Using Measurement to Assure Operational Safety, Suitability, and Effectiveness (OSS&E) Compliance for the C^2 Product Line

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Abstract. Air Force Policy Directive 63-12, ***Assurance of Operational Safety, Suitability, and Effectiveness,*** establishes the Air Force requirement to assure operational safety, suitability, and effectiveness (OSS&E) through a system's operational life. Electronic Systems Center (ESC) of Air Force Materiel Command (AFMC) is responsible to provide this assurance for each Command and Control (C^2) system developed, procured, operated, maintained, modified, or employed.

This paper discusses the role measurement must play in the OSS&E assurance process, and offers guidance to develop effective measures. While specific measures must be adapted for each system, the concepts needed to develop effective measures are the same. A combination of product, process, and performance measures may serve as indicators to show the project manager the overall project OSS&E status. These could include trends that show compliance being maintained or in jeopardy, or the positive (or negative) effects of a particular course of action. Example measures are presented to reinforce the concepts being presented.

INTRODUCTION

Background. ESC is responsible for implementing the requirements to ensure OSS&E as stated in Air Force Policy Directive 63-12, ***Assurance of Operational Safety, Suitability, and Effectivenss*** for each Command and Control (C^2) system developed, procured, operated, maintained, modified, or employed. This paper suggests a way to begin and shows examples of how measurement might be used to ensure OSS&E compliance.

There are many possible methods to develop measures to evaluate the status of projects. I have found the most effective measures are developed using the concepts of Practical Software and Systems Measurement (PSM).

WHAT IS PSM?

Overview. PSM is a systematic, flexible, and objective process for analyzing software and systems development project issues, risks and financial management. Supported by the Office of the Undersecretary of Defense for Acquisition and Technology, PSM represents the best practices of the software and engineering communities. It is based on actual DoD, government, and industry experience.

PSM Principles. The following nine principles are key to the successful implementation of a measurement program:

1. Project issues and objectives are the basis for developing the measurement requirements
2. Measurement collection is consistent with the developer's process
3. Data is collected and analyzed at a level of detail sufficient to identify and isolate problems
4. An independent analysis capability is implemented
5. A structured process leads from the measures to the decisions, and subsequent actions
6. Measurement results are analyzed and interpreted using contextual project information
7. Measurement is an integral part of project management throughout the system life cycle
8. Initial efforts should begin at the single project level
9. Measurement is the basis for objective communication.

Key among these principles, is that the PSM technique begins with identification of the project issues and objectives that are important at the current stage of the project. Measurement that is not consistent with a developer's process will impose unnecessary demands on the developer, leaving less time to do the required project work. Establisment of an independent analysis capability allows both the developer and the user to understand the raw measurement data and how it was obtained. It serves as the basis for objective communication between them.

Using PSM principles, I began with assumed project issues or concerns (notably operational safety, suitability, and effectiveness) for notional programs and developed sample measures that might be used to assess those programs. This development begins with the PSM process of mapping the project issues to a set of common PSM issues. These common issues are then narrowed to a set of applicable PSM categories, then further refined to develop a set of measures. Using these measures, I hope to instill a sense of how the analysis process works and what to look for in collected data. A complete discussion of PSM is beyond the scope of this paper, but (PSM, 2000) provides all the background to understand and use the PSM methodology.

OPERATIONAL SAFETY

Definition. Operational safety is defined in AFPD 63-12 as "the condition of having acceptable risk to life, health, property, or environment caused by a system or subsystem in an operational environment. This requires the identification of hazards, assessment of risk, determination of mitigating measures, and acceptance of residual risk." To assess a portion of operational safety, I present three potential measures: Problem Reports, Failure by Cause, and Experience Levels. The data in this section are based on real data, though to avoid specific system discussions, the systems are not identified.

Defects – Problem Reports. Figure 1 shows a measure of system failures over a ten year period.

