Earned Value Management in a Production Environment

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Executive Summary

Earned value management (EVM) is the term used to describe the project management process where a project's scope, schedule and cost is integrated and managed. Because all projects contain these three elements, EVM can be used to manage any type of schedule driven effort. While EVM is now utilized across the globe and in a variety of industries, its roots and major usage has been on United States (US) Department of Defense (DoD) projects, and the greatest usage within DoD is on development contracts.

While the historical EVM emphasis has been on DoD development contracts, DoD production contracts, sustainment contracts and many commercial or non-DoD projects also utilize EVM. However, because of the historical development project emphasis, the majority of government and industry personnel have EVM experience emanating from that type of effort. As such, when EVM is applied to a production project there is often confusion or misunderstandings and misinterpretations related to the unique terminology, processes or management practices that take place in a production environment versus a development one.

The purpose of this white paper is to define terms, explain typical production practices and relate them to EVM terminology and practices. Many companies operate their EVM system (EVMS) on production efforts, including Firm Fixed Price (FFP) contracts where no EVMS requirement exists. Many production contracts do have EVMS requirements - often early production efforts are cost plus contracts or fixed price incentive and even high rate production multi-year procurements can be fixed price incentive. When EVMS requirements exist, companies must be able to demonstrate compliance to the 32 American National Standards Institute/Electronic Industries Alliance (ANSI/EIA) 748-B EVMS guidelines (note a "C" revision is planned for mid 2012 with the document reviewed and either revised or confirmed every 5 years). As a result, it is critically important for both contractors and government personnel to understand how the 32 guidelines apply to production activity. This white paper will help all parties understand production activity may result in different EVMS focus or usage, but differences from development activity does not necessarily imply non-compliance to the 32 guidelines.

While this paper will seek to explain and highlight the unique nature of production project EVMS, it will not attempt to define a production EVMS best practice or establish whether any particular practice is compliant or not. Compliance will be discussed throughout the paper but only in general terms. It is the opinion of this working group that this important subject should be explored and evaluated further and possibly a guide or best practice document should be published by a follow on working group.

This paper was developed by a working group under the National Defense Industrial Association's (NDIA) Program Management System Committee (PMSC). A joint team of industry and government individuals (See Appendix A for a listing of primary participants) discussed issues encountered in implementing and reviewing an EVMS on production projects. The team met periodically over the course of a year and a half to identify topics of concern, discuss typical industry practices, identify potential concerns or misunderstandings in the industry process, highlight the impact or relation to the EVMS, and note the differences between the processes in a production versus a development environment. Specifically, eleven (11) areas were identified requiring discussion as noted below:

1. EVM application to production
2. WBS level or level of detail in production
3. Organization issues in a production environment
4. Production scheduling
5. Work authorization in production
6. Change management in production
7. Material topics
8. Manufacturing labor topics
9. Part movement that occurs in production
10. Scrap and/or rework
11. Production support labor

Each of the above items will be discussed separately in the body of this paper. This executive summary will highlight a couple of examples encountered to demonstrate the differences and the potential misunderstandings that are noted above.

One of the cornerstones of an effective EVMS is an Integrated Master Schedule (IMS). Depending on the size of the project the IMS may consist of detailed schedules, intermediate schedules and a summary level schedule or contain all this information in a single file/document. The IMS forms the basis for the time phasing of resources and therefore the Performance Measurement Baseline (PMB) by which earned value is measured. The status or progress of activity in the IMS allows for earned value to be determined which will translate into schedule variance and cost variance information. A basic tenet of an IMS in a development project is that all discrete project activity should be captured in the IMS. In production this may not be the case as IMS activities may be more summary like in nature. Production activity is usually controlled by a company's detailed system for managing part flow and shop floor effort. This system is referred to as Material Requirements Planning (MRP – note most companies use "second generation" systems or MRP II which include business planning, capacity planning, order processing and many other integrated efforts. For simplicity this paper uses MRP to refer to both MRP/MRP II systems). Because MRP contains all the details, it is not necessary to duplicate them again on a one for one basis in an IMS. While many companies utilize an IMS in production, often the effort portrayed will include summary like tasks, items not covered by MRP, items necessary to help calculate and manage the critical path, or the inclusion of items that will facilitate a schedule risk analysis. While many projects benefit from a production IMS, certain types of effort (usually product driven – i.e., radios produced in high volume versus aircraft produced in low volume) may only employ the MRP system and not use an IMS at all.

This difference of an IMS only including certain types of effort or maybe not existing at all will seem strange or even non-compliant to someone who has only experienced development type work. But this difference does not imply less schedule management. In truth, production efforts often have more schedule focus as delays can shut down a production line. Usually production contracts are FFP thus delays and cost growth can have a serious impact on a company's profit. Therefore, a company must be able to demonstrate how their MRP system or combination of MRP and IMS provides useful schedule information in a compliant manner. Thus, the lack of an IMS or an IMS that does not contain every activity is not what drives compliance; the effective operation of tools, adherence to documented processes, and effective management use of the information is what determines compliance.

Another difference often found between development and production efforts is the role of the Control Account Manager (CAM). In a development environment a CAM typically has an engineering background or focus, but beyond that, the CAM is typically viewed as someone who determines the budget for the scope of work, develops the schedule and time phases the cost profile. However, in production the CAM may not be the person responsible for doing this. Often for a development contract the budget comes from a proposal/basis of estimate (BOE) that the CAM (or their predecessor) estimated based on the scope of work. In production, specialized estimators often accomplish this based on historical information available for the recurring production activity. Likewise, when developing something new, the technical expert (CAM) determines the time spans necessary to accomplish the work but in production, span times are programmed into the company's MRP and thus the CAM does not necessarily dictate the schedule. This difference in scheduling responsibility also drives the time phasing of the cost profile. Therefore, in production, it seems that the CAM has less control and thus sometimes questions arise about the CAM's knowledge or involvement. However, the 32 guidelines do not require the CAMs to be all knowing only that they must be able to discuss and demonstrate the execution of compliant processes. This can be done in either a development or production setting even though their personal involvement may be different.

These examples highlight the nature of the issues addressed by this white paper. It is the opinion of this working group and the opinion of Integrated Project Management/EVMS practitioners that EVM represents a project management best practice and because the fundamental nature of managing a production project is not different from a development project these differences should not deter someone from using EVMS in a production environment. Instead, industry and government personnel experienced in both should continue to educate others on the differences and help show that EVMS compliance can be demonstrated despite the differences.

Background

In August 2009 at an NDIA PMSC meeting, a presentation was made highlighting what appeared to be inconsistent EVM practices in various production programs based on various DoD reviews conducted over a two year period. It was pointed out that the DoD community may not have consistent expectations for EVMS in a production environment. The following items are among the many observations made at the August 2009 meeting:

- Most EVM practitioners do so in a R&D environment
- Although the EVM system description is the same, a company's specific process in production may differ from development
- How work packages and control accounts are utilized and where data is generated in production is often different than a development project
- Scheduling and the resultant IMS is different in production due to the use of MRP systems
- Unique organizational issues are encountered in terms of CAM assignment and responsibility and the presence of union personnel plays a large role in production
- Material issues are more significant in production
- Change control and work authorization processes appear to be different from how they would be conducted on a development effort

It was recommended that these items be analyzed and that a working group of industry and government participants be formed.

In December 2009 a working group was formed to study the circumstance noted above and make a recommendation as to what should be done to address the situation. After several meetings, it was decided that the items noted above are accurate and that the best course of action would be to first document and explain differences in a white paper (this document) and based on the response to the white paper further action would be determined at a later date.

