CHAPTER 14

METRICS

14.1 METRICS IN MANAGEMENT

Metrics are measurements collected for the purpose of determining project progress and overall condition by observing the change of the measured quantity over time. Management of technical activities requires use of three basic types of metrics:

- Product metrics that track the development of the product,
- Earned Value which tracks conformance to the planned schedule and cost, and
- Management process metrics that track management activities.

Measurement, evaluation and control of metrics is accomplished through a system of periodic reporting must be planned, established, and monitored to assure metrics are properly measured, evaluated, and the resulting data disseminated.

Product Metrics

Product metrics are those that track key attributes of the design to observe progress toward meeting customer requirements. Product metrics reflect three basic types of requirements: operational performance, life-cycle suitability, and affordability. The key set of systems engineering metrics are the Technical Performance Measurements (TPM.) TPMs are product metrics that track design progress toward meeting customer performance requirements. They are closely associated with the system engineering process because they directly support traceability of operational needs to the design effort. TPMs are derived from Measures of Performance (MOPs) which reflect system requirements. MOPs are derived from Measures of Effectiveness (MOEs) which reflect operational performance requirements.

The term "metric" implies quantitatively measurable data. In design, the usefulness of metric data is greater if it can be measured at the configuration item level. For example, weight can be estimated at all levels of the WBS. Speed, though an extremely important operational parameter, cannot be allocated down through the WBS. It cannot be measured, except through analysis and simulation, until an integrated product is available. Since weight is an important factor in achieving speed objectives, and weight can be measured at various levels as the system is being developed, weight may be the better choice as a metric. It has a direct impact on speed, so it traces to the operational requirement, but, most importantly, it can be allocated throughout the WBS and progress toward achieving weight goals may then be tracked through development to production.

Measures of Effectiveness and Suitability

Measures of Effectiveness (MOEs) and Measures of Suitability (MOSs) are measures of operational effectiveness and suitability in terms of operational outcomes. They identify the most critical performance requirements to meet system-level mission objectives, and will reflect key operational needs in the operational requirements document.

Operational effectiveness is the overall degree of a system's capability to achieve mission success considering the total operational environment. For example, weapon system effectiveness would consider environmental factors such as operator organization, doctrine, and tactics; survivability; vulnerability; and threat characteristics. MOSs, on the other hand, would measure the extent to which the system integrates well into the operation environment and would consider such issues as supportability, human interface compatibility, and maintainability.

Measures of Performance

MOPs characterize physical or functional attributes relating to the execution of the mission or function. They quantify a technical or performance requirement directly derived from MOEs and MOSs. MOPs should relate to these measures such that a change in MOP can be related to a change in MOE or MOS. MOPs should also reflect key performance requirements in the system specification. MOPs are used to derive, develop, support, and document the performance requirements that will be the basis for design activities and process development. They also identify the critical technical parameters that will be tracked through TPMs.

Technical Performance Measurements

TPMs are derived directly from MOPs, and are selected as being critical from a periodic review and control standpoint. TPMs help assess design progress, assess compliance to requirements throughout the WBS, and assist in monitoring and tracking technical risk. They can identify the need for deficiency recovery, and provide information to support cost-performance sensitivity assessments. TPMs can include range, accuracy, weight, size, availability, power output, power required, process time, and other product characteristics that relate directly to the system operational requirements.

TPMs traceable to WBS elements are preferred, so elements within the system can be monitored as well as the system as a whole. However, some necessary TPMs will be limited to the system or subsystem level. For example, the specific fuel consumption of an engine would be a TPM necessary to track during the engine development, but it is not allocated throughout the WBS. It is reported as a single data item reflecting the performance of the engine as a whole. In this case the metric will indicate that the design approach is consistent with the required performance, but it may not be useful as an early warning device to indicate progress toward meeting the design goal. A more detailed discussion of TPMs is available as Supplement A to this chapter.

