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PERFORMANCE MEASUREMENT SYSTEM: RECENT SYSTEMS DEVELOPMENT AND APPLICATION

MASTER

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PERFORMANCE MEASUREMENT SYSTEM: RECENT SYSTEMS DEVELOPMENT AND APPLICATIONS

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Performance Measurement System: Recent Systems Development and Applications

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INTRODUCTION

An abundance of management systems exist from which to choose the one most likely to solve the problems of a given project or program. Often, the most difficult task is deciding which system, from the plethora available, to utilize.

In their basest sense, most management systems are extremely similar. They require that work be organized, planned, budgeted, analyzed, reported and revised (as necessary). What then sufficiently distinguishes one from the other to enable the best selection?

This question faced the Department of Energy (DOE) in the early seventies -- specifically as it related to the Fast Flux Test Facility (FFTF) project currently nearing completion at the Hanford Reservation near Richland, Washington (U.S.A.).

In 1974, the General Accounting Office (GAO) reviewed the project and made a number of recommendations regarding the need for expanded management systems. In early 1975, considering the GAO findings, the DOE Division responsible for the FFTF project decided to adapt an earned value approach to the reactor facility construction environment.

The earned value approach had been developed and utilized by the Department of Defense (DOD) for some of their projects. The increasing complexity and cost of developing major weapon systems over the past 25 years led the Department of Defense to develop more sophisticated management systems which produced accurate and timely cost and schedule performance information. The genesis of the earned value technique was the Navy's Polaris program development of PERT (Program Evaluation and Review Technique) and PERT/Cost in approximately 1960.

In 1964, the Air Force added the "value earned for work accomplished" approach to project cost/schedule planning and control. Specifications developed in conjunction with the earned value concept were, in effect, standards that the contractor's internal management system had to meet in order to satisfy the Air Force's needs. In 1967, the Air Force criteria approach was adopted by all the military departments and the concept evolved into the Cost/Schedule Control Systems Criteria (C/SCSC) technique set forth in the DOD directives and guides shown in the list of references. Thus, borrowing from the Department of Defense, the Department of Energy adopted the C/SCSC technique and called it the Performance Measurement System (PMS).

PMS VS CONVENTIONAL MANAGEMENT CONTROL SYSTEMS

To differentiate between the PMS and a conventional management systems approach, the question that was never answered by the conventional system

was "How many dollars worth of work was accomplished for the money spent?" Although the other systems dealt with cost status and schedule status, they never linked the two together.

This linking-pin is called, in PMS terminology, the earned value or performance indicator. The following example should help explain the concept of earned value.

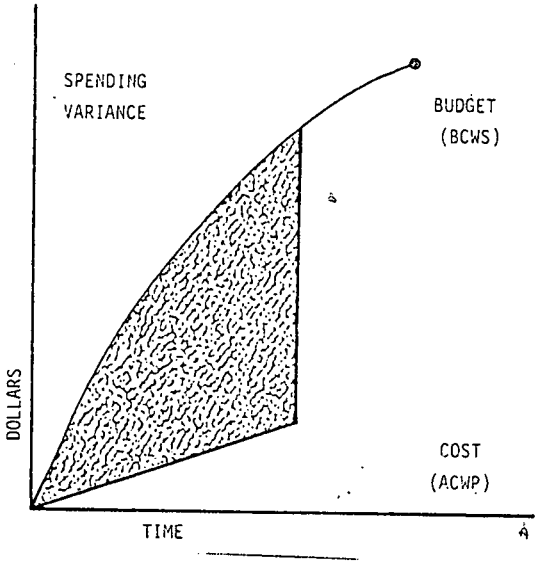
Figure 1 shows a conventional plot of the budget versus the actual costs for a particular job. What is shown leads one to believe that at the current time, the budget planned for the respective time period is being underspent.

FIGURE 1

CONVENTIONAL ANALYSIS

GIVES INDICATION OF HOW MUCH HAS BEEN SPENT AND HOW MUCH IS LEFT

DOES NOT INDICATE HOW MUCH HAS BEEN DONE OR IF SUFFICIENT RESOURCES EXIST TO COMPLETE THE REMAINING WORK.



