Enterprise Systems Engineering Metrics Plan

Document Change Record

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1.0	Initial Systems Engineering Metrics Plan	

Contents

1.0 Introduction 4

2.0 Understanding Systems Engineering Metrics 4

2.1 Business Value of Metrics 5

2.2 Linkage Between Process and Metrics 6

2.3 Use of Metrics for Improvement Programs 7

3.0 Description of the Systems Engineering Metrics Process 7

3.1 Systems Engineering Definition 7

3.2 Attributes of a Useful Metric 8

3.3 What a Metric is Not 9

3.4 Effectively Communicating Metrics Information (TeamCenter Dashboard) 9

3.5 Validation of the Metrics Process 10

4.0 Guidance for Tailoring Systems Engineering Metrics to Other Project or Customer Requirements ... 11

4.1 The Metric Package 11

4.2 Tailoring A Metric 12

Appendix A: Definitions 14

Appendix B: References 17

Appendix C: Analysis Techniques 18

C 1.0 Charts, Graphs, and Techniques 18

C 1.1 Run Charts 18

C.1.2 Control Charts 18

C 1.3 Flow Charts 19

C 1.4 Cause and Effect (Fishbone) Diagrams 20

C 1.5 Histograms 21

C 1.6 Pareto Diagrams 22

C 1.7 Scatter Diagrams 23

C 1.8 Check Sheets 23

C 1.9 X-t Plots 24

C 1.10 Network Diagrams 24

C 1.11 Gantt Charts 25

C 1.12 Line Graphs 26

C 1.13 Pie Charts 26

1.0 Introduction

The purpose of this Metrics Document for Systems Engineering and Product Development is threefold: (1) Capture the experience represented in various Enterprise and Customer projects, (2) Use the knowledge and capabilities of the International Council of Systems Engineering (INCOSE) Metrics Working Group and (3) Determine and use Industry Best Practices on relevant metrics in a Systems Engineering Integrated Product Development (IPD) and Production environment.

This document addresses benefits, techniques, tailoring, and application of Systems Engineering metrics for Enterprise engineering development and production programs. The objectives are to provide fundamental Systems Engineering metrics constructs, based on understanding system performance and performance in development and production of systems. This document is intended to provide the following:

1. Understanding of Systems Engineering metrics
2. Description of the Systems Engineering metrics process
3. An example tailored Systems Engineering metrics procedure for a specific Project
4. Guidance for tailoring the Systems Engineering metrics to and developing new Systems Engineering metrics for different project or customer requirements

This document (and the appropriate Project Metrics Document) is intended for the use of any individual or group responsible for developing and implementing a metrics capability within the Enterprise. The author of this document recognizes that there is significant differences in the terminology used to describe the engineering of systems and products within the DoD and commercial areas. However, the Systems Engineering metrics construct described in this document is useable among projects relating to the different environments, despite differences in terminology.

As a reminder during any discussion of performance note that at each cost-effective solution:

a. To reduce cost at constant risk, performance must be reduced.
b. To reduce risk at constant cost, performance must be reduced.
c. To reduce cost at constant performance, higher risks must be accepted.
d. To reduce risk at constant performance, higher costs must be accepted.

In this context, time in the schedule is often a critical resource, so that schedule behaves like a kind of cost.

2.0 Understanding Systems Engineering Metrics

The consequences of ineffective Systems Engineering at any stage of a project are cost escalations and schedule delays throughout the remainder of the project. Since Systems Engineering is mainly process related, all metrics for Systems Engineering have to measure the degree of effectiveness of both the product and the process as well as the impact. The effectiveness of any Systems Engineering product is measured by the quality of the documentation and the degree of meeting specifications/requirements.

At the outset we recognize the strong interaction and overlap between Enterprise Project Management (PM) and Systems Engineering (SE) functions. The recommended Systems Engineering metrics process described herein will help to define the types of information needed to support project management decisions and implement Systems Engineering best practices to improve performance. When performance is measured, performance improves. When performance is measured and reported, the rate of performance improves. When performance is measured, reported, and compared, the rate of performance continues to improve. The choice of the amount and depth of any metrics set 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 and what type of subcontractors/suppliers, program office size and make up, subcontractor/supplier past performance, political visibility, and contract(s) type.

