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AN EARNED VALUE TRACKING SYSTEM

FOR SELF-DIRECTED SOFTWARE TEAMS

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Abstract

As organizations begin to pursue the benefits of self-directed work teams (SDWTs), they must revise their traditional methods of management. SDWTs assume more of the responsibility for managing product development and perform many of the tasks previously done by managers. Consequently, a redesigning of the tools and procedures traditionally used to manage projects is required to address the information and decision-making needs of SDWTs.

Essential to any management system is the need to plan and, as work progresses, to know accurately the budget and schedule status as compared to the plan. An earned value tracking system is an excellent way many software organizations document their detailed plans and measure work progress. On the AEGIS Combat System Interface Simulator (ACSIS) project at Lockheed Martin Government Electronic Systems (GES) in Moorestown, New Jersey, a system of earned value tracking has evolved that has proven to be successful in enhancing a SDWT environment. At the core of the system s success, is a process by which each project team and each individual is involved in the establishment of an earned value plan, in providing status updates, and in reviewing earned value reports.

Introduction

Several years ago two ACSIS process improvement initiatives combined to produce the ACSIS Earned Value Tracking System (EVTS): the development of SDWTs and the attempt to devise a more disciplined way to perform project planning and tracking. The two endeavors became mutually supportive. This presentation describes the ACSIS EVTS development, process, and results.

Project Background

Lockheed Martin GES develops the radar and combat systems for AEGIS guided missile cruisers and destroyers for both the U. S. Navy and internationally. The AEGIS Combat System Interface Simulator (ACSIS) plays a critical role during the development of each major AEGIS upgrade. ACSIS supports the AEGIS shipboard computer programs element integration and test, system test, life-cycle maintenance, and also, crew training. There are three ACSIS software development teams of from 8 - 15 software engineers each, one for each of the ACSIS program elements.

Self-Directed Work Team Considerations

Kimball Fisher in his book, *Leading Self-Directed Work Teams* [1], states many businesses are sadly lacking in information that can be used to manage the business at each team s level. At the same time they are inundated with reports and paperwork that quantify things for reporting up and out of the organization. Although these kinds of information are helpful for coordinating things across the organization, they add little value for self-directed work teams. Earned value tracking is a powerful means of tracking work progress against schedule and budget, but is usually regarded as a management task solely for the purpose of fulfilling senior management, program management, and customer review requirements. The potential feedback benefits of earned value tracking to work teams or even individuals may often be overlooked by software organizations.

The benefit of earned value tracking to the individual is illustrated in Watts Humphrey s Personal Software Process (PSP) course in which earned value tracking is prescribed for individuals to measure their work progress, to evaluate the impact of changes to the plan, and to discover how to improve one s planning skills [2]. This can also be applied to SDWTs. SDWTs take responsibility for many traditional management tasks, such as

scheduling, budgeting, and tracking work progress, and therefore, require the training, tools, and information needed to make decisions, learn from their mistakes, and offload tasks that traditionally have been left to a manager to perform.

SDWTs evolve through a number of maturity levels before they are fully self-directed [3]. The three ACSIS teams are not all at the same level of SDWT maturity. One team, in particular, is more self-directed than the other two who are more leader-centered. However, the ACSIS EVTS proved to be effective for each of the three teams and could be applied to any team-oriented environment where individuals are given some control over the planning of their tasks.

Earned Value Tracking System Goals

The ACSIS EVTS provides information that can be used at all levels of the organization, i.e., from senior management to the engineering team level, for objectively measuring a project's work progress against an approved schedule and cost budget. The following goals were set for the ACSIS EVTS and subsequently achieved:

- To allow the project manager(s) to control the overall project-level budget and schedule parameters, but still allow each ACSIS team as much control as possible in scheduling and budgeting their team tasks.
- To be flexible, yet disciplined in handling changes. As a simulator ACSIS is subject to significant schedule fluctuations as the testing needs of the ACSIS users change. The EVTS has to be flexible in being able to accommodate replans without undergoing time-consuming approval cycles.
- To provide accurate information that allows the teams to confidently negotiate replans with other engineering groups and the ACSIS users with as little management involvement as possible.
- To provide budget and status in terms of labor days instead of dollars, and yet be able to reconcile the labor day budget status with the dollar spent status easily. It is much easier for engineering teams to relate to schedule and budget information in hours or days than in dollars. This also allows the freedom of tracking actual expenditures on tasks at a lower level of detail than is provided by the organization s financial system.
- To be as unobtrusive as possible to the ACSIS engineers, many of whom have allergic reactions to paperwork. By involving everyone in contributing their plans and status to the EVTS, no one or two people are over-burdened in maintaining the system, including the team leaders and managers. Also, the EVTS process is automated as much as possible through the use of Microsoft Excel spreadsheets and macros.
- To provide support personnel trained in collecting the plans, executing the macros, and generating the reports.
- To provide readable cost and schedule status reports easily tailorable to provide varying levels of detail for senior management review, project manager review, team review, and individual review. This is achieved by bringing all pertinent data together into the master spreadsheet where cost and schedule performance indicators and variances are calculated and the outline feature of Excel is used for tailoring reports to varying levels of detail.
- To provide training to teach the terminology, the process, and how to read the reports.

Process Description

A standard set of earned value indicators and terminology are used for the EVTS and are defined below, as well as, the EVTS process steps.

Definition of Indicators

- Budgeted Cost of Work Scheduled (BCWS) - the planned costs of tasks scheduled to be performed during a given period
- Budgeted Cost of Work Performed (BCWP) - the planned costs of tasks that were accomplished during a given period
- Actual Cost of Work Performed (ACWP) - the actual costs incurred for performing tasks during a given period
- Estimate-to-Complete (ETC) - the estimate of the cost to complete a task from the current point in time
- Indicated Final Cost (IFC) - the estimated final cost regardless of the task s budget (ETC + ACWP)
- Budget At Completion (BAC) - the full authorized budget

- Estimate At Completion (EAC) - the same as IFC or can be computed assuming past performance continues (BAC / CPI)
- Cost Variance (CV) - the difference between the budgeted cost of completed tasks and the actual cost incurred (BCWP - ACWP)
- Schedule Variance (SV) - the difference between the budgeted cost of completed tasks and the scheduled cost (BCWP - BCWS)
- Cost Performance Index (CPI) - the relationship between the actual costs vs. the budgeted costs for tasks that have been completed (BCWP / ACWP). A CPI greater than 1 indicates a cost underrun.
- Schedule Performance Index (SPI) - the relationship between the tasks that have completed vs. the tasks scheduled to be completed (BCWP / BCWS). An SPI greater than 1 indicates ahead of schedule.