Challenge

It should be noted that publishing a consolidated white paper on production EVMS requires a broad treatment of topics and issues. First, companies produce a wide array of products. Not only are there differences in terms of aircraft (fixed wing versus rotary wing) versus ground vehicles versus ships versus launch vehicles versus spacecraft, etc. but there are also the varied products that are incorporated into these vehicles. Given that different products are produced in varying rates and time spans and each company tends to have varying processes and systems the complexity goes up exponentially in trying to establish "industry norms". Even the term production project or contract can represent a wide variety of activity. For example, production can mean full rate production, low rate initial production or even recurring items in a development contract. A production lot could be dozens or hundreds of units or one unit. The production activity could be concurrent with development and thus likely to be less stable or it could be mature. All these variations contribute to the difficulty in having a "one size fits all" description and solution.

Historical Footnote

It should be noted that this white paper is not the first time a joint working group has attempted to describe and resolve production EVM issues. In June 1978 a final report from the Defense Industry 15 Man Ad Hoc Committee for the Application of Cost/Schedule & Control System Criteria (C/SCSC) to Production was published (C/SCSC was the predecessor to the ANSI/EIA 32 Guidelines). While the problem statement and goals of that group were different, several of the issues discussed below are similar in nature to this previous report. This white paper has incorporated applicable items from the prior report and thus it is believed that the excellent work done by this prior group is maintained in this paper.

Introduction

The purpose of this paper is not to make the case for utilizing EVM on production contracts. This paper assumes that EVM is being employed in a production environment, whether contractually required or not, and attempts to explain differences encountered in that environment versus development activity. A company may choose to employ EVM in production when no government requirement exists. The reasons for doing this are many:

- Company practice to manage all of its projects utilizing the same tools and processes
- Greater ability to move personnel between projects due to common tools and processes
- Benefit of using a management best practice to manage the work
- Early warning of cost or schedule issues by utilizing EVM

Whether a production contract has an EVM requirement or not, a common company goal in a production environment is to optimize production effort. This may be done for a single product line or across multiple product lines. In order to achieve the greatest level of cost, schedule and quality efficiencies companies employ a variety of program and enterprise tools. As a result, companies will employ differing methods to integrate their EVMS with other manufacturing tools and processes. These methods may differ from the way the same company operates its EVMS in a development setting. An MRP system is one example of a tool used in production that potentially drives differences in how an EVMS is used or explained versus development.

Understanding the potential differences is critical when dealing with government customers, especially when a production contract has an EVMS requirement. In this context, a customer may be a program office which receives EVM reports or data or an entity that has cognizance for ensuring EVMS compliance, such as DCMA. Compliance discussions may be held as part of annual EVMS surveillance or as part of a validation/compliance review. While both industry and government have a responsibility to fully train their personnel, it is a fact of life that not all contractor or government personnel are fully trained in EVMS to an expert level for all contract types/program phases. An additional complexity is that companies' systems vary and therefore misunderstandings may occur about differences from what is normally seen in development environments versus what is seen in a production environment.

It would not be possible to capture all the potential issues or misunderstandings that can occur in a production EVM environment. That said, there are several common issues that often show up time and again, either at the same or differing companies. One such item is the utilization of an IMS and the relationship between the IMS (if used) and the company's MRP system. This is discussed above in the Executive Summary and also addressed in the Production Scheduling section below.

Another top issue is how an MRP system operates and optimizes a company's production activities. This often results in movement of parts between control accounts or contracts and can be misunderstood or the results misinterpreted. This topic is discussed in the Parts Movement section below. Closely related to this issue is how a company plans their baseline and takes performance for material costs. Unlike development efforts where supplier or material cost and performance is often recorded based on a supplier Contract Performance Report (CPR), production material is typically not based on CPR information and follows methods prescribed by guideline 21 which is further based on a company's unique system description and Disclosure Statement (the document that describes the company's accounting system and practices). This topic is addressed in the Material Topics section below.

The CAM involvement in relation to his/her production schedule, the company MRP system, the assessment of performance and other related topics is another area where misunderstandings can occur. This subject is addressed in the Organization Issues section below. Issues in the area of work authorization and change management also come up frequently and those are discussed in the respective sections below.

This paper will not attempt to describe whether certain practices are compliant or not. In truth, two different companies may employ similar practices but one may be non-compliant and the other compliant depending on factors such as how the system description describes the process, whether data integrity is inherent in the process or even how a CAM answers questions concerning the practice. As always, it is the responsibility of the contractor to demonstrate that their system is compliant with the 32 guidelines.

While a company must be able to demonstrate compliance, it is equally important to understand that company production systems that optimize production effort (i.e., provide the lowest cost and the best schedule across a company's entire range of products) are not easily changed, nor should they be in order to try and "optimize" one contract. For example, it may be easier to understand and explain if material required on a single contract is bought individually and directly for that contract. However, this may not be cost efficient versus combining requirements from multiple contracts and buying parts into a common inventory pool and then distributing those costs to the various contracts where the requirements reside. This practice is sometimes questioned as being non-compliant when in reality the process benefits the government and can be demonstrated as compliant when properly explained and understanding takes place.

Therefore, this paper will describe typical issues encountered in production and potential differences between a production and development environment. As a follow on to this working group's output it may be beneficial to explore whether a document that identifies production EVMS best practices (like a guide) is needed or would be beneficial.

The remainder of this paper will discuss in more detail the eleven areas the working group documented and believe discussion is necessary to better understand production contract EVMS and/or an area where production and development aspects differ. It should be noted that a common definition of terms is important to ensure there is an understanding of the items being discussed. A listing of terms often encountered in a production environment is provided in Appendix B.

EVM Application to Production

As noted earlier, this paper's purpose is not to advocate EVM application on production efforts but rather discuss the issues encountered when it is applied. While EVM has proven to be effective in managing many production efforts, each company should determine the best way to manage their production programs when EVM usage is a choice and not a requirement.

It should be noted that production is not the same in all industries and for all contracts. Usually there is a transition period between development and production where small quantities are purchased during the transition time period. The pace and problems encountered in Low Rate Initial Production (LRIP) efforts are often different from Full Rate Production (FRP) efforts. Further, some production runs are always small and often unique (space launch vehicles) while others are large and don't change much (common equipment in all aircraft). The EVM issues that result from these varying types of production can therefore differ.

Some companies may choose to utilize EVM where more risk occurs (LRIP) versus stable high rate efforts. From a United States Government (USG) contracting perspective, LRIP contracts are often cost reimbursable or fixed price incentive and many are over the dollar threshold, so EVM is required. Some FRP contracts may also require EVM due to their contract type and dollar amount as is often the case in multiyear procurements. Once required on a contract, the company must ensure that the production EVMS is fully compliant to the ANSI/EIA 748B EVMS standard.

USG DoD policy instructs that EVM should not be mandated on firm fixed price (FFP) contracts unless there is a compelling reason (typically risk – although this calls into question the use of an FFP contract type) and since many USG production contracts are FFP there is often not an EVMS requirement for production. Because many production contracts do not require EVMS this is a contributing factor for the misunderstandings that can occur when production versus development differences become apparent.

As such both government and industry personnel need to understand the differences discussed in this paper.

To the extent a company utilizes EVM to manage production efforts when no requirement exists a number of methods are often employed. Some companies utilize their full EVMS in order to gain commonality and efficiencies in program management practices and personnel training and development. Due to need and/or the size or complexity of the effort, other companies may use scaled back or "EV-lite" methods where the main EV principles are employed but the full system is not utilized. Other companies may use either method depending on the circumstance. Since compliance is not an issue in these circumstances companies can use whatever method is appropriate for their situation.

Work Breakdown Structure (WBS) Level or Level of Detail in Production

A complex topic for production activity is the level of detail produced by and within the various company systems. It is generally true that the WBS tracking and reporting level for production efforts is at a higher level than during the comparable development effort. Mil-Std-881 provides requirements and guidance on WBS structure and reporting. It allows for adding additional WBS levels where risk is prevalent or the dollars involved for a particular WBS warrant additional subdivision. In a large development contract it is common for the WBS to go to level 5, 6 or even 7 (with the contract or weapon system level as WBS level 1). Typically, production efforts have the lowest WBS level at level 3 or 4. Thus it is not uncommon for the WBS level of detail on production efforts to be higher than for development efforts.