For Systems Engineering Metrics the following are considered key characteristics

- Must Measure Major Components of Systems Engineering
- Must Be Targeted for Management and Customer
- Must Be Few in Number
- Must Describe Current Status as well as historical lessons learned
- Must Allow For Comparison Between Projects, Organizations, and Time
- Must Be Cumulative (Ability to Roll-Up)
- Must Avoid Extensive Data Collection Efforts

It is also understood that to be most effective, you need performance metrics in as close to real-time as possible. Understanding the difference between lagging versus leading indicators can often be the defining factor for setting your project on the correct course. Lagging indicators help indentify historical trend information, while leading indicators provide predictive information that can allow management to make data-driven decisions to change future outcomes

2.1 Business Value of Metrics

A metrics process must efficiently deliver information to Systems Engineering and Project Managers who use it for decision-making. Metrics help the Project and Systems Engineering Manager to:

1. Monitor the progress and performance of activities
2. Analyzing trends that help focus on problem areas at the earliest point in time
3. Providing early insight into error-prone products that can then be corrected earlier and thereby at lower cost
4. Avoiding or minimizing cost overruns and schedule slips by detecting them early enough in the project to implement corrective actions
5. Identifying complexities in the requirements development, design, technical performance progress, etc., to enable a focus on risk areas and make key tradeoffs
6. Performing better technical planning, and making adjustments to resources based on discrepancies between planned and actual progress.
7. Communicate effectively throughout the project organization
8. Track specific project objectives
9. Defend and justify decisions

Metrics help facilitate quality improvement through tracking and monitoring of our current processes and capabilities so that we are able to improve upon them. In System Engineering, product and project environment metrics along with a well-defined set of System Engineering processes provide the infrastructure to promote integration of various team disciplines. Each team member then has visibility into all the functions and areas of responsibility. Process and quality metrics are effective tools for focusing management and engineering teams on activities that lessen defects and improve cycle time. Metrics goals are as much about communication as they are about goals and objectives. Interdependent tasks are coordinated with much more ease and accuracy because the engineering team members are more informed. Properly selected metrics support active risk management by early identification of deviations before major cost and schedule impacts occur. A metrics program motivates us to take the required action(s) to stay on track.

Metrics ensure that detailed measures of engineering processes, performance and product quality are defined, collected, and analyzed to provide quantitative understanding and control in support of improving performance, products and processes. With quantitative measurements, problems and results become more apparent to management, and required actions are clearer to engineers. Metrics help to identify risks early enough in the process to enable correction of the situation or problem before it is out of control – before it affects schedule and cost.

When the customer is provided insight into products, processes, progress, and performance, it raises the customer’s confidence level in Enterprise. The customer wants to know the reality of the situation – how his money is being spent. Metrics not only provide the mechanism that allows the customer to see the whole picture, but the resulting report (information) gives the customer an understanding of technical, cost, and schedule status. It can mean the difference between an aloof or nonresponsive customer relationships versus a teaming atmosphere between the customers and Enterprise. A metric gives the customer insight and allows the customer to become part of the solution.

2.2 Linkage Between Process and Metrics

Metrics are meaningful measures of the performance of a process, product, or activity and form a basis for genuine process improvement. Enterprise Systems Engineering metrics have been developed by teams with understanding of the systems engineering processes and must have management commitment to take action when required; otherwise even the best metrics are meaningless. The ability to implement change based on accumulated, measured data is the distinguishing factor between taking a measurement and having a useful metric. Metrics must communicate the health of a process and enable the Enterprise to distinguish healthy and unhealthy trends for products and processes. All processes (including systems engineering processes) exhibit some variation. Continuous improvement of our systems engineering processes means reduction of variation, within an acceptable set of limits.

2.3 Use of Metrics for Improvement Programs

The use of metrics is intrinsic to quality/improvement programs including ISO 9001 and the Software and Systems Engineering Capability Maturity Models (CMM). The metrics tell Enterprise where genuine improvement has occurred. Metrics also provides clarity in understanding the problems so that Enterprise's goals can be reached. Using metrics for monitoring and tracking provides increased visibility into the any product's progress and quality. Depicting and understanding variation with metrics is essential to systematically improving the systems engineering process. Metrics techniques assist in depicting both the normal and abnormal variations in any systems engineering process.

3.0 Description of the Systems Engineering Metrics Process

For each of the above, metrics quantifies the relevant Systems Engineering processes or work products with respect to the needs and objectives of Enterprise. Common system engineering metrics include timeliness, efficiency and effectiveness, performance requirements, quality attributes, conformance to standards, and parsimonious use of resources. An important concept of a successful metrics process is the communication of meaningful information to the decision makers, for whom understanding what is being measured and how it is to be interpreted is essential. Metrics also provides critical insight needed for continuous process improvement to achieve cost and cycle time reductions and/or quality or technical performance improvement. The Enterprise metrics process is a systematic and repeatable process and infrastructure that delivers objective information to managers and other stakeholders. This process, like other systems engineering processes, follows a documented plan which describes the goals and business value of the process, and is evaluated periodically.