Example of Measures

MOE: The vehicle must be able to drive fully loaded from Washington, DC, to Tampa on one tank of fuel.

MOP: Vehicle range must be equal to or greater than 1,000 miles.

TPM: Fuel consumption, vehicle weight, tank size, drag, power train friction, etc.

Suitability Metrics

Tracking metrics relating to operational suitability and other life cycle concerns may be appropriate to monitor progress toward an integrated design. Operational suitability is the degree to which a system can be placed satisfactorily in field use considering availability, compatibility, transportability, interoperability, reliability, usage rates, maintainability, safety, human factors, documentation, training, manpower, supportability, logistics, and environmental impacts. These suitability parameters can generate product metrics that indicate progress toward an operationally suitable system. For example, factors that indicate the level of automation in the design would reflect progress toward achieving manpower quantity and quality requirements. TPMs and suitability product metrics commonly overlap. For example, Mean Time Between Failure (MBTF) can reflect both effectiveness or suitability requirements.

Suitability metrics would also include measurements that indicate improvement in the producibility, testability, degree of design simplicity, and design robustness. For example, tracking number of parts, number of like parts, and number of wearing parts provides indicators of producibility, maintainability, and design simplicity.

Product Affordability Metrics

Estimated unit production cost can be tracked during the design effort in a manner similar to the TPM approach, with each CI element reporting an estimate based on current design. These estimates are combined at higher WBS levels to provide subsystem and system cost estimates. This provides a running engineering estimate of unit production cost, tracking of conformance to Design-to-Cost (DTC) goals, and a method to isolate design problems relating to production costs.

Life cycle affordability can be tracked through factors that are significant in parametric life cycle cost calculations for the particular system. For example, two factors that reflect life cycle cost for most transport systems are fuel consumption and weight, both of which can be tracked as metrics.

Timing

Product metrics are tied directly to the design process. Planning for metric identification, reporting, and analysis is begun with initial planning in the concept exploration phase. The earliest systems engineering planning should define the management approach, identify performance or characteristics to be measured and tracked, forecast values for those performances or characteristics, determine when assessments will be done, and establish the objectives of assessment.

Implementation is begun with the development of the functional baseline. During this period, systems engineering planning will identify critical technical parameters, time phase planned profiles with tolerance bands and thresholds, reviews or audits or events dependent or critical for achievement of planned profiles, and the method of estimation. During the design effort, from functional to product baseline, the plan will be implemented and continually updated by the systems engineering process. To support implementation, contracts should include provision for contractors to provide measurement, analysis, and reporting. The need to track product metrics ends in the production phase, usually concurrent with the establishment of the product (as built) baseline.

DoD and Industry Policy on Product Metrics

Analysis and control activities shall include performance metrics to measure technical development and design, actual versus planned; and to measure [the extent to which systems meet requirements]. DoD 5000.2-R.

The performing activity establishes and implements TPM to evaluate the adequacy of evolving solutions to identify deficiencies impacting the ability of the system to satisfy a designated value for a technical parameter. EIA IS-632, Section 3.

The performing activity identifies the technical performance measures which are key indicators of system performance...should be limited to critical MOPs which, if not met put the project at cost, schedule, or performance risk. IEEE 1220, Section 6.

14.2 EARNED VALUE

Earned Value is a metric reporting system that uses cost-performance metrics to track the cost and schedule progress of system development against a projected baseline. It is a “big picture” approach and integrates concerns related to performance, cost, and schedule. Referring to Figure 14-1, if we think of the line labeled BCWP (budgeted cost of work performed) as the value that the contractor has “earned,” then deviations from this baseline indicate problems in either cost or schedule. For example, if actual costs vary from budgeted costs, we have a cost variance; if work performed varies from work planned, we have a schedule variance. The projected performance is based on estimates of appropriate cost and schedule to perform the work required by each WBS element. When a variance occurs the system engineer can pinpoint WBS elements that have potential technical development problems. Combined with product metrics, earned value is a powerful technical management tool for detecting and understanding development problems.

