the increasing requirement. The ES(L) value of 2.50 identifies path 3-8-10, thereby selecting 12.00 as the LP forecast for period 3, indicated by the lime color in table 2.

The result of applying the ES(L) condition, Lpc, is illustrated by figure 2. The plot of LP forecasts without the condition is yellow, while for Lpc the graph is orange. Both LP and Lpc provide improved forecasts in comparison to the total project; the two overlay for periods 4 through 12. Additionally, Lpc provides an improved forecast for period 3, highlighting the anomalous forecast of LP.

**ES(L)-LP STATISTICAL FORECASTING**
Initially it was thought that the application of statistics to ES longest path might not be possible. Creating the capability to compute Confidence Limits (CLs) seemed out of reach. At best, it was envisioned that applying statistics to LP would be overly burdensome and highly complex.

Nevertheless, with the promise that LP holds for improving forecasting for highly parallel schedule networks, the effort to develop the statistical application was believed warranted. Expecting the worst, it was a pleasant surprise to find the solution is amazingly simple, as the reader will discover.

Upon inspection of the requirements, it was determined that only one item is needed. From it everything else is derived. The lone requirement is the ability to compute periodic values for SPI(t). These values, in turn, are used to compute the standard deviation, the critical component of the CL calculations.

To obtain periodic SPI(t), all that is needed are periodic values of ES, regardless of their attribution. Thus, using ES values from the total project will yield its set of statistical forecasts. And, correspondingly, the ES(L) values provide its corresponding forecasts. Simple enough.
The results of the statistical forecasting using ES(L)-LP values from the notional data are shown in figure 3. The graphs associated with ES(L)-LP are annotated by appending their identifying label with "c." Also shown are the CL plots from the ES-LP values. Larger variation is observed due to the anomaly in period 3; the CLs for ES-LP forecasts are further from the nominal forecast. Also noted for both sets of CLs, the graphs are reasonably symmetrical about the nominal forecast. Although symmetry of CLs isn’t a requirement or even an expectation, it does provide a sense that the forecasting method is providing reliable management information.

Another observation from figure 3 to be noted is period 3 CL values are absent for the ES-LP graphs. This is due to the anomaly identified for period 3. The negative change in periodic ES, discussed previously, causes problems with the calculations involving logarithms; for real number results, the logarithm function excludes negative argument values. Thus, because of the negative change in ES(L) between periods 2 and 3 discussed earlier, we have the reason for the period 3 omission; it is not calculable.

The statistical forecast from ES for the total project (TP) is provided in figure 4. Figures 3 and 4 taken together facilitate comparison between the LP methods and the total project. As observed, all forecasts converge to the actual duration of 12 periods; this point is important and oftentimes is overlooked [Lipke, 2014]. It is noted that the difference between the high and low CL is slightly greater for the LP methods for the first few periods; this is believed reasonable because the size of the data sample for the TP is much greater.

Although the TP variation is smaller overall, the LP methods, especially ES(L)-LP, are considered to be an improvement. The symmetry of CLs around the nominal forecast and, more importantly, the forecast accuracy throughout the project duration indicate the ES(L)-LP forecasting method may justify the additional analysis effort.

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7. Confidence Level of 90 percent was used for the calculations.
Of course, if ES(L)-LP proves to be an improvement through additional research and application, and subsequently automated tools are created for the statistical forecasting, then the drawback of added effort is largely removed. For researchers and early adopters, some assist is offered by three Excel files available for download from the ES website (www.earnedsschedule.com): ES Calculator vs1c, ES-LP Calculator v1b, and Statistical Forecasting Calculator v2c.

The vs1c and v1b calculators are used to compute path forecasts and ES(L) values. When Stop Work or Down Time conditions are encountered the vs1c calculator is needed, otherwise v1b is recommended due to its relative simplicity. Having the ES(L) values for the LP selections, the v2c calculator is then utilized to obtain the statistical forecasts.

SUMMARY AND CONCLUSION
Using EVM data, the forecasting of project duration with ES has proven, through research and application, to be very reliable. Its accuracy, however, has been shown in recent research to decrease as the topology of the schedule network becomes increasingly parallel. To counter this deficiency and improve ES forecasting the concept of LP has been proposed. From trials with notional data, LP appears to improve forecasting for highly parallel schedules.