3.1 Systems Engineering Definition

A common theme throughout industry and Government is the need for a definition of Systems Engineering, from which the metrics of systems engineering are developed. This Document (as does other AMG documents) follows the definition in EIA Standard IS632, Systems Engineering, "Systems Engineering involves design and management of a total system which includes hardware and software, as well as other system elements. All system elements should be considered in analyses, trade-offs, and engineering methodology."

It is important to recognize that systems engineering is a management technology, i.e., systems engineering involves the interaction of engineering science, the development/production organization, and the application environment. The interactions among these three elements are in the form of information, and some of this information will be in the form of metrics for the system. The quantification of system characteristics, i.e., system measurement, is a necessary part of system development/production and the systems engineering process. The overall system development/production process and its systems engineering component can be described as a network of activities. This section discusses why certain metrics for Enterprise's system engineering activity have been chosen. A statement of requirements for the overall system is the input to the system engineering activity. The system engineering activity partitions the requirements among hardware, software, and procedures.

These same system elements have been considered in the development of the Enterprise System Engineering metrics set. This document has established two levels of System Engineering metrics:

1. Systems engineering metrics "owned" by the System Engineering function/team member(s) and
2. Metrics about which the Systems Engineering function has "need-to-know" in order to produce the product the customer needs. These metrics may be "owned" by another Enterprise function/team, but their status is critical to an overall understanding of the system performance or system development.

3.2 Attributes of a Useful Metric

It is important that a metric and its measures reflect the defined goals and objectives of Enterprise. A useful metric promotes understanding of our performance or progress, as well as our processes, and must motivate action to improve upon the way we do business. This perspective applies from the smallest task through product development to total company operations. A strong metrics program creates an environment in which Management and Engineering Teams can make decisions based on data rather than hunches, to look for root causes of problems rather than react to superficial symptoms, to seek permanent solutions rather than rely on quick fixes.

The following are the basic characteristics of a useful metric:

1. It is accepted as having value to the customer or as an attribute essential to customer satisfaction with the product.
2. It tells how well organizational goals and objectives are being met through processes and tasks.
3. It is simple, understandable, logical and repeatable.
4. Evaluation of a metric over time shows a trend, more than a snapshot or a one-time status point.
5. It is unambiguously defined.
6. Its data is economical to collect.
7. The collection, analysis, and reporting of the information is timely, permitting rapid response to problems.
8. The metric provides product and/or process insight and drives the appropriate action(s).

In summary, for a metric to be effective it must present data that is timely and useful, thus motivating action(s) to be taken, be able to show status over a period of time, support corporate and product goals and objectives (built from strategic and tactical business plans), and be meaningful to the customer.

3.3 What a Metric is Not

What a System Engineering metric is not:

1. Metrics are not charts or any other form of display tool, although charts and graphics may display the results of a metric.
2. Metrics are not a team or personnel control tool. Metrics are a process and product control tool. If used against team members, fear, short-term reaction, and "gaming" the system become the output.
3. Metrics are not one-time snapshots or statusing measures. For metrics to be effective, they need to be collected and assessed over the entire project time frame.
4. Metrics are not forever. Different phases of the product lifecycle may require different metrics. The Systems Engineering activity has a responsibility to update the metrics set consistent with the critical processes associated with the product lifecycle phase.
5. Metrics are not schedules, though some schedules lead to good metrics.
6. Metrics are not "counts of activity," although counts of activity or statistics may be significant. Data becomes a useful metric when it is transformed to information or knowledge that can result in action.

Normal variations are usually process related. These types of variations may include work environment, communications, work methods, materials, and reliability of equipment. Internal systems engineering processes can often be improved to avoid repeating the same problem. Abnormal variations are nonroutine or unusual causes. For instance, an increase in errors may be the result of a new employee having been given the responsibility of a critical task. In this situation, the process itself may not require a change, but the additional training of personnel may be in order. Metrics help identify the point of insertion in the process where the problem occurs. Abnormal variation may show up during monitoring of a process that shows considerable normal variation as well.