Relationships exist between product metrics, the event schedule, the calendar schedule, and Earned

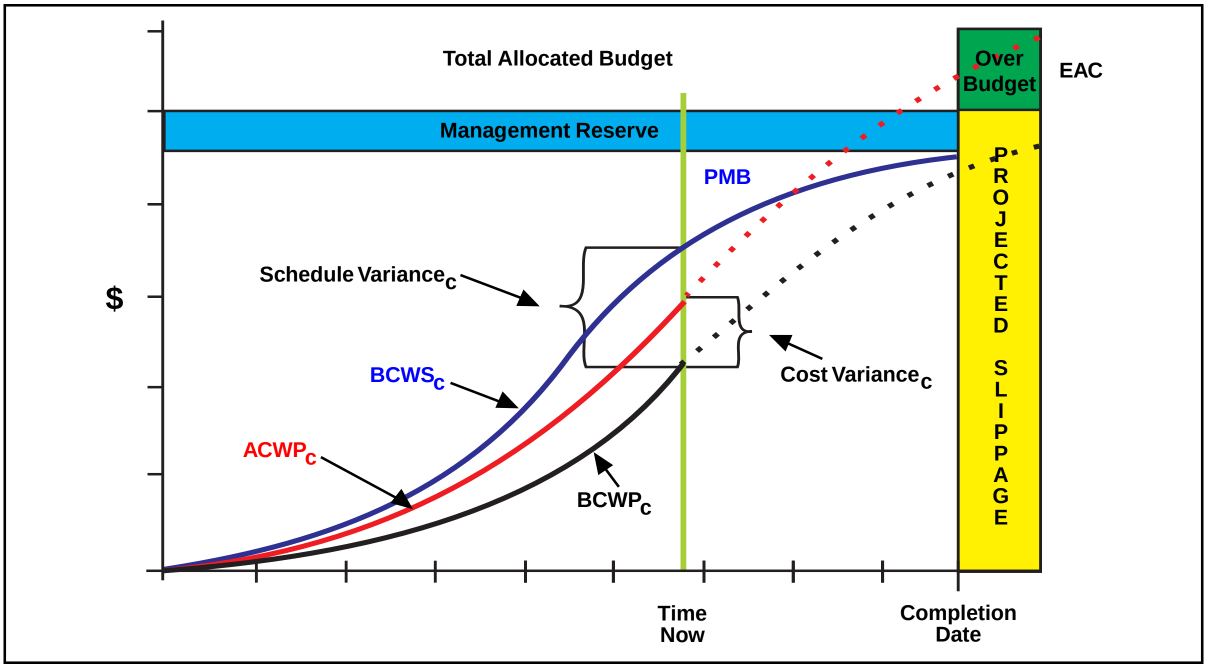

Figure 14-1. Earned Value Concept

Value:

- The Event Schedule includes tasks for each event/exit criteria that must be performed to meet key system requirements, which are directly related to product metrics.
- The Calendar (Detail) Schedule includes time frames established to meet those same product metric-related objectives (schedules).
- Earned Value includes cost/schedule impacts of not meeting those objectives, and, when correlated with product metrics, can identify emerging program and technical risk.

14.3 PROCESS METRICS

Management process metrics are measurements taken to track the process of developing, building, and introducing the system. They include a wide range of potential factors and selection is program unique. They measure such factors as availability of resources, activity time rates, items completed, completion rates, and customer or team satisfaction. Examples of these factors are: number of trained personnel onboard, average time to approve/disapprove ECPs, lines of code or drawings released, ECPs resolved per month, and team risk identification or feedback assessments. Selection of appropriate metrics should be done to track key management activities. Selection of these metrics is part of the systems engineering planning process.

How Much Metrics?

The choice of the amount and depth of metrics is a planning function that seeks a balance between risk and cost. It depends on many considerations, including system complexity, organizational complexity, reporting frequency, how many contractors, program office size and make up, contractor past performance, political visibility, and contract type.