Process Steps

1. When authorized funding is received for a new project, the project manager submits to the ACSIS teams a preliminary Work Breakdown Structure (WBS) that defines each task to be tracked by the EVTS. Large tasks are broken into manageable work packages. The WBS is limited to three levels of task breakdown and normally follows this hierarchy: program element divided into functions divided into development phases. Each program element team negotiates WBS changes with the project manager if they desire to track their tasks differently.
2. The project manager determines the overall labor day budget based upon the labor cost of the specific people that will be assigned to the job. Each task on the WBS is then given an initial budget based upon the estimate documented in the original proposal Basis of Estimate (BOE). The project manager also determines the amount of reserve to withhold, if any. A WBS/Budget sheet is then distributed to the teams that includes the time entry charge numbers to be used.
3. As the software performance specifications are received, the element teams perform impact assessments. Based upon the more current estimates, each ACSIS team may negotiate budget shifts with the project manager. If more funding is indicated for the project, the project manager must negotiate with the Program Management Office (PMO) for additional funding or for a reduction in the technical requirements.
4. A new WBS/Budget sheet with any budget adjustments, as agreed upon with the teams, is then generated by the project manager and redistributed to the teams.
5. Using the WBS/Budget sheet as the input, a Microsoft Excel (spreadsheet) Macro is run by the metrics administrator to create the Master Spreadsheet used for accumulating all ACWP, BCWS, and BCWP data, calculating the earned value status indicators, and generating charts and reports.
6. The cognizant engineers then define the break down of the lowest level tasks of the WBS into smaller subtasks on a BCWS/BCWP Worksheet. Figure 1 illustrates the contents and use of the BCWS/BCWP Worksheet.
7. Using the BCWS/BCWP Worksheet, each engineer assigns planned start dates, completion dates, and labor day budgets to each subtask in accordance with the teams schedule. From this information an Excel macro creates a staffing spread (BCWS) over the planned period of performance for each of the subtasks.
8. The subtasks BCWS from the BCWS/BCWP Worksheet are rolled up to establish the (BCWS) plan for each WBS task on the Master Spreadsheet. This BCWS plan is very accurate because it is based upon the very short, well-defined tasks of the individuals doing the work. (The BCWS/BCWP Worksheet is one level of detail lower than any of the tasks on the Master Spreadsheet).
9. The project manager defines the BCWS plan for the Level-of-Effort (LOE) tasks, e.g., administrative and management tasks that have no discrete milestones
10. At the end of each reporting period (usually monthly):
    - The metrics administrator passes out the BCWS/BCWP Worksheets from the previous reporting period.
    - Each engineer updates their task status (BCWP) and marks any replans (BCWS) on the BCWS/BCWP Worksheet and has the team leader review it for accuracy and compliance with the criteria for changing task schedule or budget. The worksheets are returned to the metrics administrator.
    - Excel Macros update the BCWP and BCWS for each WBS item in the worksheet (see Figure 1) and transfer them to the Master Sheet.
    - The actual labor charges (ACWP) for each WBS item from the organization s accounting system are received, downloaded onto an Excel spreadsheet, and transferred to the Master Sheet via Excel macros.
    - The dollars spent are also entered onto the Master Sheet by the Project Manager. The spreadsheet calculates the difference between the percent of the dollar budget spent versus the percent of the labor day budget expended. Using this difference and the computed labor day Cost Variance for the total project, an Adjusted Cost Variance in labor days is computed. The project manager may decide to establish a new labor day budget if it is not tracking with the cost budget.
    - Status reports and charts are generated from the Master Sheet and distributed for team analysis and management reviews. When possible, soft copies of the Master Sheet are provided to the managers and team members; otherwise, a detailed hard copy report is made available. The soft copy report allows

more freedom for viewing the data at various levels of detail using the Microsoft Excel outline feature. Figure 2 provides an example of one of the many possible Master Sheet views. Figure 3 is an example of a status chart that can be generated for any task at any level on the Master Sheet.

- Plans are adjusted and actions taken to address any problems that are indicated by the reports.