However, the level where information is managed is often at a much lower level on production activities. In development and production, company EVMS's track cost and schedule performance at control account and work package levels where the control account is below the lowest level WBS indenture and the associated work packages are below the applicable control account. While there may be activities below the work package in the schedule, in development this level of detail usually corresponds to how the effort is managed, reported and analyzed. For production, while the reporting and analysis may be to this same level, the work is managed at a more detailed level on the factory floor. It is often the case, that labor hours (and associated standard hours – to be discussed more fully in the manufacturing labor section) are managed well below the work package level. In fact, labor hours are usually tracked at the shop floor paperwork level or even the specific operations on the paperwork. This low level of tracking and managing is necessary in order to ensure daily/weekly shop workloads are maintained and supervisors can monitor progress. Likewise, material dollars may be tracked and managed to a specific purchase order and supplier to ensure parts arrive on time to the required process point.

This lower level of detail can be a point of confusion depending on the question being asked or issue being resolved. For example, "actuals" are accumulated at this low level but they would be labor hour actuals and not fully burdened cost actuals that one would find in a report such as a Contract Performance Report (CPR) or found in a company's EVMS. A company should be able to demonstrate how company systems integrate such that the EVMS status matches the detail coming from the company systems and likewise variance explanations correlate between the summary level information and the details from the shop floor or procurement system.

There is no specific "compliant" level of detail required for the EVMS or for the shop floor management activity. It is common for WBS levels to be collapsed as programs move from development to low rate production to high rate production as risk and product changes decrease. Likewise, companies may employ a variety of management methods/techniques which require more or less detailed information in order to achieve maximum production efficiency and cost and schedule performance. The purpose of highlighting this point is that like development efforts, there is no single answer for what level of detail is associated with production efforts.

Another example of development and production differences as it pertains to the detail contained within the EVMS data is what is considered a standard work package. It is generally desired in development to have relatively short work packages (where practical for discretely measured work) which is often defined as 2 months long or less. This goal is primarily driven by the desire to have objective measures for work performed and generally speaking, shorter duration work packages are more conducive for objective progress measurement (or earned value). However in production one can find longer work packages, often much longer, as the work package structure may be tied to the company's MRP system where similar parts (and thus all contained in the same work package) are released on an as needed basis to the floor as units are constructed. For companies that build large items (aircraft, spacecraft, ships, etc.) over long periods of time (often multiple years on a given contract) work packages may be long and beyond the typically desired time frames.

The length in duration for a work package also has implications for changing these work packages. Again, it is often desired that open work packages not be changed. But circumstances may warrant changing the work package (a customer directed change or even an internal producibility directed change that replaces or modifies a part or parts) and companies with highly integrated systems may have to change in order for their data to be aligned.

It should be noted that government groups charged with ensuring a contractor's EVMS compliance typically audit and review data at the level it is available. So, in development that data is usually at the work package and control account level as that is where plans are made and charges accrue. As noted above, production effort usually has details below this level on shop floor paperwork or individual purchase order level information. Thus the interesting dilemma arises as to whether reviewers should be examining this lower level detail for EVMS compliance or not. These details come from a company's manufacturing/procurement systems which are not necessarily the same as the company's EVMS. However, a company must be able to demonstrate system integration to their EVMS. It is the working group's opinion that reviewers should examine EVMS produced data but take into account the company's ability to demonstrate system integration.

Organization Issues in a Production Environment

As noted in the Executive Summary, one of the differences between development and production typically encountered is around organization issues. Because the structure for monitoring and managing production is more process based and potentially less aligned to a program structure, this has implications on how the production program organization is structured and therefore who the CAM is or should be. For example, on new, large development efforts it is usually the case that the organization structure employed is an integrated product team (IPT) format where groups are organized around specific program products. In production, company personnel responsible for producing the product may have responsibility for multiple program products and attempt to drive efficiency across multiple product lines. These organizations may be more functionally oriented (manufacturing, procurement, quality, etc.) vs. IPT.

The responsibilities and focus of the IPT lead or CAM on a development program and the superintendent or foreman within a manufacturing organization may not be the same and therefore questions may arise when a production CAM doesn't have the same duties as a development CAM. An example of this was discussed in the executive summary where the development of an IMS often differs between program phases. Ultimately, the CAM must be able to satisfy the duties of a CAM when EVMS compliance is involved as CAMs are the ones interviewed to determine whether system description processes are adequate and being followed.

Therefore, assigning the right person as the production CAM involves a consideration of the various issues and a balancing of program management and company efficiency goals. In development, the CAM usually has a clear connection with and has the responsibility, accountability and authority to determine budgets, create and manage scheduled activity, identify and mitigate risks, and provide the root cause variance analysis. But as previously discussed, depending on a company's processes, often the person responsible for producing or assembling parts in an area - the shop floor supervisor – may not have control of some or all of these tasks. This difference could be interpreted as the EVMS not operating as intended. However, what needs to be understood is that production processes can differ from development processes and what needs to occur is that the CAM in a production environment displays knowledge of the production processes and their responsibility and involvement in them (and of course those need to be consistent with the company system description).

For program continuity purposes it may be advantageous to keep the incumbent CAM from the development effort, however, if that CAM has an engineering background he or she may not be as knowledgeable about the production process and systems. Thus, this is another consideration for establishing the production program organization.

Industry has adopted several different methods to handle the CAM responsibilities in production. Some of them are listed below. Each may have certain advantages or disadvantages and in the end the organization structure must satisfy the intent of EVM guidelines in this area.

While not intended to be an all inclusive list, some industry examples are:

- Using Development IPT leads as CAMs, maintain IPT type structure
- Using shop superintendents as CAMs, organize functionally
- Using foreman as work package managers under an IPT structure
- Each feeder shop leader is CAM for their shop, Assembly CAMs assigned per area, again a functional organization concept
- Manufacturing Engineer is CAM, hybrid functional organization concept
- Procurement or Material CAMs responsible for purchased items, again a functional concept where material cost/items are managed separately from manufacturing labor activity
- CAM established with no specific area expertise (manufacturing, procurement, quality, engineering) but has overall authority and responsibility for directing/coordinating that activity

The bottom line is that in a functioning EVMS the single person assigned as CAM will have responsibility for the collection of activities that represent the lowest level of WBS/OBS intersection. They should be the ones who can manage the work and be able to demonstrate a thorough knowledge of EVM data, processes and interfaces. They should be able to articulate their activities in relation to the critical path, develop and implement recovery plans, manage labor and non-labor resource costs effectively, and to describe the inherent risks.

Production Scheduling

In April of 2011, the Program Planning and Scheduling Subcommittee (PP&SS) released the Planning and Scheduling Excellence Guide (PASEG). The PP&SS is an industry and USG working group under NDIA, specifically under the Industrial Committee for Program Management (ICPM). The PASEG is a comprehensive guide developed for program management teams that provides guidance for building, using, and maintaining an Integrated Master Schedule (IMS). It also identifies knowledge, awareness, and processes that enable the user to achieve reasonable consistency and a standardized approach to project planning, scheduling and analysis.

As the PASEG states, “Sound schedules merge cost and technical data to influence program management decisions and actions. Realistic schedules help stakeholders make key go-ahead decisions, track and assess past performance, and predict future performance and costs. Industry and Government agree that improving schedule integrity has a multiplier effect on improved program management. Program teams can benefit from this guide to gain a common understanding of key scheduling terms, concepts, and practices. The guide also provides practical tips and caveats for scheduling techniques that apply for any scheduling software tool or environment. Using this guide, the program team can build and maintain more robust and dynamic schedules that provide a roadmap for improved program execution.”

Section 13.2 of the PASEG provides guidance for scheduling in a production environment. The PASEG section on production scheduling is comprehensive and does not need to be repeated here. The reader should review the PASEG for a full treatment of production scheduling issues and topics.