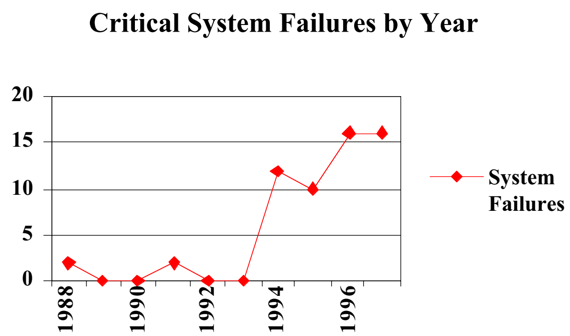

Figure 1: Defects - Problem Reports

When analyzing system failures, you should watch for sudden, or steady increases in the failure rate. For systems, thresholds may be set depending on the type of equipment, or the liklihood or seriousness of each failure. Thresholds are set to indicate what level of pain the project manager is willing to tolerate. Certainly in the manned spacecraft program, safety is the ultimate concern, where loss of life is the penalty, and the opportunities to endanger life are numerous. In a planning organization, the immediate safety concerns would be much less.

In practice, this measure might be shown to a senior manager as is, but more frequent measurements would be taken to identify the problem early. Based on the historical record of 0-2 accidents per year until 1993, you should identify the increased number of failures by the time it reached three or four, and not wait until it reached the final twelve shown in 1994.

Defects – Failure by Cause. To determine the reasons for failure, you might want to use a chart similar to figure 2. This shows the total number of mishaps per year within the Air Force. Also mapped is the number of accidents attributed to maintenance failures.

Figure 2 shows that total mishaps have been decreasing since 1985. This is a very good trend, but without considering the possible reasons, it may be misleading. Much of the decrease could probably be explained by base closings and force reduction that took place in the late 1980s and early 1990s. In fact, that might explain the leveling effect of the graph after the force reductions had ceased. On the positive side, the

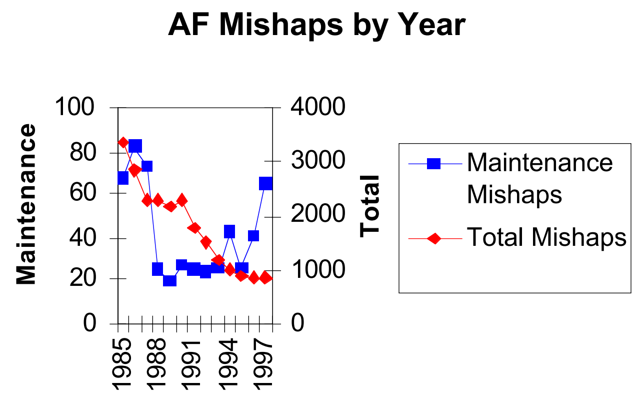

Figure 2: Defects - Failure by Cause

reduction might be attributed to an improved safety program and emphasis. Note that we can't tell the causes, only the results. Further analysis is needed.

We see an equivalent, even steeper drop in the number of maintenance-related accidents at first , but then, after a leveling, the rate has increased. In fact, where prior to 1995, maintenance accounted for generally 3% or less, it accounted for 4.8% of the accidents in 1996 and 7.7% of the accidents in 1997. Although this might be due to specific statistical variability, it is not a trend we'd like to see, so further investigation is needed.

Personnel – Experience Level. One approach to investigate these bad trends might be to look at the experience levels of the maintenance force. Figure 3 shows such a compilation of data.

We observe at least a couple of items. First, there are fewer maintenance personnel in 1999 than in 1994. We should have expected this since the rest of the force has similarly reduced. Second, there is a shifting of experience with a growth in the percentage of Skill Level 1 personnel (up 35%) and a reduction of the advanced levels (5 and 9 down about 24% each and 7