For identifying the LP from all of the serial path forecasts, it was determined that a condition is required to preclude anomalous selection. The LP selected for a performance period is the longest duration forecast having a positive change in the representative value of ES for the path, ES(L).

Initially believed to be difficult and complex, statistical forecasting was determined to be reasonably straightforward. It is accomplished by using the ES(L) values associated with the LP selections identified at the periodic status points of project performance. From the ES(L) values the standard deviation is derived, which then allows the computation of the CLs.

As depicted in figures 3 and 4, the application of ES(L)-LP is an improvement to ES-LP and TP statistical forecasting. Although the sample is small, it is believed this finding is generally true.

In conclusion, research is recommended to validate/reject the described methods and the claimed project duration forecasting improvement. If validated, then it becomes reasonable to automate the methods, thereby increasing the practicality of their application. Although it will take some time, the vision appears achievable.

REFERENCES


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Lipke, W. “Project Duration Forecasting ...A Comparison of Earned Value Management Methods to Earned Schedule,” The Measurable News, 2009 Issue 2: 24-31


Lipke, W. “Speculations on Project Duration Forecasting,” The Measurable News, 2012 Issue 3: 1, 4-7
The path to project success requires innovative EVM expertise.


ABOUT THE AUTHOR
Walt Lipke retired in 2005 as deputy chief of the Software Division at Tinker Air Force Base, where he led the organization to the 1999 SEI/IEEE award for Software Process Achievement. He is the creator of the Earned Schedule technique, which extracts schedule information from earned value data.

Credentials & Honors:
- MSc Physics
- Licensed Professional Engineer
- Graduate of DOD Program Management Course
- Physics honor society - Sigma Pi Sigma (PS)
- Academic honors - Phi Kappa Phi (FKF)
- PMI Metrics SIG Scholar Award (2007)
- PMI Eric Jenett Award (2007)
- EVM Europe Award (2013)
- CPM Driessnack Award (2014)
INTRODUCTION

A reliable schedule is necessary for successful program management. A reliable schedule will describe when the program’s set of work activities and milestone events will occur, how long they will take, and how they are related to one another. A reliable schedule provides a road map for the systematic execution of a program, the means by which to gauge a program’s progress and ways to identify and address potential problems and promote accountability.

Developing an integrated schedule is a key for managing program performance and is necessary for determining what work remains and the expected cost to complete it. Therefore, the success of any program depends, in part, on having a reliable schedule.

SCHEDULING ASSESSMENT GUIDE OVERVIEW

The Government Accountability Office (GAO) developed a Schedule Assessment Guide in order to further develop the scheduling concepts initially discussed in the GAO Cost Estimating and Assessment Guide. An exposure draft of the Schedule Assessment Guide was published in May 2012. GAO is currently in the process of incorporating comments from the exposure draft of the guide into a final version.

The guide outlines ten scheduling best practices for developing and maintaining high-quality schedules that provide credible forecast dates. These best practices are:

<table>
<thead>
<tr>
<th>Best Practice</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture All Activities</td>
<td>The schedule should reflect all activities as defined in the project’s Work Breakdown Structure (WBS), which defines in detail the work necessary to accomplish a project’s objectives, including activities both the owner and contractors are to perform.</td>
</tr>
<tr>
<td>Sequencing All Activities</td>
<td>The schedule should be planned so that critical project dates can be met. To do this, activities need to be logically sequenced- that is, listed in the order in which they are to be carried out. In particular, activities that must be completed before other activities can begin (predecessor activities), as well as activities that cannot begin until other activities are completed (successor activities), should be identified. Date constraints and lags should be minimized and justified to help ensure that the interdependence of activities that collectively lead to the completion of events or milestones can be established and used to guide work and measure progress.</td>
</tr>
<tr>
<td>Assigning Resources to All Activities</td>
<td>The schedule should reflect the resources (labor, materials, overhead) needed to do the work, whether they will be available when needed, and any funding or time constraints.</td>
</tr>
<tr>
<td>Establishing the Duration of All Activities</td>
<td>The schedule should realistically reflect how long each activity will take. When the duration of each activity is determined, the same rationale, historical data, and assumptions used for cost estimating should be used. Durations should be reasonably short and meaningful and allow for discrete progress measurement. Schedules that contain planning and summary planning packages as activities will normally reflect longer durations until broken into work packages or specific activities.</td>
</tr>
<tr>
<td><strong>Verifying that the Schedule can be Traced Vertically and Horizontally</strong></td>
<td>The schedule should be horizontally traceable, meaning that it should link products and outcomes associated with other sequenced activities. These links are commonly referred to as “hand-offs” and serve to verify that activities are arranged in the right order for achieving aggregated products or outcomes. The integrated master schedule (IMS) should also be vertically traceable— that is, varying levels of activities and supporting sub-activities can be traced. Such mapping or alignment of levels enables different groups to work to the same master schedule.</td>
</tr>
<tr>
<td><strong>Confirming the Critical Path is Valid</strong></td>
<td>The schedule should identify the program critical path—the path of longest duration through the sequence of activities. Establishing a valid critical path is necessary for examining the effects of any activity’s slipping along this path. The program critical path determines the program’s earliest completion date and focuses the team’s energy and management’s attention on the activities that will lead to the project’s success.</td>
</tr>
<tr>
<td><strong>Ensuring Reasonable Total Float</strong></td>
<td>The schedule should identify reasonable float (or slack)—the amount of time by which a predecessor activity can slip before the delay affects the program’s estimated finish date—so that the schedule’s flexibility can be determined. Large total float on an activity or path indicates that the activity or path can be delayed without jeopardizing the finish date. The length of delay that can be accommodated without the finish date’s slipping depends on a variety of factors, including the number of date constraints within the schedule and the amount of uncertainty in the duration estimates, but the activity’s total float provides a reasonable estimate of this value. As a general rule, activities along the critical path have the least float.</td>
</tr>
<tr>
<td><strong>Conducting a Schedule Risk Assessment</strong></td>
<td>A schedule risk analysis uses a good critical path method (CPM) schedule and data about project schedule risks and opportunities as well as statistical simulation to predict the level of confidence in meeting a program’s completion date, determine the time contingency needed for a level of confidence, and identify high-priority risks and opportunities. As a result, the baseline schedule should include a buffer or reserve of extra time.</td>
</tr>
<tr>
<td><strong>Updating the Scheduling Using Actual Progress and Logic</strong></td>
<td>Progress updates and logic provide a realistic forecast of start and completion dates for program activities. Maintaining the integrity of the schedule logic at regular intervals is necessary to reflect the true status of the program. To ensure that the schedule is properly updated, people responsible for the updating should be trained in critical path method scheduling.</td>
</tr>
<tr>
<td><strong>Maintaining a Baseline Schedule</strong></td>
<td>A baseline schedule is the basis for managing the project scope, the time period for accomplishing it, and the required resources. The baseline schedule is designated the target schedule, subject to a configuration management control process, against which project performance can be measured, monitored, and reported. The schedule should be continually monitored so as to reveal when forecasted completion dates differ from planned dates and whether schedule variances will affect downstream work. A corresponding baseline document explains the overall approach to the project, defines custom fields in the schedule file, details ground rules and assumptions used in developing the schedule, and justifies constraints, lags, long activity durations, and any other unique features of the schedule.</td>
</tr>
</tbody>
</table>

The guide also contains explanatory text, illustrations, and detailed case studies to help program staff identify a schedule’s appropriate schedule logic and risk elements. It also includes appendices that list key questions, documentation, etc. While reviewing the comments, GAO noticed that there was a gap in addressing how Agile relates to the identified ten best practices. As a result, an Agile Appendix was initiated. To assist in the
completion of this appendix, GAO has set up a sub-group of experts to help develop an appendix that addresses scheduling in an Agile environment.

The project team that develops a project’s schedules will find the guide indispensable. Agencies that do not have a formal policy for creating schedules will benefit from using the guide because it will inform them of GAO’s criteria for assessing a schedule’s credibility.