Given the importance of a sound schedule to managing a project, including production efforts, it is incumbent upon the company to ensure their processes and schedule information provide an accurate portrayal of program progress and forecasted dates. As with other sections in this paper, the company must also be able to demonstrate how their scheduling activity complies with the various guidelines that pertain to planning and scheduling tasks. As noted elsewhere in this document a challenge for both industry and government is that systems, processes, and output vary company to company. In terms of production scheduling, the PASEG provides the necessary attributes and expected results from a production schedule which should help resolve some of the challenging issues in this topic.

Work Authorization in Production

Companies employ various systems and processes to authorize work and trace that activity from contract award to the establishment of a PMB. Depending on the company, the work authorization method may or may not be the same for development and production efforts. For example, if a company's process begins at contract award and culminates in the issuance of a baseline change request (BCR) to establish the initial baseline that process may be the same for both types of efforts. In this case, work is authorized at contract award and then steps take place transitioning work from undistributed budget to distributed budget (establishing the PMB with its attendant control accounts and work packages). In this scenario, the steps taken are the same. Processes that follow this example or something similar would have the loading of MRP as a separate step. That is, MRP is loaded providing all the details of the production project but the cost roll up into work packages and control accounts is provided via the BCR.

Conversely, companies may call out the loading of MRP as the work authorization step. So in these cases, the process will likely be different between how MRP and engineering work is authorized. Using MRP as the work authorizing step is not independently right or wrong - again it is the company's responsibility to demonstrate compliance to its stated processes.

What can raise questions is MRP's automated process. If MRP is the work authorization step then a question may be who provides approval as it is unlikely the CAM is calculating and approving the detail part "explosion" MRP calculates. A follow on question may be who develops the schedule and approves the budget (covered above in the Organization discussion). That may lead to a question on how changes are approved (covered below in the Change Management section). Companies need to understand this thought process and be prepared to answer these legitimate government questions. This may lead to choosing one work authorization solution, but companies are free to define their applicable process.

At the heart of the issue is the automated MRP process – dates are entered into the system, typically the major sequence of product build and/or delivery dates, and then the exploded bill of material is "backward" scheduled utilizing things like lead time information, span time information, delivery routing times and the like. This process is automated so that the greatest amount of production efficiency can be maintained. As a result, this differs from normal development process where span times are determined on a left to right basis and the CAM is driving the process.

As stated several times, differences do not imply non-compliance but they do need to be understood and explained. In development, CAMs are the ones with the detailed knowledge of what the effort entails and how long it will take. In production, a product has been previously built and historical evidence shows how long the activity will take. In an optimized production environment, no company would want every CAM to speculate how long parts take to build when documented evidence already exists. In development multiple variables may need to be considered – what are the risks, are there alternative solutions, can analysis be accomplished or is a test needed, etc. Presumably, these issues have been resolved once production starts. Of course not all projects are completely stable at production start but the variability should be greatly reduced.

The bottom line is that each company must be able to demonstrate that their work authorization processes meet the guidelines intent, ensure only authorized work is started, changes are controlled, logs are created to track changes, and all the necessary elements are in place.

Change Management in Production

Change management in production is not necessarily different from change management in any other contract phase. The goals are all the same within a functioning EVMS – establish a sound performance measurement baseline and then control changes to that baseline to ensure that only authorized changes are made, the changes are well coordinated between CAMs and the PM, the changes are tracked, schedules are monitored to ensure changes do not impact others or that impact is known and communicated, and other practices that go with a sound change management process.

For any company, the change management discussion usually involves a philosophical discussion as well. That is, should baselines stay fairly stable or unchanging or should baselines be maintained and therefore potentially change more frequently. It is probably not the right answer that baselines should never change nor that they should constantly change. Clearly, there are times where customers authorize contract modifications that result in a change. There are also many valid circumstances where future baseline work should be adjusted to account for changes in a plan or a reaction to an unforeseen event. But it is equally true that if baselines have constant change then the value of EVM information can be compromised. As such, the philosophical debate should be decided based on the merit of the change and the desire to not disrupt the baseline for trivial or inappropriate changes.

Typically, in development efforts, companies should desire to have work packages that are fairly short so that accurate and objective performance measurement can be assessed. Often in production, work packages can tend to be longer and therefore the frequency of changing an open work package can be higher, while still maintaining very objective earned value measurement. In addition, MRP system constraints may exist regarding the closure of in-process open work packages. While this may be viewed as unusual to someone only familiar with development experience the key is to determine the appropriateness of the change. If the change is appropriate then it should be made regardless of whether it affects an open work package or not.

The primary production difference when discussion change management is the use of the MRP system. As previously discussed, an MRP system is used by a company to efficiently manage and control its production activities. While utilized by and integrated with a company's EVMS, the primary purpose is to ensure the manufacturing floor operates as efficiently as possible. To do this, manufacturing personnel require real time information on part availability, personnel availability, machine availability and the like. The interaction and status of all these components can often change and as a result it is common practice for an MRP system to update frequently, usually every week (although some companies may update the system more or less frequently).

With MRP systems potentially changing weekly, what are the implications to an EVMS change management process? If a company's system is highly integrated, has strong controls in place, and can handle the volume of change then it is possible that a baseline could be updated weekly. However, this is typically not common practice. Instead, most companies will establish the baseline based on the initial run of the MRP system (or when the plan is considered final) and then only when significant changes to MRP are made or needed will changes to the baseline be made. The word "significant" of course is often in the eye of the beholder but each company should be able to demonstrate the impact of making or not making the change thus showing why any given change is considered to be significant or not.

Since production efforts involve the delivery of a product to a customer, it is clear that no change should be made if delivery dates (or even interim control milestone dates if they are specified in the contract) will be missed without prior consultation with the customer. However, changes made in production can occur without impacting delivery dates and thus can or should be made if significant enough to impact the way in which products are assembled thus maintaining the integrity of the EVMS information. It is always acceptable to keep a baseline and just explain variances to a plan but if the production plan varies significantly from the EVMS baseline then there typically is a point where EVMS data will not be useful unless a change is made.

In severe circumstances, a production plan can become so far off track that an Over Target Baseline (OTB) or Over Target Schedule (OTS) – or both – become necessary. An OTB/OTS represents a significant change and by definition means that a company can no longer manage to the baseline. Circumstances like this require significant customer interaction and can lead to a "resetting" of variances, the need to populate the reprogramming column on the CPR, and a major change to the MRP system.

The bottom line for production change management is a company must be able to demonstrate that the change is authorized, necessary, has proper traceability, and can be articulated by the CAM. Depending on the span time for producing a product, changes may be rare or common to a baseline. As noted above, changes should be made prospectively with all parties informed on the change and should never be made only to eliminate variances.

Material Topics

Material cost is a major topic in production as it is not uncommon for 50% or more of a contract's cost to come from suppliers/vendors. While it is not practical in this white paper to cover every potential material cost topic, the major issues and the differences to what is often found in a development environment will be discussed.

A good place to start in the discussion of material cost in a production environment is what type of material is being discussed and how is that material planned in the system. In general terms, material cost in a development environment is usually associated with suppliers who are developing a new system or product that will become part of the prime contractor's product. While it is true that there may be non-recurring material cost purchased for tests, non-recurring material bought for tooling or even recurring material used to build prototypes or test vehicles, in most cases the majority of the material cost in development is for suppliers doing design work. Often suppliers submit CPRs to provide EVMS information to the prime. Of course, the majority of the supplier's cost is for engineering effort to develop their new product. On the other hand, material cost in production primarily consists of supplier's manufacturing labor and their own purchased material from lower tier vendors. Typically, there are fewer CPRs from production suppliers because production cost is lower than development cost and EVMS thresholds are not met, or equally likely, production contracts with suppliers become firm fixed price (FFP) and therefore CPRs are not required.

Because the majority of production material cost is not reported on CPRs, FFP contracts are utilized, and the issuance of purchase orders and receipt of material is managed and controlled by MRP, the establishment of the baseline is driven by the MRP system. Typically, material is planned based on one of two primary methods: 1) upon receipt of material, or 2) upon issue of material into work-in-process (WIP). When establishing the baseline based on receipt of material, supplier delivery dates based on purchase orders are contained within the MRP system and utilized to establish the budget value (fully earned on delivery unless some other interim milestone method is used).