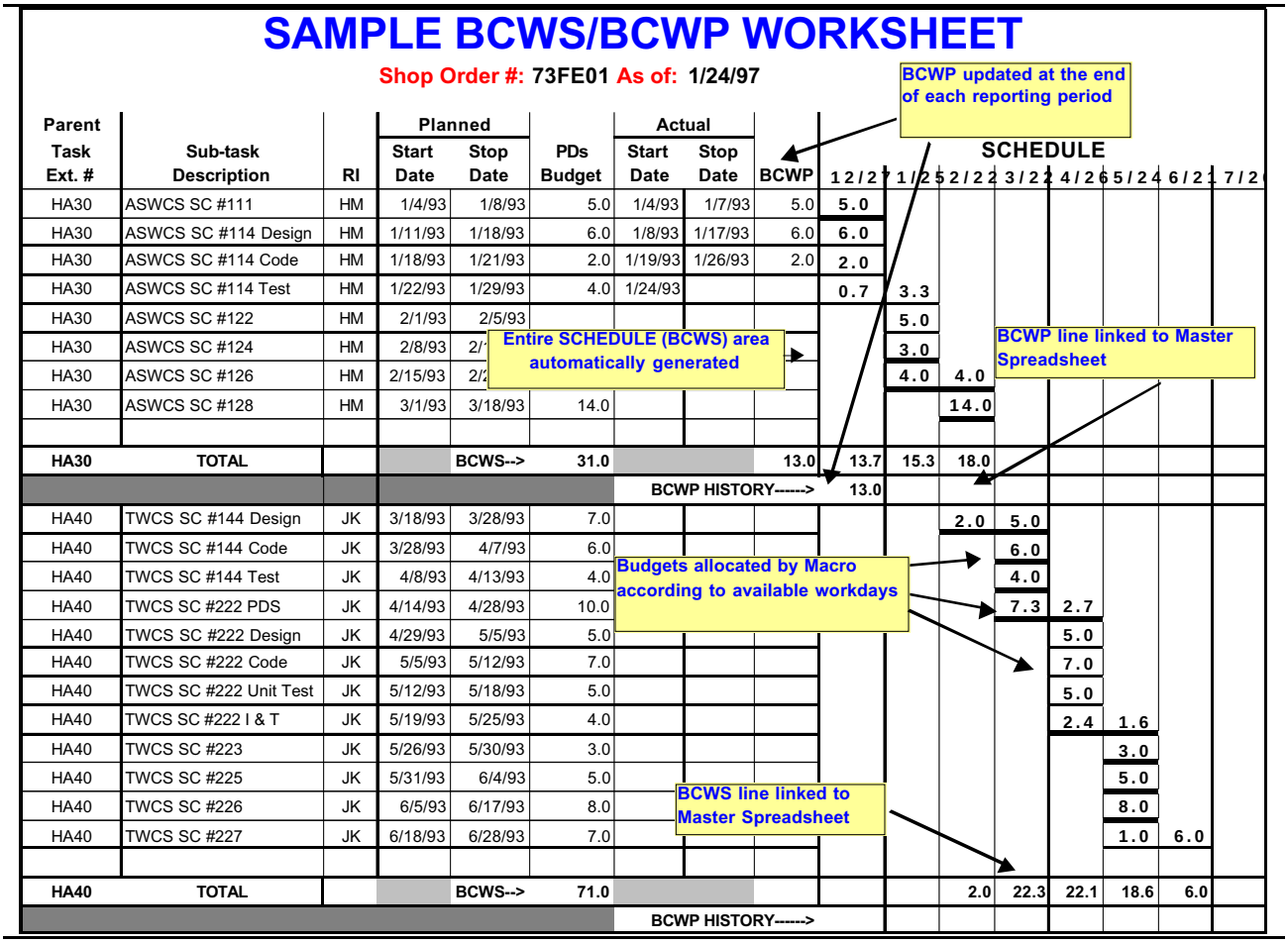

Figure 1. Sample BCWS/BCWP Worksheet

Earned Value Tracking System Guidelines

The BCWP on the BCWS/BCWP Worksheet for each subtask is computed as follows:

- For tasks with discrete milestones, when the Actual Start Date for a subtask is filled in, 50% of the subtask s budget is earned. When the Actual Stop Date for a subtask is filled in, 100% of the subtask s budget is earned.
- For Level-Of-Effort tasks, each month the BCWP is set equal to the tasks BCWS value for that month.

The lowest level subtasks should not exceed 15 working days. This ensures the monthly accrued BCWP accurately represents the work performed. Once budgets and schedules are established, changes are subject to approval. The approval authority required depends upon the severity of the change. For example, to increase the funding level of the ACSIS cost account, the PMO must be involved, but to make budget adjustments to tasks that do not impact a teams total budget, only the team leader s approval is needed. To make budget adjustments among teams, the project manager may be involved with negotiation among the teams.

A consistent set of schedule and budget change criteria are established and communicated as a part of the EVTS process training to ensure changes aren t made just to make the status look good. A legitimate reason is required before a team leader will permit engineers to change their original plans. This is to ensure the quality of the original planning and the performance of the team against the plan is accurately represented by the EVTS reports. At the same time, changes must be made to accurately reflect new agreements made either internally or with external groups. Reporting status against an out-of-date schedule can also be misleading and confusing.

(A feature that currently is not in the EVTS, but will be added, is the ability to capture the original BCWS for reference while still reporting against the revised BCWS).