Now, Figures 2 and 3 show the same job but with the earned value indicator added. The time-phased budget (called Budgeted Cost of Work Scheduled or BCWS) has been plotted. Then, the line representing the value for the work actually performed during the sample period (Budgeted Cost of Work Performed or BCWP) was also plotted.

The result is a means for measuring schedule performance, in dollars worth of work, ahead or behind schedule. This differs from other systems where schedule status is evaluated in terms of time ahead or behind schedule with no dollar value attached. As shown on Figure 2, the job is behind schedule.

FIGURE 2

PMS ANALYSIS

COMPARISON OF WORK PERFORMED (BCWP) WITH BUDGET (BCWS) GIVES SCHEDULE VARIANCE.

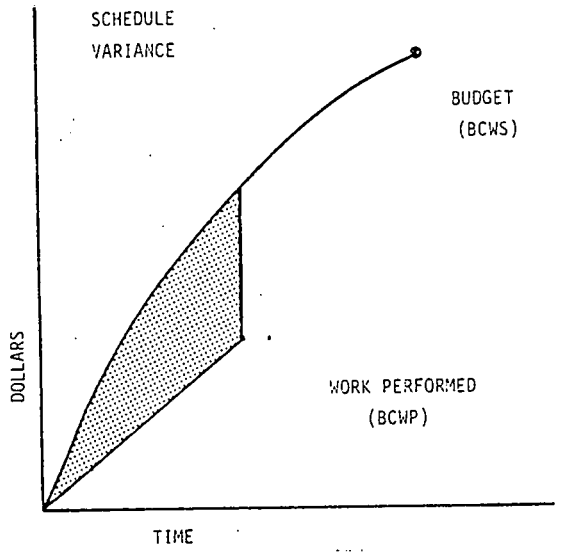
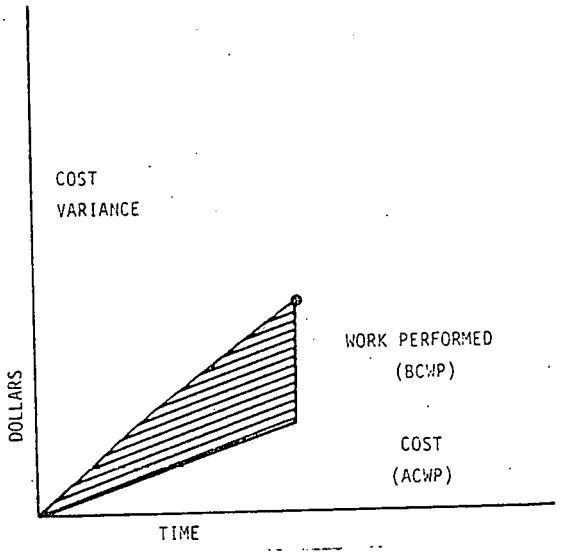


FIGURE 3

COMPARISON OF WORK PERFORMED (BCWP) WITH COST (ACWP) GIVES COST VARIANCE.



Now, by turning to Figure 3 and adding the curve for actual costs (Actual Cost of Work Performed or ACWP) a comparison of actual cost (ACWP) with the value of the work performed (BCWP) can be made. This gives a cost variance and shows our costs are underrun and indicates a favorable cost variance.

Completing the scenario, by adding in management analysis of the total job outlook, it can be summarized that although the job is behind schedule, resources are being underrun and with proper attention focused on problem areas it is still possible to complete the job within cost and on schedule.

Comparing this to what was learned from Figure 1, where there were no visible problems and underrunning costs, it is evident that the earned value indicator provides a powerful tool for analysis.

PMS IMPLEMENTATION ON A PROJECT/PROGRAM

Presently, about twenty DOE projects are either using, implementing or considering the use of PMS to some degree. Individual project costs for these applications range from approximately $15 million to over $2 billion. For those contracts designated for PMS application, the requirements are placed first in the solicitation document and then in the contract. These clauses, appropriate to the system involved, require the contractor to:

1. Establish and use a management control system in accordance with the stated requirements.
2. Document the system and provide for system change processing.