AGILE APPENDIX OVERVIEW
Many GAO audits for IT systems did not have schedules because they were using the Agile method to develop software. One of keys to the Agile development process is to measure progress through the implementation of software. Programs using this development method still need to maintain an IMS. The Agile appendix will describe the applicability and benefits of scheduling best practices for Agile projects with various considerations. The appendix will also identify key document differences between Agile and Traditional scheduling.

The following table provides definitions for selected Agile terms:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Also Called</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Roadmap</td>
<td>High level view of the features the project will set out to accomplish along with the expected business value</td>
<td>Project Vision</td>
</tr>
<tr>
<td>Release Plan</td>
<td>Schedule for developing working software that identifies the expected number of sprints and features that will be included in a release</td>
<td></td>
</tr>
<tr>
<td>Epics</td>
<td>High level capabilities</td>
<td>High Level Requirements</td>
</tr>
<tr>
<td>Features</td>
<td>Next level below an epic which represents items of specific business value. Some features may need several stories to be complete.</td>
<td>Capabilities</td>
</tr>
<tr>
<td>User Story</td>
<td>Small chunk of software that identifies business value and success criteria that can be completed within a sprint time box. A user story defines the work to be done to satisfy a feature.</td>
<td></td>
</tr>
<tr>
<td>Story Points</td>
<td>Assessed value of effort for an epic, feature, or user story based on team consensus</td>
<td></td>
</tr>
<tr>
<td>Sprints</td>
<td>Short-term, time boxed effort for delivering an agreed upon number of story points</td>
<td>Iterations, Increments</td>
</tr>
<tr>
<td>Product Backlog</td>
<td>List of prioritized user stories identified as Must Haves, Should Haves, Could Haves and Nice to Haves</td>
<td>Requirements Backlog, Feature List</td>
</tr>
<tr>
<td>Burn Down Chart</td>
<td>Burn down charts represent completed user stories and reflect the rate of progress over time. Can be compared to estimated number of stories to be completed during each sprint for variance analysis.</td>
<td>Burn Up Chart</td>
</tr>
<tr>
<td>Retrospective</td>
<td>Final review of what was accomplished during a sprint and documentation of lessons learned (Agile team and customers/stakeholders attend)</td>
<td></td>
</tr>
<tr>
<td>Velocity</td>
<td>The rate of progress accomplished by the team during a sprint (measures number of story points delivered per sprint to better estimate future work). Velocity reflects a team’s cadence and will vary among teams.</td>
<td>Cadence</td>
</tr>
</tbody>
</table>
SCHEDULING BEST PRACTICES AND AGILE

**Best Practice 1: Capture All Activities:** There are five levels of planning in an Agile framework; the vision provides teams with a top level plan and the daily work provides the lowest level of detail. The following graphic illustrates the different levels of planning:

The Roadmap outlines the base features (must haves) that are planned for the project. As time goes on the features will have a more detailed plan as more information becomes available, including feedback from customers/stakeholders. Agile relies on rolling wave planning, where only the highest priority work is selected for detail planning for the current sprint cycle. In order to properly implement this type of planning, teams and customers learn more about what the project should deliver as software is prototyped and demonstrated which results in refined requirements after each sprint.

The lowest level recommended for inclusion in the IMS is the “release” level; with the understanding that a specific number of sprints will be planned for each release. Part of release planning is that the releases will identify the desired features to be developed as part of each release. As more is learned about the project, the number of sprints can change based on user needs and priorities. All backlog items are tied to sprints and specific WBS products in order to track what work is expected to be done.

**Best Practice 2: Sequence All Activities:** In an Agile framework, time is fixed with a steady team to complete the work so that tracking sprints in a schedule means analysts are only monitoring the level of effort (LOE). Analysts will not be able to determine tasks’ progress using a schedule that tracks sprints. In this case it is better to use Agile metrics (such as daily stand-up meetings, completed stories, burn-down charts, etc.) to determine the amount of working software scope being delivered in each sprint. In order to know the progress of the effort using a schedule that tracks sprints, dependencies should be identified at the release level. Critical task external dependencies are needed within a release (e.g. there is a need to procure an item before starting), that can be modeled in the schedule. Work should also be prioritized using the product backlog. The product backlog ranks features and user stories according to customer needs and preferences.