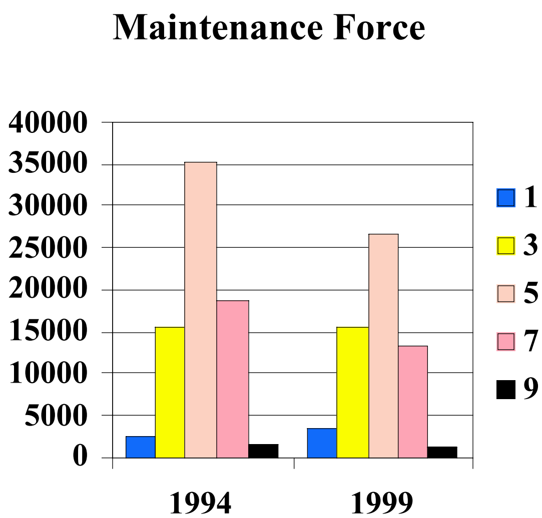

Figure 3: Personnel - Experience Levels

down 28%). This smaller, less experienced maintenance force may well be the reason for the increase in maintenance related accidents, with the resultant threat to system safety. Potential solutions available to the manager could include additional training for maintainers, or increased effort to retain experienced personnel. Even though this chart addresses the maintenance force as a whole, it can certainly be applied at any level, even the unit level, with sometimes eye-opening results.

OPERATIONAL SUITABILITY

Definition. AFPD 63-12 defines Operational Suitability as "the degree to which a system can be placed satisfactorily in field use, with consideration given to availability, compatibility, transportability, interoperability, reliability, wartime use rates, maintainability, safety, human factors, manpower supportability, natural environmental effects and impacts, and documentation and training requirements." This definition goes beyond the familiar reliability, maintainability, and availability to include the training of personnel and the adequacy of documentation. A system may be perfectly suitable in every way except for lacking trained personnel who are unable to perform their duties or lack the proper documentation to operate the system. Also included are such items as tracking supplier sources of spare parts to be aware in advance of the loss of a supply source. This could result when the last remaining supplier is going out of business, or is located in a country that will not always be available politically to deliver parts to a US customer.

As we move further into the definitions, it becomes clear that there is not a clear-cut division between the areas of safety, suitability, and effectiveness. Rather there is a continuum involving all three areas in assessing the usefulness of a system. It is easy to imagine a system that is very effective, yet is so difficult and cumbersome to use and maintain, that it is unsuitable, and possibly unsafe. Measures developed for one area, such as suitability, also may give indications of the safety and effectiveness of the system. Just as the PSM principal states that analysis must be done within the context of other areas, so must the safety, suitability, and effectiveness measures be evaluated not in a vacuum individually, but with regard to the overall effect on the system.

Measures of CPU Utilization, Systems Reliability, and Mean Time and Effort to Fix can provide some insight into operational suitability of a system.

Resource Utilization – CPU Utilization. Figure 4 shows a typical graph of CPU Utilization. Normally during development there is a specified threshold that must be met before system acceptance. Much fine tuning is done almost daily to ensure that the threshold is met. After delivery, much less attention is paid to this value.

Once operational, the threshold is generally less important for a system than it was before delivery. Added requirements have likely used up some of the spare capability. Unexpected changes in the utilization

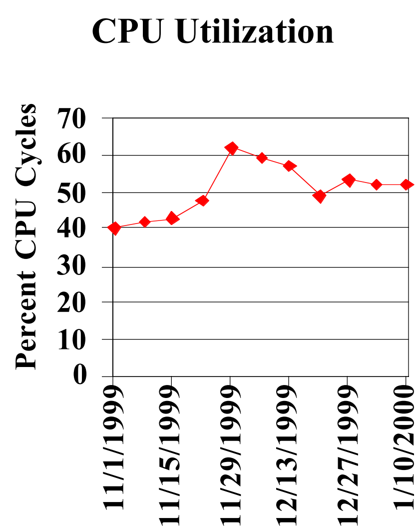

Figure 4: Resource Utilization

of the system bear investigating to determine their cause.

Product Quality – System Reliability. Figure 5 shows a graph of a system's reliability. The number of hours between failures is shown over several months.

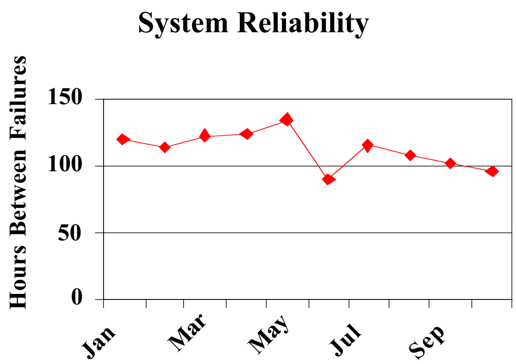

Figure 5: Product Quality

Historical or benchmark values are important to know in evaluating system reliability. Sudden drops may be less important in the analysis than trends which show a worsening of the system reliability. Changes should be compared against recent system modifications. Trend changes without associated hardware changes may be an indication of system degradation leading to eventual system failure.