Baselines established when material is issued to the manufacturing floor and thus into WIP are driven by the factory need date (when is the material required to be issued to the assembly operation) within MRP. In these instances the delivery of the product from the supplier could be days or months before the actual need date. Some companies may employ both methods depending on their categorization of material and/or material type.

It should be noted that in either case, there is likely to be low dollar value parts (nuts, rivets, bolts, wire, paint, etc.) that may be called plant stock, bulk parts or other such terminology. Companies often differ on how these costs are treated – they could be accumulated into a pool with baseline cost and later performance calculated via a rate (usually per manufacturing hour or dollar), or they could be charged discretely but the budget/performance is tracked using an apportionment method, again usually a factor to manufacturing activity. In some cases, these low dollar parts used over the course of the manufacturing activity may be treated as LOE.

As with the establishment of the baseline (budgeted cost for work scheduled – BCWS), two primary methods are used to earn performance (budgeted cost for work performed – BCWP). Within the two methods, it should be noted that BCWP is dependent upon accomplishment of work scope as opposed to an accounting action, such as receipt of invoice or payment to a supplier and that BCWP is earned using the same criteria/logic as used to schedule BCWS, i.e., receipt of material or requisition of part into work-in-process. Lastly, the dollar value earned as performance (BCWP) is the same dollar value scheduled for that part in BCWS.

Under the receipt method, performance would be earned for a part upon the receipt of that part as identified in MRP and purchase order (assuming on time delivery). Receipt specifically refers to a company taking possession of the part, often once receiving inspection has determined the part to be undamaged via the transportation process. Since MRP contains the capability to transfer material from project to project, this data should be calculated as of the accounting month end. If the part was <u>received</u> to project "A" in month one, BCWP would be earned in month one. If the part is transferred to project "B" in month two, BCWP would be reversed/unearned on project "A" and earned on project "B". This reversal, or unearning, of BCWP reflects the actual accomplishment on the respective projects.

Under the issue into WIP method, performance would be earned for a part upon the issue of that part into WIP as identified in MRP. As noted earlier, when BCWP is earned at issue by definition the part was actually received by the company at an earlier date but performance isn't earned until the part is issued. When using the issue method it is likely that instances of reversing performance as noted above will be fewer. Regardless of method, the process of knowing when performance is taken at a part by part level is needed to ensure BCWP calculations are accurate.

Whether utilizing the receipt or issues philosophy for material, the material accounting system must provide for full accountability for all material including residual inventory purchased for the project. Material costs must be accurately charged to control accounts using recognized costing techniques, and when necessary and significant, the use of estimated actuals (actual cost of work performed – ACWP) is required to ensure accurate performance measurement if actuals are not yet available in the company's accounting system. The need for estimated actuals can occur when a part has been received/issued but an invoice from a supplier has not yet been received or paid. Since ACWP is to be based on accomplishment of a task in the authorized scope of work (i.e., part delivery) and is not based on an accounting activity such as a financing arrangement with a supplier where payments might be made monthly but deliveries are every quarter, the use of estimated actuals to match performance and actuals is an important practice in material EVM (this is true in development efforts as well but much more prevalent in production).

Many companies utilize an automated process where parts and their associated cost (and therefore performance) move between lots or contracts. Often referred to as Grouping, Pegging and Distribution (GPD) a part may have earned BCWP and ACWP but then that part may be transferred to another contract. In this example, BCWP and ACWP will move systematically with each other thus causing a reduction, or "de-earning" in the "giving" project's data (although depending on the volume of activity the change may not be noticeable). This subject will be covered in more detail in the Part Movement section of this document.

Once BCWS is determined and BCWP and ACWP start to accumulate, variances will likely occur. This section will discuss the primary aspects of material variances. A schedule variance (SV) will occur when parts are either received in advance of their planned date (favorable) or when hardware that was schedule to be received but was not prior to the end of the accounting month (unfavorable). The same would hold true for parts being issued early or late. Regardless of the reason, visibility into the individual parts and milestones that are contributing to the schedule variance is required for accurate and meaningful variance analysis. The variance analysis should cite the parts and milestones that are the major contributors as well as the corrective action, anticipated recovery date, and program impact associated with these major items. Care should also be taken that dollar value does not mask critical parts identification. If a part or milestone is not a major dollar driver, but is a major contributor to impacting the critical path, the part or milestone should be addressed in the variance analysis.

Cost Variances (CV) follow the same methodology, either the ACWP for the part is less than the BCWP taken at receipt/issuance (favorable) or it is higher than BCWP (unfavorable). CVs for material are broken into two distinct categories. Price Variance, the difference between budgeted/earned price per unit and actual price per unit multiplied by the actual quantity should be identified so that it is understood that parts are costing more or less. A number of reasons could cause this – usually parts negotiated at a higher or lower value than the amount set at the time of budget establishment. For most material this will first be identified at the time of PO placement or negotiation, and realized in the variance at completion through an increase or decrease in the EAC. In some instances it will be a result of transfer of a part from another project. Usage Variance, the difference between the budgeted/earned quantity of parts and the actual quantity of parts used multiplied by the earned unit price should also be identified so that it is understood that a process is using more or less parts than originally planned.

As variances are identified, estimate at completion (EAC) forecasts should be reviewed and potentially updated. As with any EAC there are two primary focus areas, 1) what is the new value for the material items, and 2) what is the time phasing or profile of the new EAC amount. In determining the new value for an EAC, the following should be considered: a) actual costs incurred whether in WIP, inventory, residual inventory, or considered excess material, b) open commitments - the portion of purchase orders, or other contractual commitments, placed with suppliers which is not included in the WIP or inventory actual cost (normally this equates to parts that have not been received) c) balance of requirements – additional parts or non-recurring costs or services that are authorized but are not yet on purchase order, regardless of whether the requirements are released in an MRP system, and d) anticipated future residual inventory, obsolescence, excess usage, etc. The impact of progress payments or other supplier financing plans should also be evaluated to ensure no double counting of material costs is occurring, especially when estimated actuals are being used. Time phasing of the estimate to completion (ETC) should be accomplished in the manner in which performance is earned (receipt or issues).

Another important material topic is to what degree are parts shown in an IMS. This subject was discussed in the Executive Summary and is also addressed in the PASEG (referenced in the scheduling section). Companies need to assess which critical parts should be indentified in the IMS (if an IMS is utilized) and what is the method or process for identifying parts that are not normally critical but could become so due to late delivery.

The subject of material cost can be a source of confusion between development and production efforts. Some of this is driven by the nature of the types of costs – as noted above usually engineering activity associated with design work submitted as material cost from a supplier and often reported via a CPR versus hardware cost comprised of lower tier material cost and manufacturing labor typically related to a specific delivery date. Misunderstanding can also occur due to the need to understand MRP and purchasing processes as well as the information needed to understand material being at extremely low levels (i.e. cost by part) versus a discussion around work package cost.

There are many other detailed topics that cannot be adequately covered in this white paper, however companies should have established processes and be able to explain them for how material cost is planned, performance is earned, actuals are accrued and all of the potential variations that could occur.

Manufacturing Labor Topics

The other large cost driver in a production program is manufacturing labor (companies may refer to this as factory or operations labor). There are two primary categories of manufacturing labor – fabrication (building parts) and assembly (putting parts together, whether fabricated or purchased, to create the end product). As noted in the material discussion above, a large percentage of cost is purchased – in part due to companies outsourcing their fabrication efforts and focusing on assembling their product. However, many companies still fabricate parts, often in areas where competitive technology exists or because of production efficiencies at their facility.

One of the major differences between engineering work performed in development efforts and manufacturing work performed in production efforts is the use of standard hours to track and measure factory performance. Standards are most often used in fabricating parts but can be used in assembly operations. Companies with production activity typically have management systems in place that measure the cost and schedule status of production activity on a daily basis. Manufacturing labor standards in conjunction with MRP scheduling are usually at the heart of these production systems.