3. Provide access to system records and data.
4. Apply performance measurement requirements to selected processing.

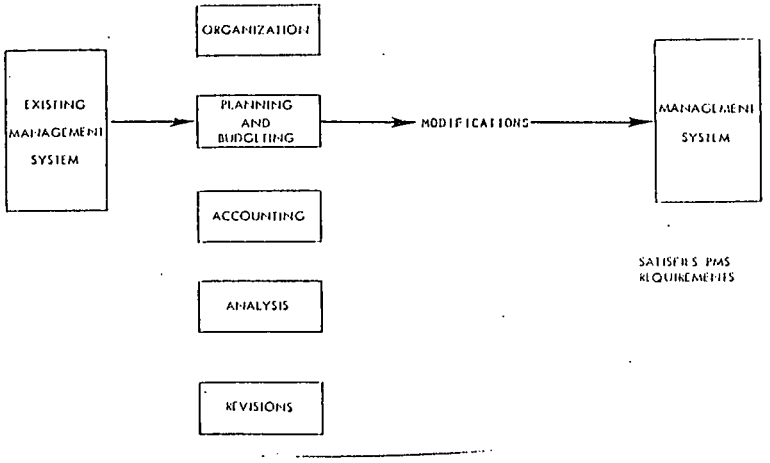
Contractors respond to the solicitation by describing how their internal management control systems meet the PMS requirements. Implementation of PMS to an ongoing contract is by contractual agreement between DOE and the contractor.

After contract award, the contractor's management control system is reviewed by the customer (DOE) to verify compliance with the PMS contractual requirements. This assures that the data generated by the contractor's system depict actual conditions, contain information derived from the same data base as that used by the contractor's management, and contain clear and comprehensive problem analyses including proposed corrective action. Figure 4 gives a representative flow of activities during PMS implementation.

FIGURE 4

PMS IMPLEMENTATION PROCESS

PMS CRITERIA



In the PMS application, after the contractor demonstrates compliance with the criteria and reporting requirements, a formal PMS review report is prepared to document the reviews and describe in detail how the contractor's system complies with the criteria. The review report is the basis for DOE acceptance of the contractor's management control system. A letter of system acceptance (or validation) is issued by the division director, and the appropriate contracting officer officially notifies the contractor of his acceptance. After acceptance, the contractor is required to update system documentation, as necessary, to accurately describe the system.

A memorandum of understanding referencing the accepted system description may then be expected relative to application of the system to other DOE

contracts which may require compliance with the PMS criteria. The contractor may then respond to solicitations for potential contracts that require PMS by citing the memorandum of understanding in his proposal.

After the system acceptance, DOE is responsible for the conduct of surveillance at the contractor's facility to insure the contractor's continued compliance with the requirements of the executed contract.

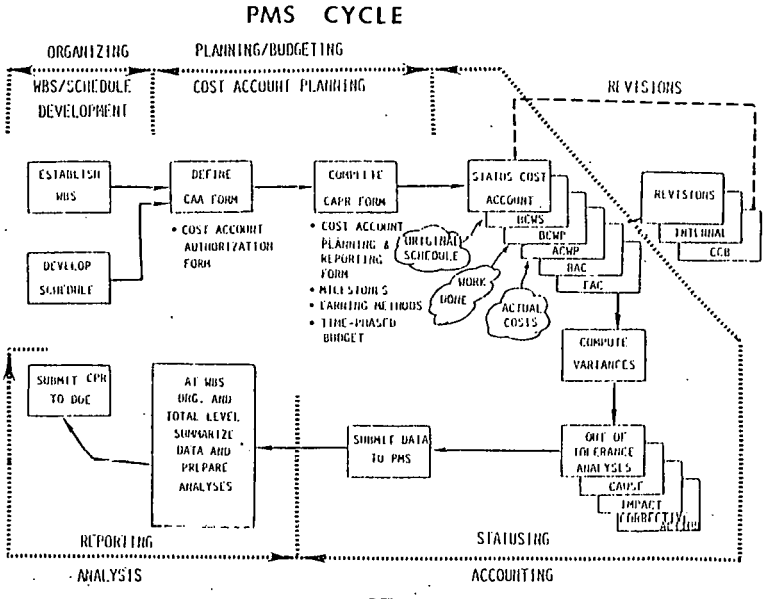
PMS DATA ELEMENTS

The Performance Measurement System is composed of the following basic ingredients:

1. A set of 35 criteria.
2. Use of a work breakdown structure (WBS).
3. Solicitation and contract provision for PMS.
4. A validation process that includes an implementation visit, readiness assessments, and demonstration review and acceptance.
5. Availability of a more flexible, less formal version of the earned value technique, called Mini-PMS, for use on small contracts.
6. A set of standard contractor reports.
7. Surveillance of contractor systems after acceptance.

It is most useful to think of PMS in a composite sense -- with each phase of the implementation following the next in a logical progression. Thus, let us look at the various divisions of the criteria (Organizing, Planning, Budgeting, Accounting, Analysis and Revisions) and follow these through to the end of the cycle as shown on Figure 5.

FIGURE 5



Organization

The organization criteria require that the contractor provide for clear definition of the overall contractual effort, including major subcontrac-

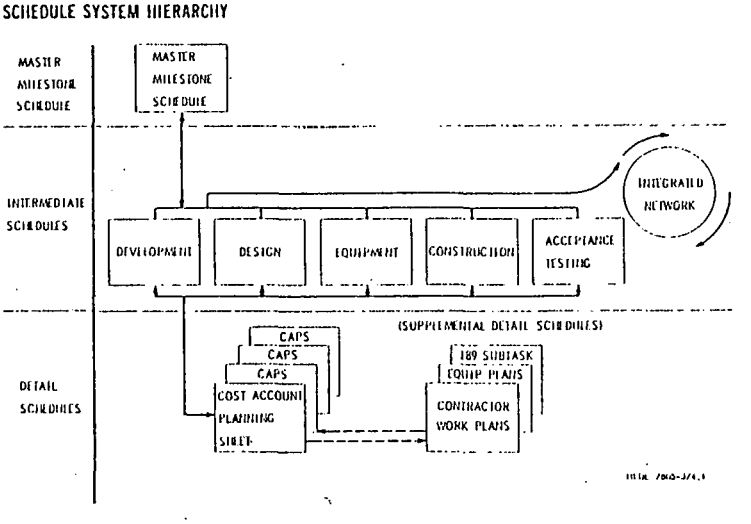
tors, with the Contractor Work Breakdown Structure (CWBS) identifying the subdivisions of effort. Integration of the CWBS with the organizational structure is required in order to provide for assignment of responsibility of identified work tasks and to facilitate performance measurement. Additionally, integration of the planning, scheduling, budgeting, work authorization and data accumulation system is a critical element in implementation of an effective management control system in compliance with the organization criteria.

Planning and Budgeting

All the contractually authorized work must be planned, scheduled, budgeted, and authorized by the contractor. Establishment of the contractor performance base line is based on scheduled cost accounts supported by work packages, and is the key in properly planning and budgeting the contract effort.

Another important aspect of the planning and budgeting group of criteria is the requirement for a disciplined scheduling system that includes traceability for top level schedules down through intermediate networks to detailed work package plans. This schedule hierarchy is shown on Figure 6.

FIGURE 6



Accounting

Project cost and performance measurement data elements are summarized from the bottom up as directly as possible without allocations. Costs of materials are handled on an applied cost basis, if possible, in order that the cost of work does not include cost of materials on order or in inventory. A certain amount of latitude is provided in this requirement depending on the kind and amounts of material involved. Procedures are required for identifying overhead to the incurring organizations.

Analysis

Incorporation of changes authorized by the government and those due to contractor internal replanning and formal reprogramming are covered by

these criteria. Particular emphasis is placed on the need to retain a meaningful performance measurement base line. Other requirements include reconciliation of estimated costs at completion with contract funds requirements reports and project management access to data for system evaluations and surveillance.