**Best Practice 3: Assigning Resources to All Activities:** This does not apply to Agile sprints since the development team is usually stable; only the scope associated with the sprints will be variable. Team size should be small (ideally between 5-9 people) and there can be several sprint teams working in parallel. In order to help with this application, management teams should receive training in the Agile Method. Additionally, teams should be led by an Agile coach or Scrum Master. The teams should be cross functional and self- organizing. Teams receive their work by pulling it from the prioritized product backlog.

**Best Practice 4: Establishing the Duration of All Activities:** In an Agile framework, time is fixed with steady teams to complete work so tracking sprints in a schedule means you are only monitoring the LOE. However, releases should be included in the IMS as they often have duration of two months or more. Release duration will be driven by the number of sprints planned to deliver a set amount of features, as identified in the release plan. Sprints consist of the following steps: planning, coding, testing, and retrospective. Sprints are based around test driven development; meaning that testing will be done continuously for each sprint, resulting in higher quality code because defects are discovered early. Sprints will be the same amount of fixed time. This is typically 2-3 weeks in length so that a cadence can evolve. This cadence is the key to Agile metrics and is used outside of the
schedule to measure progress. After several sprint’s planners can track a team’s velocity to better estimate the remaining effort.

Duration can be shortened through several means. One is by adding more Agile teams to do the work. Another is by the customer reprioritizing work to be implemented in later releases. A third is by the customer determining the work is no longer necessary. Releases could end up being longer than planned if desired functionality takes more sprints than originally identified in the release plan.

**Best Practice 5: Verifying that the Schedule can be Traced Vertically and Horizontally:** This best practice only applies to an Agile framework at the release level. Horizontal integration below the release level can be determined by examining whiteboards which show, using sticky notes or index cards, what work has been done, what work is underway, and what work is still left to be accomplished in a sprint. Vertical Integration below the release level relied primarily on Agile metrics, such as the burn down chart, which provides management and oversight officials information on what work is done and how this corresponds to the work status in the release.

**Best Practice 6: Confirming the Critical Path is Valid:** The IMS should reflect the sequence of releases that identify “must have” features so that a critical path can be identified and tracked. However, as the releases are included in the program’s IMS, the critical path would not apply to the sprints. At the sprint level, the program should rely on Agile metrics to determine what features and user stories can be delivered in each sprint cycle.

**Best Practice 7: Ensuring Reasonable Total Float:** Since the sprints are time-boxed, the float should only be tracked at the release level or higher.

**Best Practice 8: Conducting a Schedule Risk Assessment:** In order to begin the SRA process, the team asks the customer whether they really need any outstanding features in the backlog or if what was delivered is good enough. The key is that the customer decides whether the release should be extended or not in order to capture the desired features. Risk in an agile setting is based on both how good the original estimate is (based on the assumed velocity) and uncertainty regarding new work that arises through the customer discovery phase of completing sprints.

Agile develops smaller chunks of software at a time; this helps to minimize risk. That is, the Agile approach provides more feedback loops so that programs deal with risks sooner and are able to mitigate them faster. However, an SRA can be done at the release level to help answer whether an extra sprint or extra team needs to be added in order to deliver the “must haves”. This will provide analysis of the schedule’s scope flexibility in an Agile environment. During sprint planning the team can further assess what impacts their ability to develop the “must have” promised features; but for the IMS an SRA need only be conducted at the Release level.

**Best Practice 9: Updating the Scheduling Using Actual Progress and Logic:** Daily stand-up meetings allow the team to organize their work and identify any impediments they encounter. Stories that are not completed at the end of the sprint are returned to the product backlog. If a sprint feature is relying on a dependency from an outside source that is not ready, the team can pick a different story point to work on so that no teams are sitting idle. In these cases, the product owners should be available in order to reprioritize the work. Agile has excellent metrics already (burn down chart, team velocity, etc.) so the schedule, at the release level, can reflect progress based on those metrics. For integration into an IMS, this best practice should be maintained at the release level.