14.4 SUMMARY POINTS

- Management of technical activities requires use of three basic types of metrics: product metrics that track the development of the product, earned value which tracks conformance to the planned schedule and cost, and management process metrics that track management activities.

- Measurement, evaluation and control of metrics is accomplished through a system of periodic reporting that must be planned, established, and monitored to assure metrics are measured properly, evaluated, and the resulting data disseminated.

- TPMs are performance based product metrics that track progress through measurement of key technical parameters. They are important to the systems engineering process because they connect operational requirements to measurable design characteristics and help assess how well the effort is meeting those requirements. TPMs are required for all programs covered by DoD 5000.2-R.

SUPPLEMENT 14-A

TECHNICAL PERFORMANCE MEASUREMENT

Technical Performance Measurement (TPM) is an analysis and control technique that is used to: (1) project the probable performance of a selected technical parameter over a period of time, (2) record the actual performance observed of the selected parameter, and (3) through comparison of actual versus projected performance, assist the manager in decision making. A well thought out program of technical performance measures provides an early warning of technical problems and supports assessments of the extent to which operational requirements will be met, as well as assessments of the impacts of proposed changes in system performance.

TPMs generally take the form of both graphic displays and narrative explanations. The graphic, an example of which is shown in Figure 14-2, shows the projected behavior of the selected parameter as a function of time, and further shows actual observations, so that deviations from the planned profile can be assessed. The narrative portion of the report should explain the graphic, addressing the reasons for deviations from the planned profile, assessing the seriousness of those deviations, explaining actions underway to correct the situation if required, and projecting future performance, given the current situation.