A direct labor standard is the specified time allowance and quantity of output (usually established through time and motion studies) associated with a particular labor operation. As such, standards are a quantitative measure of manufacturing labor tasks. Proper time standards are not derived from knowing what has been done, but knowing what should be done, as they define both a prescribed method and time allowance. MRP establishes requirements need dates for all parts on a BOM (Bill of Material) based on the end item deliverable dates. Fabrication and assembly parts are back scheduled from the end item deliverable using spans, banks, and queues. The spans used by MRP are typically derived from the labor standards for the manufacturing activity.

Industry has established that labor standards are an excellent process for managing their manufacturing effort. This same process can be utilized in EV systems, thus enhancing a company's ability to demonstrate management use of EV as the same process is used by both program management and operations management.

Since the standard is a quantitative measure of manufacturing effort, it can be used in the manufacturing baseline process. MRP will provide schedule dates for the parts in the BOM. Standards are applied to the parts and a time-phased spread of the standards is created. The standards spread is often used for shop floor metrics, such as manpower planning and past due analysis. EV metrics which measure to budget require the application of a budget factor (often referred to as a realization or efficiency factor). The budget is typically established from the proposal which was also based on a BOM and either historical actual hours or historical performance to standard. The baseline plan can simply be calculated by applying the budget factor to the time phased standards spread.

When standards are used, EV in manufacturing will be based on earned standards. Earned standards are those standards associated with completed operations. The budget factor (realization or efficiency) is applied to the earned standards to calculate BCWP or a percent complete can be calculated using earned standards and the total standards required to complete the effort. The percent complete would then be applied to the BAC to arrive at the BCWP.

Thus the detailed method used to calculate performance (standards completed versus standards planned) in the factory can also be used to calculate EV metrics. Sound company systems can then evaluate CVs and SVs at the control account or work package level and then if necessary, drive down to the low levels of detail to determine the cause of any variance.

The use of standards may be confusing for personnel who have not dealt with them previously. While this paper has provided a simplified explanation the main thing to note is that standard hours and BCWS hours will not be the same and require a factor as noted above to develop the BCWS spread and to earn BCWP. The advantages of standards are that they tie directly into the company's MRP and factory processes and are a completely objective form of EV measurement – the operation/task is complete or not. Not every company will use standards and may instead use actual hour history or that history combined with learning curves (to be discussed later).

Another unique manufacturing labor topic is the use of "setup" hours/cost. Setup cost is required to "set up" a process or a machine so that multiple units can be produced. Setup costs are typically found in a fabrication or machine shop environment. Setup costs may also be known as change over costs. Companies must determine a specific methodology for handling the setup cost. They often allocate the setup cost over the pieces that were produced during the setup. In other words, if 5 parts are machined with 1 setup, each part would assume 1/5 of the setup cost. Setup and run time (the time it takes to actually make the part after the machine has been setup) may be segregated within the contractors manufacturing systems. This also means that standards are segregated within the manufacturing systems as well. Companies must also have a methodology for determining the planned release logic or number of parts to be produced per setup. Typically an economic order quantity is developed per part based on the value of the setup and the value of the run time for that part.

Setup Costs can be a large driver of manufacturing labor costs, especially if low quantities of a part are being produced. As such, companies should have a method to account for and analyze setup costs. Changes to release logic could drive cost on a contract. Sometimes the group in charge of planning the manufacturing effort, production control, can drive a change to the release logic for reasons other than minimizing cost. Companies should have an early warning system for changes to their MRP logic which could drive cost increases due to the change in setup costs. This is important as EV data is rarely at a level where setup costs can be analyzed as setup is a portion of cost on a part and thus well below work package or control account level data.

Establishing a baseline when setup costs are part of the budget can also prove challenging. When a production contract is baselined, the hours for setup will likely be included in the budget (assuming the company charges the setup as direct labor and not to a pool). The release logic that was used for budgeting, by default, also becomes a part of the baseline. However, as MRP changes, the release logic may also change, thus changing the schedule for parts as well as the standards on the parts (since parts share setups based on the release logic). Companies must have a method for handling this change. Systems may not be in place to account for a baseline with one set of release logic and earning with another set of release logic.

Setup affects BCWS, BCWP, ACWP, and EAC. BCWS is dependent on setup since release logic must be assumed when budgeting a production contract. The release logic will affect the schedule of parts in the shop as some parts will be grouped and worked together. It will also impact the standards as the quantity of setups will be used to calculate the number of setup standards. If a contractor earns BCWP based on earning standards, setup will affect earning as well. In a machine shop environment, setup can be a significant part of the ACWP and can cause significant cost variances, depending on the release logic that is applied compared to the release logic that was estimated. In the same manner, EACs may increase or decrease as setup logic changes. Manufacturing systems must be used to perform any analysis of setup.

Another important area to understand concerning manufacturing labor is the use of learning curves. Just as setup cost is primarily related to fabrication efforts, learning curves are most often associated with assembly efforts (although learning curves can be applied to fabrication effort). Learning is the process by which a worker acquires skill, knowledge, and ability. When a new process is started, the performance of a worker is not at its best and learning subsequently takes place. Processes typically also improve as the product matures, which contributes to the rate of learning. As experience is gained, the performance of the worker improves, time taken per unit reduces and thus the productivity increases. The Learning Curve Theory explains this phenomenon. Learning Curve theory states that as the quantity of items produced doubles, costs decrease at a predictable rate. The constant percentage by which the costs of doubled quantities decrease is called the rate of learning. The slope of the learning curve is 100 minus the rate of learning. For example, if the hours between doubled quantities are reduced by 20% (rate of learning), it would be described as a curve with an 80% slope. Other names given to learning curve are Experience curve, Improvement curve, and Progress curve. Unit 1 on the curve is typically referred to as T1 and will align with the cost of that unit. Since studies show that the results of learning are regular enough to be predictive, cost estimates should account for the learning curve improvement.

Learning curve theory should be applicable to the budget baseline process and to the EAC process. However in some circumstances it may be difficult to apply learning in either case. A single contract typically has a large number of parts and budgeting or forecasting by unit could be very difficult unless an automated system is in place. Additionally, many parts may not be released or built by unit but rather as a lot or group. Learning in this case would manifest itself between lots or in increased productivity over time. The use of productivity measures, such as efficiency to standard may be the preferred method of accounting for learning in the EAC.

That said, for products that have not already been produced in large quantities, learning curves are typically applied to major assembly activity, often with different budgets established for each unit produced. This practice usually comes directly from the proposal phase of a project. Most companies use learning curves to predict the cost of high value assemblies by unit. Several approaches are used within an EVMS to account for learning curves in the baseline process:

1. Learning curves are used in the budget baseline process and are applied by unit. Each unit has a budget value based upon its place on the curve.

2. Average values from the proposal are used for the budget baseline process. Each unit of a like part would have the same value. Learning would only be visible when lot to lot comparisons are made or in improved performance or efficiency over time.
3. A hybrid of the above approaches is used where a select “few” high dollar parts are chosen to budget by unit using learning curve values. The remaining “many” parts are budgeted at the lot average.

Industries are more likely to account for learning in the grass roots or bottoms up EAC processes. EACs can take into account the learning within a lot and the learning between lots. High values parts may be tracked by unit and learning applied to each unit. The many detail parts may be forecast using standards and performance to standard with allowances for improved performance over time or as learning occurs.

The above discussions highlight the importance of CAM selection to manage manufacturing efforts. If the CAM’s background is in manufacturing then the above topics should be well understood. However, if the CAM comes from another discipline and they are overseeing manufacturing labor, training in the various manufacturing labor topics will likely be necessary. The above discussion also highlights the need for a company’s EVMS to be integrated with the other company systems so that there is an ability to drill down from summary level information into the part level detail or roll up the details to the summary levels. An effective EVMS in production will avoid the issues sometimes encountered where the EV data doesn’t sync with the performance in the factory.