**Best Practice 10: Maintaining a Baseline Schedule:** In an Agile framework, time is fixed with a steady team to complete the work so tracking sprints in a schedule means you are only monitoring the LOE. However, at the end of each sprint, you will have data about whether or not you overestimated or underestimated the sprint velocity. Furthermore, at the end of each sprint there should be a demo to the customer of the features/stories that were developed followed by a retrospective. Conducting a retrospective allows the team and customer as well as stakeholders to learn more about the requirements implemented and left to be done. Retrospectives also allow for continuous learning by recording the lessons learned for that sprint. The demos and the sprints provide an opportunity for the customer to discuss their satisfaction and to determine lessons learned for the next sprint.

Additionally, capturing customer satisfaction information and metrics regarding software quality can help with better estimating for future effort and help to prioritize the remaining
backlog items. “Must Have” items needed to be addressed while “Should Haves” and “Could Haves” may never get developed if they are not considered a priority by the customer. Since sprints represent a level of effort, there will be no variances at the sprint level. Therefore, this best practice should be maintained at the release level and up.

**SOURCES**
www.gao.gov/products/GAO-12-120G
www.gao.gov/products/GAO-09-3SP

**ABOUT THE AUTHORS**

Karen Richy is an Assistant Director for the Applied Research and Methods Team at the Government Accountability Office (GAO). She is a senior cost analyst responsible for performing cost, schedule, and Earned Value Management analyses to support audit findings on a wide range of government programs. Certified by the National Defense University as a Chief Information Officer (CIO), Karen is also Level-III certified in the field of cost estimating and financial management. She has 23 years experience in the fields of cost estimating, scheduling, and EVM analysis.

Before joining the GAO, Karen was a cost analyst for the Department of the Navy where she performed earned value management and developed independent cost estimates for major weapon programs and automated information systems. Karen holds a degree in Statistics and Mathematics from the University of South Carolina. In the past few years, she has developed and delivered a one day training class for auditors on EVM as well as co-authoring articles in The INTOSAI IT Journal and the Navy Comptroller Magazine.

In June 2009, Karen received an Award of Excellence from the Federal Capital Planning and Investment Control (CPIC) and an Award of Merit from the Association for the Advancement of Cost Engineering International for leading the development of the GAO Cost Estimating and Assessment Guide. In March 2011, she received a CPIC Best Educational Contribution award for providing an outstanding contribution in training and educational tools for CPIC and related fields.

Jennie Leotta is Senior Research Analyst for the Applied Research and Methods Team at the Government Accountability Office (GAO). She is responsible for performing cost, schedule, and Earned Value Management analyses to support audit findings on a wide range of government programs. Certified by the International Cost Estimating and Analysis Association, Jennie is also Level-III certified in the field of cost estimating and financial management. She has 9 years experience in the fields of cost estimating, scheduling, and EVM analysis.

Before joining the GAO, Jennie was a senior operations research analyst for the Department of Homeland Security where she performed proposal evaluation reviews and developed and reviewed cost estimates for major programs and high priority projects. She has also worked as an operations research analyst at the Navy and a survey statistician at the US Census Bureau. Jennie holds a B.S. degree in Quantitative Finance from James Madison University and an M.A. degree in Economics from George Mason University.

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These opportunities are listed on our website: www.mycpm.org/ABOUT US/VOLUNTEERS
“The release of the IPMR DID was revolutionary in that for the first time, Government will receive integrated cost and schedule information that will facilitate analysis to identify potential issues earlier in the program life cycle and allow for course corrections.”

- Mr. Gary Bliss, Director PARCA

The Office of Performance Assessments and Root Cause Analyses (PARCA) is a legislatively mandated office in the Department of Defense (DoD) with responsibility to conduct performance assessments and root cause analysis of Major Defense Acquisition Programs (MDAP). PARCA is also responsible and accountable for EVM policy and implementation across the Department. The PARCA Deputy for Earned Value Management (DEVM) believes that EVM is one of DoD’s and Industry’s most powerful integrated program management tools and should be tailored to the specifics of the program.

In 2012, PARCA released the Integrated Program Management Report (IPMR) Data Item Description (DID) that combined and replaced the Contract Performance Report and Integrated Master Schedule DID’s, and included a requirement for data to be submitted in a standard electronic format (UN/CEFACT XML format). This standard format allows for integrated cost schedule analysis using common fields such as the work breakdown structure or the organizational breakdown structure.