Under Mini-PMS, the contractor's management control system is not required to comply with the PMS criteria. As a minimum, the contractor's system is expected to provide a framework for defining work, assigning work responsibilities, establishing budgets, controlling direct and indirect costs, and summarizing with respect to planned versus actual accomplishments the cost, schedule, and related technical accomplishment information for management purposes. The system characteristics, like the PMS criteria, reflect a good common sense approach to contract management.

Reports

A group of related reports is used in conjunction with contract performance measurement. These reports are the Cost Performance Report (CPR), the Cost/Schedule Status Report (C/SSR), the Schedule Status Report (SSR), and the Contract Funds Status Report (CFSR). The C/SSR is the one report specifically designed for Mini-PMS; it replaces the CPR used with PMS. Other CPR formats provide for WBS, functional, base line and manpower reporting and variance/problem analysis.

The contents of these reports are obtained from the same data base that supports day-to-day contract management and provide the means of reporting summary level cost, schedule and funding data from contractors for project management purposes, including project status reporting to upper DOE management. These reports are placed on contract through the use of data item descriptions that contain instructions regarding the level of detail and frequency of reporting.

Normally, contract reporting is at Level 3 of the CWBS. Although DOE relies on summarized data in these reports for contract management, detailed data may be requested for problem areas. The cost and schedule reports are usually received monthly by the government, with the funds status report generally being a quarterly contractor submission.

Performance Measurement Data Elements

For performance measurement purposes, a unique set of data elements is generated that the contractor uses internally for management and externally for contract performance reporting. Table A lists the data elements and Table B displays their relationship.

Actual Cost of Work Performed (ACWP) consists of direct and allocated indirect costs applicable to the contract. The Budgeted Cost for Work Scheduled (BCWS) is the time-phased budget plan (base line) which represents the contract work plan. The Budgeted Cost for Work Performed (BCWP), the "earned value" or the "planned value of work accomplished", represents the value of completed work.

TABLE B

INTERPRETATON OF BCWS/BCWP/ACWP RELATIONSHIPS

Schedule Variance		Cost Variance		
BCWS	BCWP	ACWP	DESCRIPTION	
$1	$1	$1	On Schedule	On Cost
$2	$2	$1	On Schedule	Under Cost
$1	$1	$2	On Schedule	Over Cost
$1	$2	$2	Ahead of Schedule	On Cost
$1	$2	$3	Ahead of Schedule	Over Cost
$1	$2	$1	Ahead of Schedule	Under Cost
$3	$2	$1	Behind Schedule	Under Cost
$2	$1	$3	Behind Schedule	Over Cost
$2	$1	$1	Behing Schedule	On Cost

Schedule Variance = BCWP - BCWS
Cost Variance = BCWP - ACWP

INTERPRETATION OF BAC/EAC RELATIONSHIPS

At Completion Variance

BAC	EAC	DESCRIPTION
$1	$1	Forecast On Budget
$2	$1	Forecast Underrun
$1	$2	Forecast Overrun

At Completion Variance = BAC - EAC

TABLE C

BCWP EARNING METHODS

Measured Effort:
- Milestone
- Percent Complete
- Modified Milestone/Percent Complete
- Equivalent Units

Level of Effort
Apportioned Effort

RECENT PMS APPLICATIONS

As mentioned previously, the first project on which DOE applied the earned value concept was the FFTF Project. Details of this application include:

- Project: Fast Flux Test Facility (reactor facility to test fuels and materials for liquid metal fast breeder reactor power plants)
- Location: Hanford Reservation, Richland, Washington (U.S.A.)
- Cost: $647 million
- Schedule: Start in 1967: completion in August, 1978
- Contractors: Westinghouse-Hanford; Westinghouse Advanced Reactor Division; and Bechtel
- Mid-stream implementation of earned value system
- Preliminary evaluation: March and October, 1975
- Demonstration review in February, 1976
- Initial system January, 1976, Final System June, 1976
- System extended to total program October 1976

This application served as a pilot test although normal validation was not sought. The cost/schedule performance information produced by PMS is an important element in the management of FFTF.