Part Movement that Occurs in Production

As discussed earlier, a primary focus of a company’s production effort is to optimize the efficiency of producing the parts and final product. One way to achieve this is to combine the purchase or build of the same part or like parts so that larger quantity efficiencies occur. Another critical aspect of the goal is to ensure that the factory workers have the parts they need when they need them. While all companies strive to achieve this, the fact is that problems with purchased or fabricated parts will occur at times – whether due to a problem in the manufacturing process, a part that gets damaged in transit or for any variety of other reasons.

In order to keep workers supplied with the parts they need, industry has implemented enterprise level systems that gather requirements from multiple sources (multiple contracts) to group them together and allow for movement of parts between contracts and/or control accounts to ensure part availability for the worker is maximized. The term used to describe these systems is Grouping, Pegging and Distribution (GPD).

Standard functionality for Grouping, Pegging and Distribution has been around since the late 1990’s. GPD is based on Material Requirements Planning (MRP) that enables the grouping of common part numbers with multiple contract requirements. GPD provides for efficient lot sizing in project-based manufacturing and automates the assignment of costs to the project (program) receiving the product. The letters GPD stand for:

- Requirements **G**rouping
- Replenishments **P**egging
- Cost **D**istribution

In requirements grouping, common project requirements (demand) are grouped together and thus purchased or built parts can occur in larger sizes. In replenishments pegging, costs are "pegged" back to the originating project requirements. The pegging process assigns the supply objects within the group to the demand created by the individual WBS elements to satisfy the top level requirements based on First-In, First-Out. The supply objects scheduled to be completed the earliest will peg to the earliest demand. In cost distribution, the costs of the requirements (demand from projects) is assigned to the individual WBS elements within the group for which the production orders are pegged. Cost distribution always follows pegging.

Thus, among the benefits of GPD are:

- Common part numbers can be used interchangeably across multiple projects. Building/Buying the same items across several projects on the same production orders results in economies of scale
- GPD allows cross-plant demand planning
- GPD reduces manual cost transfers since pegging is a dynamic process where cost follows the material demand schedule and physical product. Units produced by a GPD production order are continuously pegged and re-pegged to the demanding work package until the part is consumed to the project.

Thus, when utilizing a GPD system, if a part originally scheduled to arrive gets delayed the next part in line will be "pegged" to a contract. As noted, cost will follow and thus the "part movement" takes place. A couple of illustrations may help explain the effects of a GPD system:

- A part may already have been built/bought and pegged to contract A. Performance and actuals accrue to contract A but contract A work does not require the part to be installed yet. Contract B has had a delay in the same part and needs the part as soon as possible. GPD thus will move the part on contract A to contract B and the associated performance and actuals will also move. A new part will then be built/bought to replace the part on contract A.

- The same scenario as above can be contemplated except from contract B's viewpoint. In the first bullet, the scenario is such that contract A was ahead of schedule (the part wasn't needed yet) but when performance and cost moved it reverted back to being on schedule (all else equal). For contract B, it may have been that the delayed part caused an unfavorable schedule variance but when GPD moved the part it now was back on schedule.

- Depending on the frequency of contract awards and delivery date requirements, it is conceivable that a part could move multiple times thus changing the performance status on multiple contracts each time the movement occurs.

The movement of performance and cost subsequent to customer reporting has resulted in some concern from government reviewers. The key for industry is to be able to explain the process, discuss the cost and schedule benefits of utilizing the GPD functionality, demonstrate how GPD works, and be able to identify impacts on variances resulting from parts movement in a GPD environment. Lastly, since GPD attempts to leverage production efficiencies across the company, it should be discussed/demonstrated that GPD does not favor one contract over another, but instead works to ensure a smooth production flow and economies of scale.

Some companies have not implemented the GPD functionality and still use the traditional part movement processes of loans (borrow/payback) and transfers. The goals of these processes are similar but the effects are different. In a loan, the physical part will move but the costs and therefore any performance earned does not change. This is in part due to Material Management and Accounting Systems (MMAS) requirements that costs do not transfer in a loan. The loan means that the sending contract still requires the part and will be paid back from the receiving contract. MMAS standards require "expeditious" repayment of loans. Thus if using loans it is possible that a contract that has taken performance and accrued actuals does not actually have the part in question and another contract that has not taken performance or accrued actuals (or at least not fully) actually has the physical part.

A related technique for companies that do not employ GPD is to utilize part transfers. Under this condition if a contract has parts that are in excess of requirements then in certain circumstances that part could be transferred (along with its associated cost) to another contract. Several things have to be considered for a transfer including the type of contract (parts acquired under a cost reimbursable contract are government property) and the effect of cost differentials between one contract's actuals and another's budget. A company must be able to demonstrate that parts are treated equally and consistently to ensure that transfers are not determined to be biased.

Part movement is unique in a production environment and necessary to achieve maximum efficiency for the factory. While it can affect EVM data, it should not do so in a significant way as long as parts are being fabricated and purchased to the schedule requirements or need dates. The key as with other topics covered in this paper is whether the process, any variances, or changes to data can be explained and/or documented.

Scrap and/or Rework

Scrap and rework are non-value outputs of production operations. Scrap may be defined as material in excess of the requirement or unusable (e.g., waste material) for production need as a result of production process yields (e.g., the remnant of aluminum sheet stock left over after cutting the maximum number of sheet-stock parts possible). Scrap can also be defined as unusable for production as a result of damage, spoilage, or other process quality escape. Indentured scrap may be defined as the detail parts that are unusable due to the scrap of their next assembly. Indentured scrap must be re-fabricated along with the scrapped assembly. Rework may be defined as the additional material (including production, processing materials, and supplies) and effort (production labor, inspection, material review board, liaison and quality engineering, production planning, etc.) required to bring a production part, subassembly, or assembly into conformity with production and quality standards.

Scrap and rework can result from a number of causes during the production process to include limitations of production yield (the part may be extremely difficult to make), production quality capability or variability, human error, or a variety of other causes. Lean, Six Sigma, Quality Function Deployment (QFD), and other process improvement initiatives can help improve the reliability, consistency, yield, through-put rate, and quality of production processes and thereby reduce scrap and rework incidents; however, a minimal amount of scrap and rework may still be anticipated and planned for in the production process.

Typically, companies will have historical data that tracks the effects of scrap and rework on their processes. The MRP systems will usually account for scrap in planning and scheduling by adding attrition parts into the plan and/or by expanding span times. Rework is usually accounted for in an increased span and cost for labor and materials.

For production planning and EVM, scrap and rework present a challenge given their non-value-added and potentially unplanned nature. Budgets and schedule cushions may be established for scrap and rework based on either prior production performance or estimates. Additionally, work stations or locations where scrap and rework are likely to occur can be identified and used for budget and scheduling purposes. EVM treatment of scrap and rework can vary given the nature, rate, and quality of the production process in question. As an example, high-rate, highly-automated, and highly controlled production processes would differ substantially from low-rate, highly-manual, highly-variable processes as to the rates and causes of scrap and rework. As a result of these differences, EVM handling of scrap and rework could be tailored for the production process in question and the company's approach to EV.

For EVM, scrap and rework should be considered and appropriately planned for based on the specific conditions in effect for the production process in question. As noted previously, EVM handling of scrap and rework should be decided based on production factors such as rate, degree of automation, level of variability and quality, complexity of products produced, company approach to EVM, etc. Companies may also differ in accounting treatments for the cost of scrap and rework, thus some companies may charge these cost as a direct charge while others charge into a pool and may allocate the cost as a rate. Regardless, scrap and rework should always be included in the EAC analysis.

Potential issues within EVM for handling scrap and rework include the following:

1. As scrap and rework are non-value added aspects of production, should they earn "value" or performance? That is, should historical rates of scrap and rework be budgeted and then as it occurs performance is earned.