The Interim DoDI 5000.02 states, “The structure of a DoD acquisition program and the procedures used should be tailored as much as possible to the characteristics of the product being acquired, and to the totality of circumstances associated with the program including operational urgency and risk factors.”

The IPMR is the primary means of communicating program cost and schedule information between the prime contractor and the Government and should be tailored to meet the needs of each individual program. The IPMR’s seven Formats should reflect the true programmatic status and be used to assist in making program decisions. Section 3.2 of the IPMR Guide provides optional tailoring guidance.

During the November 2014 Integrated Program Management Workshop, PARCA presented a workshop session on options of tailoring the IPMR. The session was based on real world situations that PARCA has received through requests for advice on tailoring of the IPMR. The tailoring scenarios that were presented included: IDIQ reporting, use of Alternate WBS (non-881C), actuals-only reporting, IMS-only reporting, IPMR requirements when DFARS EVM clauses are not applicable, and subcontractor reporting. The PARCA team members facilitated a discussion of each of the scenarios, provided a summary of the scenario, and listed resulting recommendations for tailoring. Results of the discussion are provided on the next page:
<table>
<thead>
<tr>
<th>Example Scenario</th>
<th>EVM Applicability</th>
<th>Reporting</th>
<th>WBS</th>
<th>Contract Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDIQ</td>
<td>Applied to a task order or group of related task orders upon review of scope, dollar value, duration</td>
<td>Per task order or group of related task orders based on determination of needs for each TO; summary report to provide overall program status</td>
<td>Determined at task order or group of related task orders upon review of scope; no singular WBS for all TO’s in the IDIQ unless all TO’s are related -- program WBS conglomeration of TO’s</td>
<td>Dependent upon task order or group of related task orders, however the DFARs and other SOW language should be included in the IDIQ language</td>
</tr>
<tr>
<td>Integration effort; CPFF; &gt;$20M; 3-year effort</td>
<td>Yes, based on the integration and testing scope, duration, contract value, and contract type</td>
<td>Standard reporting with the IPMR</td>
<td>Non-881C; utilize contractor’s structure for EVM reporting</td>
<td>Standard DD Form 1423 and standard SOW language. Include note that states “EVM reporting structure based on contractor’s modular WBS.”</td>
</tr>
<tr>
<td>Production effort; FFP; $280M; monthly insight into schedule of production and delivery; 5-year effort</td>
<td>No, FFP and production work generally do not have EVM applied</td>
<td>Tailor IPMR to only have the IMS in order to meet Govt schedule insight requirement</td>
<td>MRP driven WBS or 881C Appendix B Electronic Systems</td>
<td>Add SOW language and CDRL that state IPMR Formats 5 and 6 will be used. No DFARS requirement.</td>
</tr>
<tr>
<td>Maintenance and repair effort ($1B); system development and upgrade ($800M); 10-year effort; AT&amp;L wants to see staffing information by CLIN for development</td>
<td>Yes, due to contract type, value, and duration for scope with development work; deviation for services work</td>
<td>Full IPMR with tailored Format 4 request for CLIN structure on development work; actuals only reporting for services work (or services treated as LOE)</td>
<td>Combination services and software development WBS</td>
<td>Standard DD Form 1423 with comment regarding Format 4 structure; standard SOW language for the development work efforts only</td>
</tr>
<tr>
<td>Development and testing effort; CPFF; $201 quadrillion; 6-year effort; Integration of subcontractor efforts in the Prime’s reporting</td>
<td>Yes, based on the scope, contract type, value, and duration</td>
<td>Full IPMR</td>
<td>881C compatible WBS</td>
<td>Standard DD Form 1423 and standard SOW language; Note: Prime should get reporting needed from sub to integrate into prime reporting; due to contractual relationship prime does not need to flow exact reporting to sub</td>
</tr>
</tbody>
</table>

The bottom line is that the IPMR is tailorable and suitable for cost and schedule reporting on programs even when EVM is not required. The IPMR can be used by any program for situational awareness to gain insights into program performance using integrated cost and schedule data. PARCA and the Service Agency EVM focal points are available to assist with report tailoring.
CPM WASHINGTON DC (CPM WDC) MEETING
AGILE AND EVM: A ROUND TABLE - JANUARY 21, 2015
By Barbara Phillips, Chair

A College of Performance Management Washington, DC (CPM WDC) meeting was held on January 21, 2015 in Reston, VA at the Hyatt Regency Reston, Reston Town Center from 4:30 to 7:00.