The second DOE application of PMS was on the CRBRP Project. The full PMS is being implemented, with four contractors validated to date (Atomics International, Westinghouse, Burns & Roe, and General Electric). PMS reports provide information which is included in briefings to the Office of the Secretary of Energy. Details of the PMS application on the CRBRP Project include:

- Project: Clinch River Breeder Reactor Plant (large scale liquid metal fast breeder reactor demonstration power plant)
- Location: Oak Ridge, Tennessee
- Cost: $2.3 billion
- Schedule: Start in 1973; completion (under review)
- Contractors: Westinghouse Advanced Reactor Division, PA; sub-contractors: General Electric - Sunnyvale, CA, Atomics International - Canoga Park, CA, Westinghouse ARD; Burns & Roe, Oradell, NJ; Stone & Webster Engineering, Boston MA
- First contractor reports: October, 1975
- Contractor systems operational: April, 1976
- Validations completed in 1978

Two other projects at the Hanford Engineering Development Laboratory (HEDL) also utiliing PMS are the FMEF and FMIT, detailed below:

FMEF

- Project: Rescoped Fuels and Materials Examination Facility (Facility for handling and examination of full size fuel, materials and absorber assemblies irradiated in FFTF, fuel fabrication)
- Location: Hanford Reservation Richland, Washington (U.S.A.)
- Cost: $170 million ($221.7 million total)
- Schedule: Start in January 1978; completion in March 1983
- Contractors: Westinghouse-Hanford
  Norman Engineering, Architect - Engineer
- System designed: October 1976
- Trial reporting: February - April 1977
- (SSR) Schedule Status Report - January 1978
- Comprehensive monthly status report - February 1978

- DOE readiness review - February 1978
- Initial project fund status report - May 1978
- DOE system validation - June 1978

FMIT

- Project: Fusion Materials Irradiation Test facility
- Location: Hanford Reservation, Richland, Washington
- Cost: 83 million (target)
- Contractors: Architect - Engineer
  Construction manager
  Constructor(s)
  Los Alamos (accelerator design)
- Components:

Accelerator	30 million
Target system	11 million
2 Irradiation test cell facility	18 million

At this point, all activities at HEDL are utilizing PMS -- this is the first and only total laboratory application of the system at this time. The first laboratory Contractor Performance Report (CPR) was issued on April 30, 1979.

CONCLUSIONS

In addition to the projects detailed above the PMS (or C/SCSC) has also recently been utilized on an international basis. The United States Army Corps of Engineers is currently utilizing C/SCSC, for the first time, on the King Khalid Military City Project in Saudi Arabia expected to exceed $5 billion and have a construction duration of ten years. Their mission is to provide complete engineering and construction management services for design, contracting and construction of certain facilities for the military forces of the Saudi Arabian government. Their experience to date was summarized as having been beneficial to their work at the project. Specifically the following areas were noted as being extremely useful: authorization of work, insistance on use of a WBS, and development of a matrix to be applied to completed work in providing an award fee index.

The PMS was also utilized at the Tokamak Fusion Test Reactor (TFTR) -- a U.S. DOE magnetic fusion energy research project. This is being constructed at Princeton University and is cited as being possibly the first time a rigidly structured earned value system has been applied to the construction of a scientific device. The implementation was complicated due to the effect of nine participants being involved with TFTR. The benefit of PMS to the TFTR was given as: encouragement of management by exception; and, enablement of problem areas to be focused on at the fourth level or lower by management in a cost effective manner.

In a summary form, other contractors list the following benefits from PMS:

1. Improved operational discipline.
2. Added dimension of earned value.
3. Improved planning.
4. Better communication internally and with the customer.
5. More detailed and earlier program visibility.
6. Increased cost and schedule awareness at lower management levels.

Implementation of PMS/Mini-PMS is a worthy goal for both the government and the contractor. Each system provides management flexibility to project participants and encourages refinements and innovations to operational systems. Successful and expeditious implementaton promotes effective project/contract managements and enhances communication amoung project participants by use of standard terminology to describe contract and project performance.

FUTURE OF PMS

The past years have shown that there is an increasing pressure on all government contractors for more effective performance measurement -- and this has led to increased requirements for the application of PMS.

Current discussions show that not only is it a system that is being effectively employed in the United States, but also one being considered on an international basis.

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