3.4 Effectively Communicating Metrics Information (Dashboard)

Metrics collected and not communicated have little value. Most organizations have significant amounts of data that fall in this category (whether or not they are called metrics). The best measures of the utility of a metric are its pertinence to the population from which the data was collected and the use to which the information is put. Annual, mandated sweeps of information collection are unlikely to improve the product or process from which the data was extracted. Useful information by definition must improve a systems engineering process in a timely way. Information (not just data) from which knowledge can be extracted and action taken must be presented in a manner that clarifies and fairly presents findings. The delivery of the information can be verbal, written, or electronically distributed. However, the needs remain the same:

1. Information that is useful
2. Information that is objective, accurate, and internally consistent
3. Information that is regularly available to all members of the team

Communicating metrics information within Enterprise will be accomplished in several ways. Dissemination of the metrics information will be by TeamCenter dashboard, briefing, bulletin board, on-line access and team newsletter. The key is to disseminate useful metrics information as rapidly as possible to the population that can benefit (take action) from the information.

The Enterprise will use a Dashboard to communicate metrics and performance information. As part of this framework, TeamCenter provides program execution management capabilities that executives, product managers, project managers and SE personnel use to increase their visibility into project performance and broaden their control over project execution. The Systems Engineering Organization uses these capabilities to automate the extraction and reporting of Systems Engineering and performance metrics and treat them as an intrinsic component of their work. The real-time Dashboard capability enables the Enterprise personnel to extract key process information from individual groups and gain visibility into our up-to-date and comprehensive program information. In addition to providing key process information, this dashboard provides access to each project's rolled-up Systems Engineering and performance metrics, process metrics, customized strategy-specific KPI and risk analysis metrics.
The Systems Engineering organization also leverages Dashboard capabilities to make certain that all project participants are fully aware of the Enterprise's business goals and the individual roles they play in meeting these objectives. The dashboard rolls up the day-to-day activities of these participants into dashboards that summarize the most important metrics in our metrics hierarchy. As part of these capabilities, dashboards provide executives and managers with extensive reporting and tracking capabilities. Executives can receive summary updates that highlight the status of all of their organization's teams and projects. All entitled stakeholders can request big picture views to multiple project schedules in easy-to-read Gantt format. They can also access cross-project management reports that present organization-wide project information.
By being able to view numerous reports in dashboard format, Systems Engineering management has access to all of the vital systems engineering and product development metrics required to assess project performance. A dashboard makes it easier to determine which processes are on track, which are missing their targets and where improvements can be made. This functionality enables Enterprise Systems Engineering to use closed loop processes to manage the project lifecycles and their entire set of systems engineering processes. Together, these capabilities provide deeper visibility and control into the activities that comprise most product development and manufacturing processes while maintaining a holistic view that covers the entirety of both processes.

3.5 Validation of the Metrics Process

The Enterprise Systems Engineering metrics process/procedure is validated by putting it into action and implementing the process. It is important that all levels of management and their staff support implementation of the metrics plan – it is a crucial factor for success. A regular metrics collection and reporting schedule has been established, requiring cooperation of most of the Enterprise organizations (Finance, Parts Management, Product and Design Engineering, Quality), management, and the Systems Engineering process group. The metrics collection process consists of the following steps:

1. Raw data is collected and input to the appropriate database
2. Results are calculated based on the appropriate procedure
3. Results are analyzed and briefed to management

4. Based on the analyzed results, appropriate action is taken to ensure that the project objective and customer requirements are met.

4.0 Guidance for Tailoring Systems Engineering Metrics to Other Project or Customer Requirements

A Metric (as defined by the Enterprise) is a composite of meaningful, quantifiable, product or process attributes (measures) taken over time that communicates important information about quality, processes, technology, products and/or resources. A metric consists of three basic elements: (1) the operational definition, (2) the actual measurement and recording of data, and (3) the metric presentation. Together these elements are called the "metric package," as defined below. However, for a metric to have value, it must have a purpose or a reason to exist – it must yield systematic insight, whether by itself or when combined with other metrics. Management is then able to take action (to fix a problem, to improve a product or a process) based on the insight that the measurement data is providing. Systems Engineering Metrics selection and implementation must be specifically designed to improve processes and products. A strong Systems Engineering metrics program allows the Enterprise to measure progress toward any goal (even those unique to the Enterprise), a specific project, or a specific task.