Sample Mastersheet - Detailed View of Subtask Totals

As of:	March 23, 1997		REPORT PERIOD TOTALS									
WBS	TASK DESCRIPTION		TOTAL	CPI	SPI	CV	SV	CV%	SV%	BAC	EAC	VAR
	CDSIS											
	CDSIS - Orig B6P1 Tasks	ACWP	280.9	0.55	1.03	-127.6	4.1	-83%	3%	178.1	326.3	-148.2
	TOTALS	BCWS	149.2									
		BCWP	153.3									
	CDSIS Capture of IOC-96	ACWP	79.3	0.96	1.00	-3.1	-0.0	-4%	0%	113.7	118.3	-4.6
	TOTALS	BCWS	76.2									
		BCWP	76.2									
	CDSIS CEC-to-ACTS Module	ACWP	24.6	2.81	1.00		0.0	64%	0%	107.8	38.3	69.5
	TOTALS	BCWS	69.3									
		BCWP										
	CDSIS Other OPEVAL-98 Mods											
ZH0	Transition Support	ACWP					0.0	0%	0%	21.0	0.0	21.0
		BCWS										
		BCWP										
RH0	Requirements Review	ACWP	30.2	0.42	1.00	-17.5	0.0	-138%	0%	12.7	30.2	-17.5
		BCWS	12.7									
		BCWP	12.7									
PH0	Preliminary Design	ACWP	16.3	1.28	1.00	4.5	0.0		0%	20.8	16.3	4.5
		BCWS										
		BCWP										
DH0	Detailed Design	ACWP	88.7	1.60	0.99	55.4	-1.4		-1%	143.5	89.6	54.0
		BCWS	143.5									
		BCWP	142.1									
CH0	Code and Unit Test	ACWP	106.7	1.08	0.99	8.6	-1.0	7%	-1%	119.2	110.3	8.9
		BCWS	116.3									
		BCWP	115.3									
IH0	Element Integration and Test	ACWP	12.2	2.26	0.71	15.3	-11.3	56%	-29%	83.0	36.8	46.2
		BCWS	38.8									
		BCWP	27.5									
UH0	Maintenance/Rework	ACWP	2.6	.00	.00	-2.6	0.0	0%	0%	68.0	0.0	68.0
		BCWS										
		BCWP										
	CDSIS Other OPEVAL-98 Mods	ACWP	257.5	1.24	0.96	60.9	-13.7	19%	-4%	468.2	378.6	89.6
	TOTALS	BCWS	332.1									
		BCWP	318.4									
	CDSIS	ACWP	669.7	0.92	0.97	-52.5	-16.3	-9%	-3%	963.5	1045.5	-82.0
	TOTALS	BCWS	633.5									
		BCWP	617.2									