Maintainability – Mean Time and Effort to Fix. Another indication that a system is becoming less suitable is when more and more effort is required to maintain the system. At some point, the maintenance costs can become more expensive in the long run than replacing the system. Figure 6 shows a typical way to measure the effort and time involved in maintaining a system.

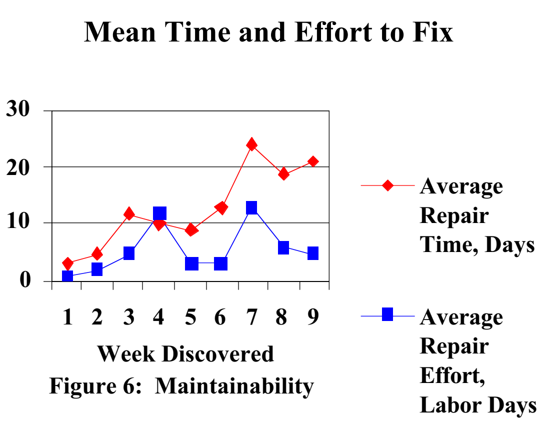

Figure 6: Maintainability

An upward trend in either line could indicate a loss of experience or availability of maintenance personnel, or the degradation of system parts, or something as mundane as bad weather, if the repair requires outside maintenance. Identification of the actual cause requires additional analysis and investigation.

OPERATIONAL EFFECTIVENESS

Definition. Finally AFPD 63-12 defines Operational Effectiveness as "the overall degree of mission accomplishment of a system used by representative personnel in the environment planned or expected (e.g., natural, electronic, threat) for operational employment of the system which considers organization, doctrine, tactics, survivability, vulnerability, and threat (including countermeasures, initial nuclear weapons effects, and nuclear, biological, and chemical contamination threats)." In many ways, this is the easiest of the concepts to understand. These are the system operational performance measurements. Often significant data collection and analysis effort is required to show the simple charts. Only one example is presented here, Response Time.

Performance – Response Time. Response time measures show how well the system is performing. It is essential that some historical or benchmark data exist during different levels of system activity. It is comparison with this benchmark data that allows meaningful interpretation of the observed data. Figure 7 shows a simple response time diagram for three system functions, input processing, algorithm processing, and output processing. Correct interpretation will depend on historical data available and the experience of the measurement analyst.

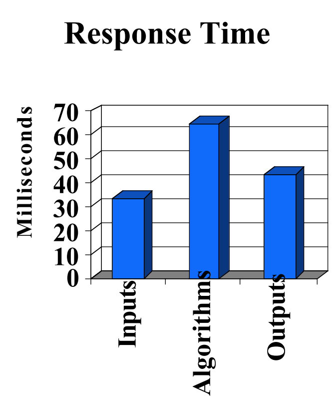

Figure 7: Performance

SUMMARY

There are many techniques available to evaluate the Operational Safety, Suitability, and Effectiveness of an operational Command and Control system. The Practical Software and Systems Measurement process provides one of the most useful since it is based on the current issues and goals of the project of interest. It is important to note that the issues and goals of any project will vary significantly according to the life cycle stage it is in. Typical concerns during development are cost, schedule and quality. After implementation, concerns often shift to performance and maintenance areas. Finally, nearing decommissioning or replacement of the system, the main concern is maintaining and transitioning mission capability so no loss of operational capability unexpectedly occurs.

The effective use of measurement takes a great deal of planning. The data sharing and access needed to provide independent analysis capability and the means for objective two-sided communications between the developer and user must be included during all phases of the contract from the Request for Proposal to Contract Award and execution.

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BIOGRAPHY

Dave Smith has 27 years experience with Cheyenne Mountain and the systems of Air Force Space Command and NORAD. He has been a systems engineer with The MITRE Corporation in Colorado Springs for 22 years. During the last three years, he has been a certified PSM instructor.