4.1 The Metric Package

A metric consists of three basic elements: (1) the operational definition, (2) the actual measurement and recording of data, and (3) the metric presentation. Together these elements are called the "metric package". The operational definition is the precise explanation of the process being measured. The measurement and data collection is the translation of data from the process into understandable and useful information. The metric presentation is the metric's communication link to the product team and process owner. For Enterprise, metrics packages consist of:

a. Metrics, ground rules, and rationale
b. Names, roles, responsibilities, and schedules
c. Blank data collection forms
d. Sample completed data collection forms

The first element of the metric package is the operational definition. The operational definition is the who, what, where, and how of the metric. It is customer oriented and accepted. It must be made over time and is the key to internal communication for process understanding. The detail required will vary from metric to metric, but development should consider at least the following elements:

1. An unambiguous description of the metric
2. Population that the metric will include
3. Frequency of measurement
4. Source of data
5. Equations required in doing the measurement
6. Precise definition of key terms
7. Description of the graphic presentation that will eventually be used to display the data
8. Customer of the metric

9. Accountable process owner
10. Desired outcome expressed in terms of positive or negative trend (not a numerical goal)
11. Link between the process being measured, your organization's strategic plan, and the goals.

4.2 Tailoring A Metric

Step I. Identify Your Purpose
It is important to first align your purpose with your organization's mission, vision, goals, and objectives. These should be linked to meeting customer needs and serve as a foundation for accomplishing and sustaining continuous, measurable improvement.

Step II. Develop Your Operational Definition, Starting with Your Customer
Define the who, what, when, why, and how of this metric in sufficient detail to permit consistent, repeatable, and valid measurement to take place. The operation definition starts with an understanding of your customer's expectations. You then "operationalize" the expectation(s) by defining characteristic(s) of the product, service, or process that are internally measurable and which if improved, would better satisfy your customers' expectations. This is actually an iterative process involving Steps II through VII. This is the first element of your metric package.

Step III. Identify and Examine Existing Measurement Systems
Once the link to objectives and goals has been established, it is essential to determine if existing metrics or other measurement systems exist that satisfy your requirements. Don't "reinvent the wheel." Use existing process measurements/metrics when they exist.

Step IV. Generate New Metrics if Existing Metrics are Inadequate
Most metrics used in the past were results indicators related to final outputs, products, or services for external customers. With metrics, the focus includes the process input in making these final outputs. These upstream process measures drive the final outcome and are the key to making process improvements. When process performance is monitored and improved, the quality of the products and service improves.

Step V. Rate Your Metric Against the "Eight Attributes of a Good Metric" Section 2.2.
If you feel your metric sufficiently satisfies these criteria for a good metric, go to Step VI. If not, return to Step II and correct the deficiencies.

Step VI. Select Appropriate Measurement Tools
Select the proper tool for analyzing and displaying your data. The tools discussed in Appendix C are the most common. However, other statistical and nonstatistical tools may be more appropriate for your application.

Step VII. Baseline Your Process
Start acquiring metric data. This serves as a baseline for determining the capability of your process. Ask if the data accumulated over time adequately measures the important

characteristics of your process. If the answer is uncertain, examine other possibilities. When metrics are changed, remember to coordinate it with the SEIT and your customer again.

Step VIII. Collect and Analyze Metrics Data Over Time
Continue aggregating metric data over time. Examine trends. Special and/or common cause effects on the data should be investigated and assigned. Compare the data to interim performance levels. This is the second element of your metric package.

Step IX. Finalize the Metric Presentation
Based on the results of the previous steps, you are finally ready to present the metric externally. The descriptor will provide enough information to communicate the appropriate details of the metric to Enterprise Management and your customer. The appropriate level of detail should be determined by discussion with Enterprise Management and the customer. This information should be an abbreviation of the key elements of the operational definition. The graphic presentation clearly and concisely communicates how you are performing. This is the third element of your metric package.

Step X. Initiate Process Improvement Activities
Initiate process improvement activities in conjunction with the key process owners. Once improvements have been implemented, the process above may start over or it may pick up again at almost any step. **Remember that metrics have two major requirements. First, they must allow AMG Management to understand the status and progress of existing work efforts and second is continuous process improvement.**

Appendix A: Definitions

Accuracy - The extent to which the measured value of a quantity agrees with the accepted value for that quantity.

Assignable cause - A cause believed to be responsible for an identifiable change of precision or accuracy of a measurement process.

Bias - Systematic error that is manifested as a consistent positive or negative deviation from the known or true value. It differs from random error which shows no such deviation.

Environmental data - any measurements or information that describe environmental processes, location, or conditions; ecological or health effects and consequences; or the performance of environmental technology. For EPA, environmental data include information collected directly from measurements, produced from models, and compiled from other sources such as data bases or the literature.

Certified Reference Material (CRM) - A reference material, for which one or more property values are certified by a technically valid procedure, accompanied by or traceable to a certificate or other documentation which is issued by a certifying body.

Measurement - The process of assigning numerical values to attributes. A “measure” is therefore the quantified value of an attribute. A metric is distinct from a measure in that it is a measure compared to what is expected.