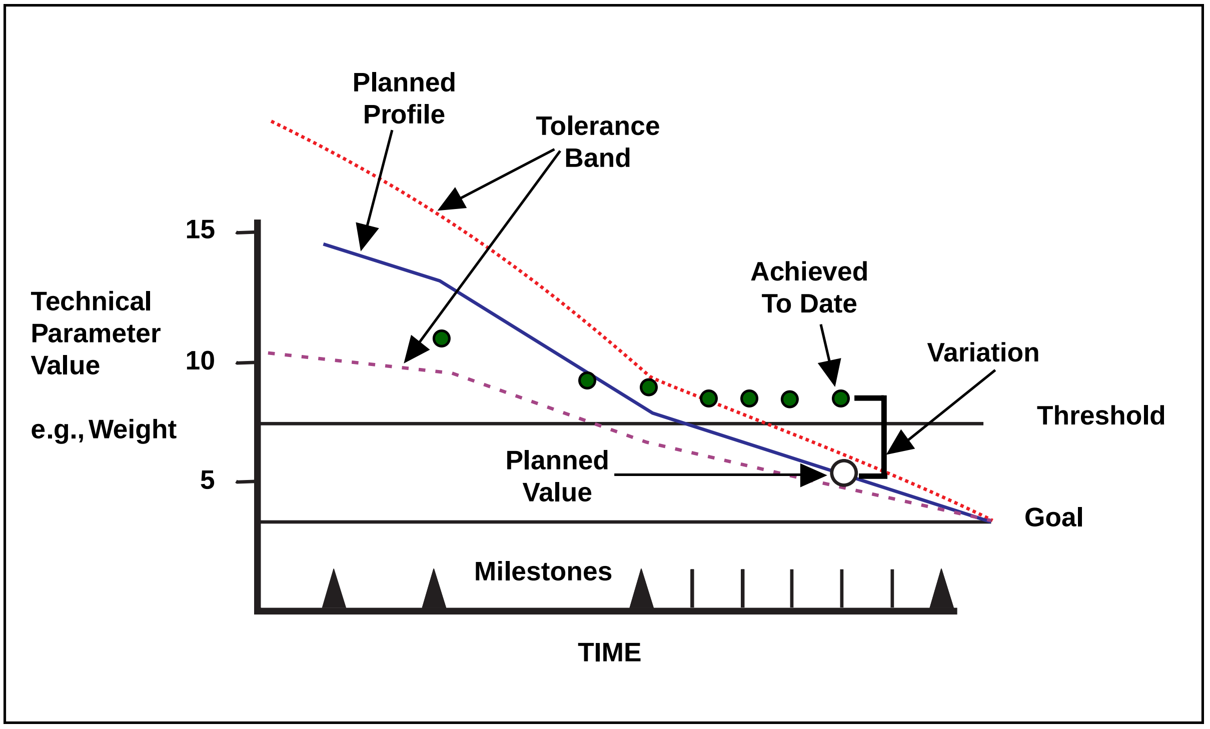

Figure 14-2. Technical Performance Measurement – The Concept

Parameters to be tracked are typically based on the combined needs of the government and the contractor. The government program office will need a set of TPMs which provide visibility into the technical performance of key elements of the WBS, especially those which are cost drivers on the program, lie on the critical path, or which represent high risk items.

The TPMs selected for delivery to the government are expected to be traceable to the needs of the operational user. The contractor will generally track more items than are reported to the government, as the contractor needs information at a more detailed level than does the government program office.

TPM reporting to the government is a contractual issue, and those TPMs on which the government receives reports are defined as contract deliverables in the contract data requirements list. Which parameters are selected for reporting depends on a number of issues, among which are resources to purchase TPMs, the availability of people to review and follow the items, the complexity of the system involved, the phase of development, and the contractor's past experience with similar systems.

A typical TPM graphic will take a form somewhat like that previously shown. The actual form of the projected performance profile and whether or not tolerance bands are employed will be a function of the parameter selected and the needs of the program office.

Another important consideration is the relationship between the TPM program and risk management. Generally, the parameters selected for tracking should be related to the risk areas on the program. If a particular element of the design has been identified as a risk area, then parameters should be selected which will enable the manager to track progress in that area. For example, if achieving a required aircraft range is considered to be critical and a risk area, then tracking parameters that provide insight into range would be selected, such as aircraft weight, specific fuel consumption, drag, etc. Furthermore, there should be consistency between TPMs and the Critical Technical Parameters associated with formal testing, although the TPM program will not normally be limited just to those parameters identified as critical for test purposes.

Government review and follow up of TPMs are appropriate on a periodic basis when submitted by the contractor, and at other major technical events such as at technical reviews, test events, and program management reviews.

While TPMs are expected to be traceable to the needs of the user, they must be concrete technical parameters that can be projected and tracked. For example, an operational user may have a requirement for survivability under combat conditions. Survivability is not, in and of itself, a measurable parameter, but there are important technical parameters that determine survivability, such as radar cross section (RCS) and speed. Therefore, the technical manager might select and track RCS and speed as elements for TPM reporting. The decision on selection of parameters for TPM tracking must also take into consideration the extent to which the parameter behavior can be projected (profiled over a time period) and whether or not it can actually be measured. If the parameter cannot be profiled, measured, or is not critical to program success, then the government, in general, should not select it for TPM tracking. The WBS structure makes an excellent starting point for consideration of parameters for TPM tracking (see Figure 14-3).

A substantial effort has taken place in recent years to link TPMs with Earned Value Management in a way that would result in earned value calculations that reflect the risks associated with achieving technical performance. The approach used establishes statistical probability of achieving a projected level of performance on the TPM profile based on a statistical analysis of actual versus planned performance. Further information is available on the Internet at http://www.acq.osd.mil/api/tpm/.