A lively discussion was ignited by the 40+ attendees in person (and another 20+ attendees on the phone) asking questions of panelists, Ron Terbush, Finance & Business Operations, LM IS&GS Defense & Intelligence Solutions and Robert Eisenberg, LM Fellow IS&GS Defense & Intelligence Solutions, and Paul Gorans, Agile Competency Lead for IBM Global Business Services. In fact, the moderator, Barbara Phillips, was given limited opportunity to ask questions but rather facilitated. Discussion ran the gambit from how to build the WBS for agile programs to how to change the baseline with plenty of conversation on how to capture and report performance. No doubt the meeting period could have been extended.

As a result, our next meeting is planned in the same format, a panel, on the same subject, which is agile and EVM. It is scheduled for Wednesday, April 22, 2015 from 4:30 to 7:00 at the same location, the Hyatt Regency Reston.

Special thanks to Don Kaiser and Rachael Schmidt of DMG. Tom Shanahan and Brad Arterbury of ProjStream http://www.projstream.com provided the majority of sponsorship for the room and polycom. Refreshments were hosted by Josh Gravy of ClearPlan http://clearplanconsulting.com. The dial in capability was hosted by Mark Tillema of Integrated Management Concepts (IMC) http://www.intgconcepts.com. The meeting was made possible by our sponsors.

Thank you.

Your CPM WDC Committee,
Barbara Phillips, Walter Barnes III, Eva Walter and Ryan Smith
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The CPMTV chapter held its spring quarterly meeting on Tuesday, March 3 in Huntsville, Alabama. Over 20 individuals attended the meeting with representation from industry, government and education. The meeting was graciously hosted by ClearPlan and Defense Acquisition University (DAU) with ClearPlan providing speakers and refreshments and DAU providing the meeting space at their training facility. The meeting was emceed by Bob Wasser of BCF Solutions with presentations by Josh Garvey, Brad Duvall, and Jon Fleming.

Bob Wasser welcomed everyone to the meeting, discussed CPMTV being incorporated into the national chapter and encouraged those in attendance to consider volunteering for CPMTV officer positions. Bob also asked for sponsors and speakers for future meetings and stated that potential speaker topics can be from a wide variety of program management fields.

Josh Garvey, President of ClearPlan, began the meeting with an enlightening presentation entitled “The Art of Planning” in which he discussed successful project management from a planner’s point of view. In his talk Mr. Garvey highlighted 3 keys to successful program planning and emphasized the importance of utilizing a well-crafted integrated master plan and schedule.

John Fleming, Project Management Specialist at NASA’s Marshall Space Flight Center (MSFC), followed with an interesting presentation “The IBR: Your Insurance Policy for a Sound Baseline”. In this presentation Mr. Fleming discussed the purpose of an Integrated Baseline Review (IBR), presented a timeline for the four phases of an IBR, noted the documentation needed to conduct a proper IBR, and gave some useful best-practices and NASA “rules of thumb” from his years of experience with IBRs.

Brad Duval, Program Manager with Northrop Grumman, and Josh Garvey then partnered for an educational talk “Agile Software Development & EVMS”. Highlights of their discussion included giving a brief introduction to Agile SW development, presenting their expert take on managing Agile software development utilizing an Earned Value Management System (EVMS), and summarizing the latest industry and government discussion on this topic. Bob Wasser wrapped up the meeting by thanking the presenters, ClearPlan, and DAU. He also reminded meeting attendees to let himself or Julie Curns know if they are interested in speaking at or sponsoring a future CPMTV meeting.

The next CPMTV quarterly meeting is scheduled for Tuesday, June 2nd from 1 p.m. to 4 p.m. and is being sponsored by Deltek. More details will follow.
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