Measured Value - The stated or recorded value after all appropriate adjustments and corrections, if any, have been incorporated into the observed value.

Nonconformity - A departure of a quality characteristic from its intended level or state that occurs with severity sufficient to cause an associated product or service not to meet a specification requirement.

Observed Value - A raw, uncorrected value; the magnitude of a specified measurement, a variable, or a unit of space, time or quantity; a datum.

Outlier - A datum which appears to deviate markedly from that for other members of the sample in which it occurs.

Performance Evaluation - An audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data in order to evaluate the proficiency of an individual or group.

Precision - The degree of similarity among independent measurements of the same quantity, without reference to the known or true value. It often is presented as the inverse of the standard deviation.

Quality - The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.

Quality Assurance (QA) - All those planned or systematic actions necessary to provide adequate confidence that a product or service is of the type and quality needed and expected by the customer.

Quality Assurance Program - The documented plans for implementing the quality system.

Quality Assurance Project Plan (QAPP) - a document describing in comprehensive detail the necessary quality assurance, quality control, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria.

Quality Management Plan (QMP) - a formal document describing the management policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization or group for ensuring quality in its products.

Quality Audit - A systematic and independent examination and evaluation to determine whether quality activities and results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

Quality Circle - A small group of individuals with related interests that meet at regular intervals to consider problems or other matters related to the quality of outputs of a process and to the correction of problems or to the improvement of quality.

Quality Control (QC) - The operational techniques and the activities used to fulfill and verify requirements of quality.

Quality Management - That aspect of the overall management function that determines and implements the quality policy.

Quality Policy - The overall intentions and direction of an organization as regards quality as formally expressed by top management.

Quality System - The organizational structure, responsibilities, procedures, processes, and resources for implementing quality management.

Reference Material - A material or substance one or more properties of which are sufficiently well established to be used for the assessment of a measurement method or for assigning values to materials.

Sample - A representative part of a larger whole; a finite part or subset of a statistical population.

Standard - Something established for use as a rule or basis of comparison in measuring or judging capacity, quantity, content, extent, value, or quality.

Standard Method - An assemblage of techniques and procedures based on consensus, or other criteria, and often evaluated for its reliability by a collaborative testing and having received organizational approval.

Standard Operating Procedure (SOP) - A written document which details the method of an operation, analysis, or action whose techniques and procedures are thoroughly prescribed and which is accepted as the method for performing certain routine or repetitive tasks. It may be a standard method or one developed by the user.

Standard Reference Material (SRM) - A certified reference material (CRM) produced by the U.S. National Institute of Science and Technology.

Appendix B: References

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Appendix C: Analysis Techniques

C 1.0 Charts, Graphs, and Techniques

Charts and graphs are a good way to present measurement data. They are useful for displaying progress and performance over time. This section provides a brief discussion of 13 tools useful in the presentation and analysis of metrics.

C 1.1 Run Charts

Run Charts are used to illustrate trends or shifts in the average, to identify problems early in the life cycle as well as to perform analysis. This type of chart provides a clear picture of how smoothly the project is running; it does not indicate control. It provides a simple display of trends within an observation window over a period of time.

The example shown in Figure C 1-1shows a shift in the expected measurement, indicating a statistically unusual event. If the change is favorable, whatever caused that change should be made a permanent part of the process or system. If unfavorable, the cause should be identified and corrected or eliminated.