In summary, TPMs are an important tool in the program manager's systems analysis and control toolkit. They provide an early warning about deviations in key technical parameters, which, if not controlled, can impact system success in meeting user needs. TPMs should be an integral part of both

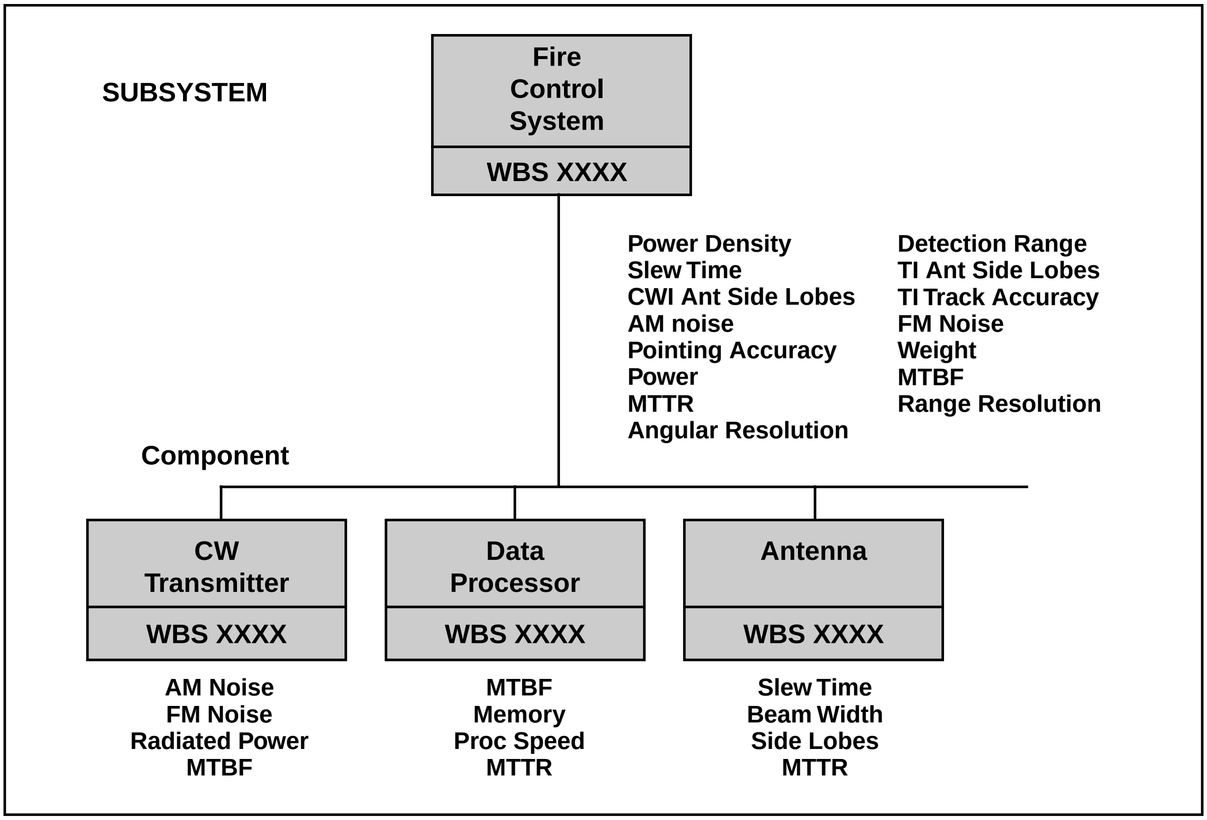

Figure 14-3. Shipboard Fire Control System (Partial)

periodic program reporting and management follow-up, as well as elements for discussion in technical reviews and program management reviews. By thoughtful use of a good program of TPM, the manager, whether technically grounded or not, can make perceptive judgments about system technical performance and can follow up on contractor plans and progress when deviations occur.

Relevant Terms

Achievement to date – Measured or estimated progress plotted and compared with planned progress by designated milestone date.

Current estimate – Expected value of a technical parameter at contract completion.

Planned value – Predicted value of parameter at a given point in time.

Planned profile – Time phased projected planned values.

Tolerance band – Management alert limits representing projected level of estimating error.

Threshold – Limiting acceptable value, usually contractual.

Variance – Difference between the planned value and the achievement-to-date derived from analysis, test, or demonstration.