Task Summaries

Subtask Details

Element Summary

Figure 2. Sample View of the EVTS Master Sheet

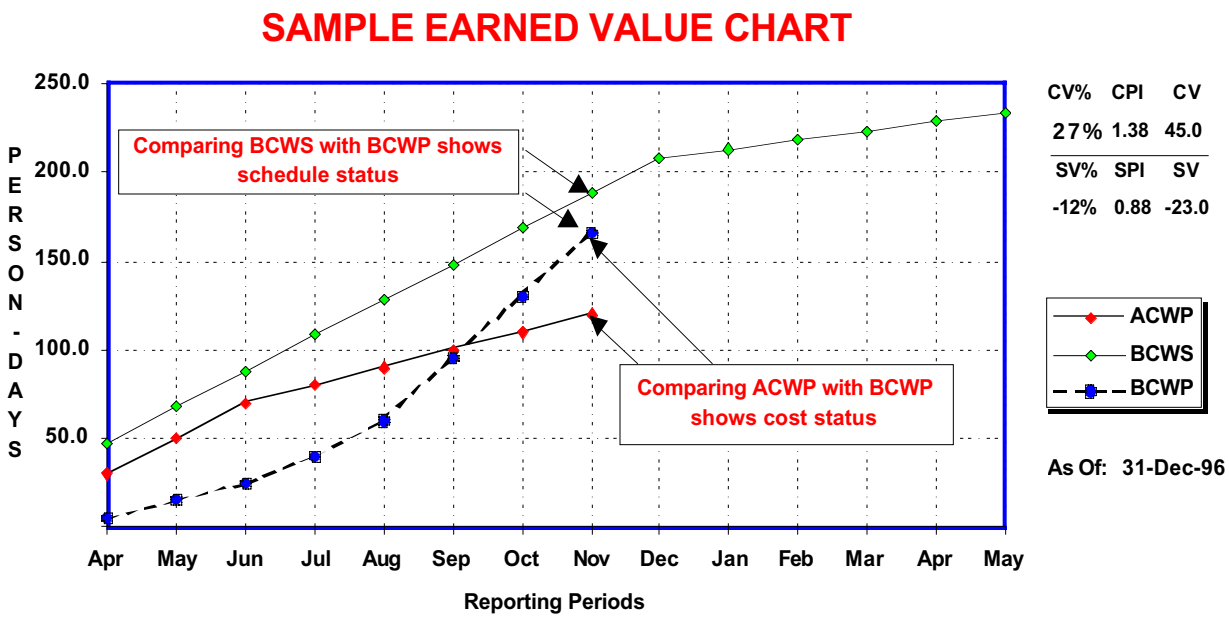

Figure 3. Sample Earned Value Chart

Implementation Considerations

The successful implementation of the EVTS eventually required the following:

1. In-house competence in spreadsheet design and macro writing and availability of the spreadsheet/macro designer to address problems and questions
2. Knowledge of project management principles, including earned value tracking, as well as, an understanding of the needs of SDWTs
3. The ability to download labor hour information from the organization s time entry system
4. A training course with follow-up support for teaching the EVTS terminology, process, and analysis guidelines to the engineers
5. A support staff trained in administering the EVTS

Results

The ACSIS EVTS has proven to be very successful. Senior managers and program managers exhibit more confidence than before in the status they are presented. They trust the process and like the fact that the charts they are shown reflect detailed planning and well-documented, objective status.

The EVTS has provided the project managers with more detailed insight into the budget and schedule status of all tasks. Problems are apparent much earlier than before the EVTS was established and root cause analysis is done quickly. Also, in many cases when the need arises to negotiate schedule or budget changes with the PMO, the data from the EVTS is very helpful in supporting the project manager s cause. The EVTS data from completed projects has also proved very valuable in planning new projects. For example, the ratio of design time to coding time for a particular team, or the percent of the total budget that should be allocated to level-of-effort administrative tasks, can be accurately predicted.

The EVTS has aided the project managers in being more empowering. The managers are able to establish the initial budgetary parameters, negotiate changes as needed with the teams, and receive detailed status in the earned value reports. Once confidence in the process is established, the project managers do not feel compelled to spend as much time in status-related activities and are freed up to pursue more strategic, forward-looking

activities. The EVTS and the SDWT environment have contributed to ACSIS managers being able to take on additional responsibility.

The ACSIS engineers and especially the team leaders have developed project management skills that are normally only taught to new managers. All the team leaders and most of the engineers have taken an interest in the EVTS and in the reports that are made available for review. The engineers are significantly more aware of their individual task budgets and schedules than ever before, and have improved noticeably in their ability to plan and meet their own commitments. There also seems to be evidence of individuals being more interested in their team s success when they are able to see charts reflecting their team s performance.

In summary, the EVTS has provided the three ACSIS teams with improved insight into the project's status leading to better decision-making regarding schedule and budget changes, better understanding of risks or problem areas, improved planning, and improved communication of status to all levels of the organization, with less management participation than in the past.

References:

[1] Fisher, Kimball, *Leading Self-Directed Work Teams.* New York, NY: McGraw-Hill, Inc., 1993.

[2] Humphrey, Watts S., *A Discipline for Software Engineering*. Reading, Mass., Addison-Wesley Publishing, 1995.

[3] Orsburn, Jack D., Moran, Linda, Musselwhite, Ed, and Zenger, John H., *Self-Directed Work Teams*. Burr Ridge, Ill., Irwin Professional Publishing, 1990.