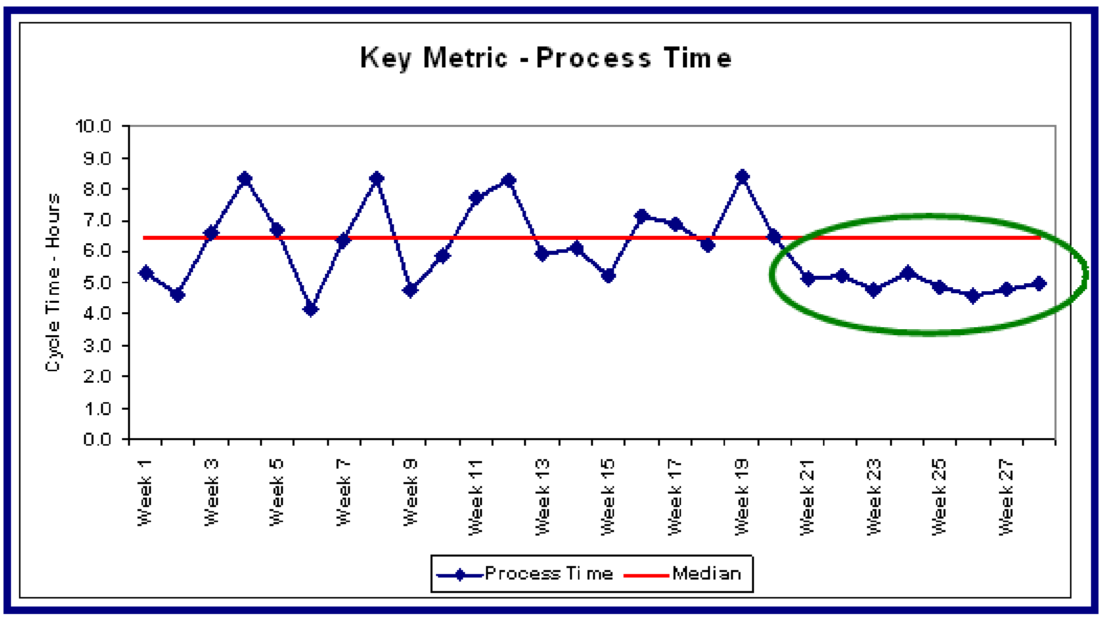

Figure C 1-1. Run Chart Showing Key Metric for One Project

C.1.2 Control Charts

Control Charts are run charts with statistically determined upper and lower limits drawn on either side of the determined average. Control Charts allow a tolerance range and provide a means for analyzing project variables over time as well as identifying areas out of control or under control. Those measurements within the tolerance range are indications as well as those measurements out of tolerance. The tolerance limits are set when statistically significant sample sets have been collected.

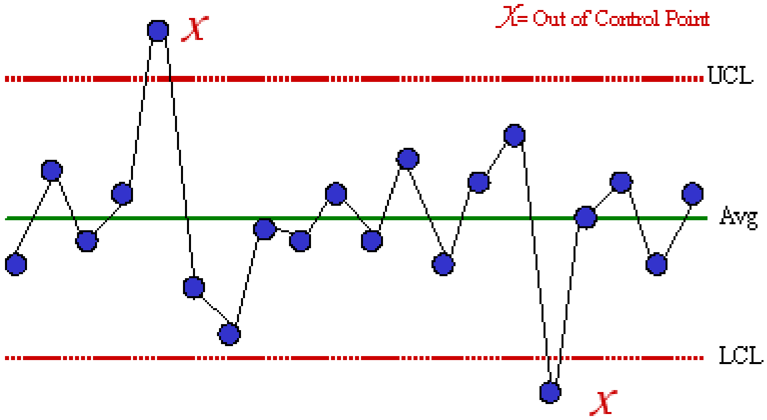

Figure C 1-2. Control Chart Showing Out of Tolerance Point

Limits are calculated by running a process without adjustments or tweaking. Samples are taken at periodic times and plotted onto the graph. If any of the points fall above or below the line, something within the process is out of control and requires corrective action.
Fluctuation of the points within the bounds are usually caused by normal variations already built into the process (such as design decisions or choice of platform, etc.) and can only be affected by changing the platform or the design. Points outside of the bounds represent abnormal or special causes. Abnormal causes are usually related to people, errors, unplanned events, etc., and are not a part of the normal process.

C 1.3 Flow Charts

Flow charts are useful for analyzing and breaking down any process or task into smaller steps and identifying possible errors or problem areas. Use of this tool is especially good for visualizing a process thread for easier understanding and to identify areas where metrics would be appropriate, as illustrated in Figure C 1-3.
The flow can also show the actual path versus the ideal path of a product or service. When trying to identify a problem, compare the actual steps versus the ideal steps to find the differences and where the problems will surface.