2. Should budget and schedule cushions be established for unplanned scrap and rework? If so:
    a. What is the basis of estimate for such budgets and schedule cushions?
    b. Should this budget and schedule be reflected in the Control Account (CA) where the scrap and/or rework were initially caused or in a separate CA established to capture unplanned, non-value added work?

3. If budget and schedule are established for scrap and rework, but if actual scrap and rework rates are lower than planned, how is Performance earned? What happens to budget unused due to lower than planned (a good thing) scrap and rework rates?

4. How should scrap and rework be reflected in ETCs and EACs?

5. How should cannibalization of parts (e.g., at the direction of the customer, the removal of a usable, conforming part from a "donor" ship or assembly for use on a "receiver" ship or assembly) be treated?
    a. How should the reinstallation of parts on the donor ship or assembly be treated?
    b. How should this condition be treated if occurring after initial production completion of the donor ship or assembly?

6. Companies that de-earn (reduce previously earned BCWP) when scrap occurs must insure that they adequately explain the reasons for de-earning.

7. Indentured scrap may be difficult to identify in production systems.

All of these and other questions should be discussed in company process instructions, treated consistently and personnel should be trained in the process to be able to explain causes of variances related to scrap and rework.

Production Support Labor

For the purposes of this paper, production support labor includes all the other functional labor activities that assist, support or inspect the manufacturing labor efforts. These would include but are not limited to tooling, quality, production control, industrial engineering, design engineering (support to the manufacturing line), manufacturing engineering, manufacturing supervision and other related disciplines.

Companies have a myriad of ways in which production support labor is budgeted and how performance is earned. At any one company, some of the activity may be direct charge, some may be indirect, and some may be charged to a pool and then allocated per a base cost relationship (usually manufacturing labor hours or dollars). Some examples are:

- Engineering effort that supports the manufacturing line may be charged direct to the applicable effort/contract or charged to a pool and allocated to all contracts with the appropriate base relationship. Charging engineering support labor to a pool may be necessary as a manufacturing issue may occur across multiple products or multiple lots of a product and the effort therefore applies to multiple contracts.

- Similarly, tool maintenance may be charged direct to a contract but other companies may charge these costs indirect or to a pool because the tool in question is used for multiple contracts and therefore the cost should be allocated appropriately.

- For each of the various support labor costs, the same scenarios as noted above can apply.

- Quality inspection may be charged similarly but it is typically unique in that there is a direct relationship to the inspection time and part and the associated manufacturing labor. As such, inspection cost is often “apportioned” such that the budget and performance (usually calculated as a percent of the manufacturing labor hours) exactly tracks to the timephased profile of the manufacturing labor.

Another aspect of these costs is that often the cost is treated as level of effort (LOE) as it is not known when support will be needed and therefore it cannot be planned. Inspection typically isn’t charged as LOE but if charged direct, engineering support labor, supervision, tool maintenance and other disciplines are often LOE. These support labor efforts are sometimes contracted for differently or separately. Customers may issue contracts for sustaining activities (often on an annual basis) and therefore support labor is charged to one contract – covering support to as many lots or other contracts that are ongoing – while the actual production of the product is covered under a separate contract.

While the manner in which support labor is budgeted and earned may be different across companies, certain characteristics of this activity should be constant:

- The manner in which the cost treatment is made should be covered in the company’s disclosure statement

- EV techniques such as an apportionment method should be addressed in the company’s EV process documentation

- CAMs should be trained and understand the various ways in which these costs are planned and performance is earned

- Other EV processes are equally applicable to these types of effort – costs should be scheduled in periods where the activity takes place, EACs are updated frequently to reflect performance trends, change management processes are followed, and variances to plan are analyzed and addressed.

Appendix A
Primary Working Group Participants

Jon Adams – Lockheed Martin
Laura Ayres – Price, Waterhouse & Coopers
David Bates – Price, Waterhouse & Coopers
James Burke - Raytheon
Kenly Burkhart – General Dynamics
Bill Chitty – U.S. Navy
Blake Crenshaw - Raytheon
Toni Dooley - Boeing
Karen Frisk – Pratt & Whitney
Fran Fulton – Northrop Grumman
Scott Gring – Lockheed Martin
Kim Herrington – Bell Helicopter, Production EVM Working Group Lead
Shannon House – U.S. Air Force
Jennifer Hurley – Northrop Grumman
Janie Jones – Bell Helicopter
Jon Kanicsar – Orbital
Bob Loop – Delta Resources/U.S. Navy
Christa Martin – Rockwell Collins
Dave Pantano – Lockheed Martin
David Peterson – Bath Iron Works
Aaron Risdal – Delta Resources/U.S. Navy
Dave Roberts – Consultant
Michele Rouse - Sikorsky
John Santora – Northrop Grumman
Mitzi Shepard – Lockheed Martin
Ed Silvia – Raytheon
Melissa Slaughter – Delta Resources/U.S. Navy
Rick Smith – Rockwell Collins
Brad Temple – Rockwell Collins
Tracie Thompson - ATK
Beau Willis – U.S. Navy

Appendix B
Common Production Terms

Bill of Materials	List of raw materials, subassemblies, intermediate assemblies, subcomponents, components, parts and the quantities of each needed to manufacture an end item.
Critical path	A sequence of activities in a logical network that has the longest total duration through a designated end point, such that a delay to any one of those activities will cause a corresponding delay to that end point.
Earned Standards	Labor standard associated with a completed operation. When labor standards are earned, this forms the basis of BCWP.
Excess Parts	Parts purchased or manufactured that are greater than the quantity required to manufacture the contracted quantity. Depending on contract type and customer, the excess parts can be transferred to other contract requirements and used there.
Integrated Master Schedule	A logically integrated, network schedule containing the activities used to define all of the discrete work packages and planning packages necessary to support project requirements.
Labor Standard	Target number of hours to perform a shop floor operation. Standards are typically fixed unless a process changes or when there is a periodic evaluation. A realization factor is applied to achieve the budgeted hours for the operation.
Material movement	Processes used by companies in which parts are moved (between contracts, control accounts, etc). Typically differs by company and cost/performance may or may not move depending on the circumstance.
Non Recurring	Non repetitive elements of development and investment cost that generally do not vary with the quantity being produced, irrespective of system life cycle phase and the appropriation.
Offload	Work that is transferred to a supplier typically due to temporary capacity constraints.
Outsource	Work that is permanently moved to a supplier.
Production	The act of manufacturing goods.
Production Earned Value	The use of a company's production and earned value systems regardless of contract type or phase.
Production Lot	A grouping of parts or end items that receive a similar treatment.
Production management system	A software based Production planning and inventory control system used to manage manufacturing processes. Systems may vary by company.
Production Master Schedule	Schedule that identifies major end item deliverables that is the basis for MRP planning.
Realization	Ratio between planned standards and actual hours. Also forecasted to develop a budget or estimate at complete. Typically developed via historical performance.
Recurring	Repetitive elements of production (manufacturing labor and material cost) and support cost that may vary with the quantity being produced, irrespective of system life cycle phase and the appropriation.
Residual Material	Material charged to a contract to manufacture a product(s) but not consumed during the process.
Rework	Effort required to return a defective part back to intended condition.

Run cost	Cost of the individual unit manufactured. Associated with setup – run time is the time it takes to build the item while setup is the time needed to prepare the machine in order to make the part.
Scrap	A part that is damaged during the manufacturing process that is not usable and cannot be repaired.
Set up costs	Cost required to "set up" a process or machine so that multiple units can be produced. Typically found in a fabrication or machine shop environment.
Shop Floor Operation	One of the set labor tasks necessary to produce a part. Typically the lowest level task identified.
Standard Cost	A company accounting treatment used to pre-assign value to a part or product.
Travelled Work	Circumstance where an assembly moves between stations/fixtures/tools and less than 100% of the parts are installed. Missing items will be installed at another station/fixture/tool later in the sequence.
Unit Cost	The cost of a completed part or product. Includes all recurring cost associated with the cost of making the item. Would not include non-recurring cost to develop/design/test the part/product unless the intent was to amortize all the non-recurring cost into an average unit cost.