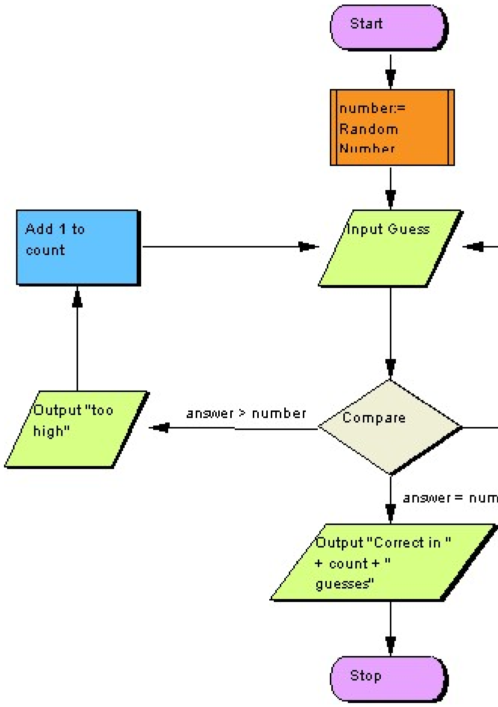

Figure C 1-3. Flow Chart Example

C 1.4 Cause and Effect (Fishbone) Diagrams

Cause and effect (or fishbone) diagrams are commonly used for problem identification; showing relationships between possible root causes and their effects. For each effect, there may be several major categories of causes. This tool helps to sort out and relate the various relationships to help facilitate finding the problem area(s). Cause and effect diagrams are also useful for identifying areas where metrics would be beneficial. It is important to look to cure the cause and not the symptoms. Figure C 1-4 is an example of a cause and effect diagram showing relationships between root causes and effects. A cause and effect diagram is developed using the following steps:

1. *Specify the problem to analyze.* The effect can be positive (objective) or negative (problems). Place the problem's title in a box on the right side of the diagram as shown in Figure 5.1.4-1.
2. *List the major categories of factors influencing the effect you are studying.* You can use the "4Ms" (methods/manpower/materials/machinery) as shown in Figure 5.1.4-1 or the "4Ps" (policies/procedures/people/plant) as your starting point.
3. *Identify factors and subfactors.* Ask yourself "Why?" or use brainstorming or mental imaging to generate ideas. Start with the major categories and work from there.
4. *Identify significant factors.* What factors appear repeatedly? List them. Then list the factors having a significant effect. (Your data can help you identify those.)
5. *Prioritize your list of causes.* Don't confuse location with importance – a subfactor may be the root cause to all your problems. When you prioritize you may also discover new factors; then you will need to collect more data.

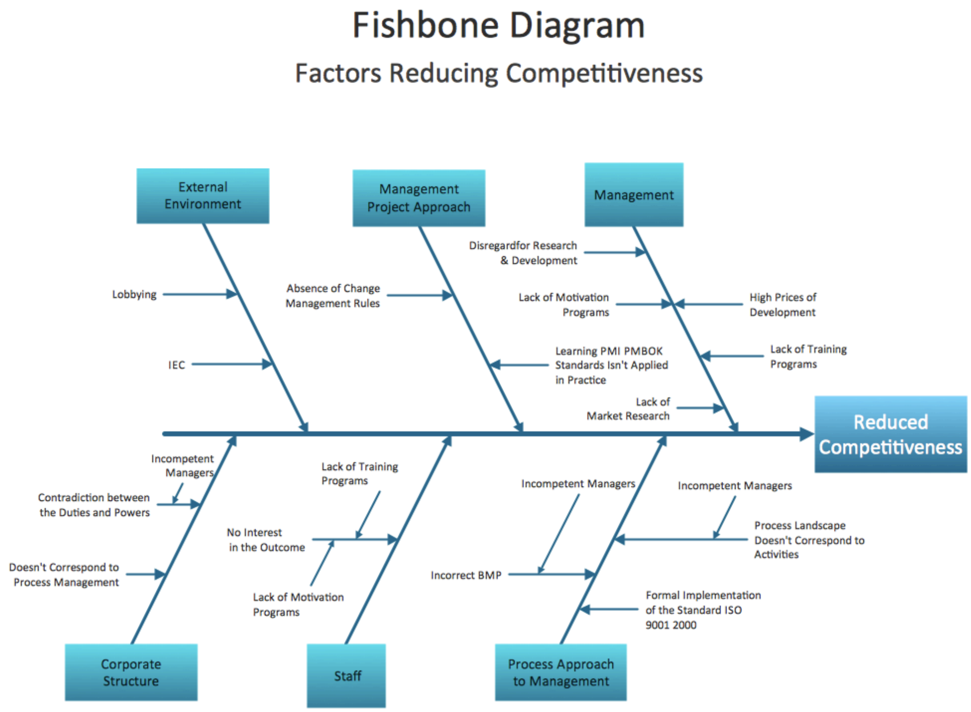

Figure C 1-4. Cause and Effect (Fishbone) Diagram Example

C 1.5 Histograms

Histograms are often used to show a picture of process performance over a period of time. The Histogram displays data distribution and provides problem identification and analysis. Histograms may be used for a wide variety of data, such as labor hours predicted versus actual for various tasks, predicted labor hours over time, or SP/CRs per category of software problem or function. Histograms provide effective analysis of task durations for PERT networks to determine areas that require more detail. Data abnormalities and variations become evident such as in the example in Figure C 1-5.

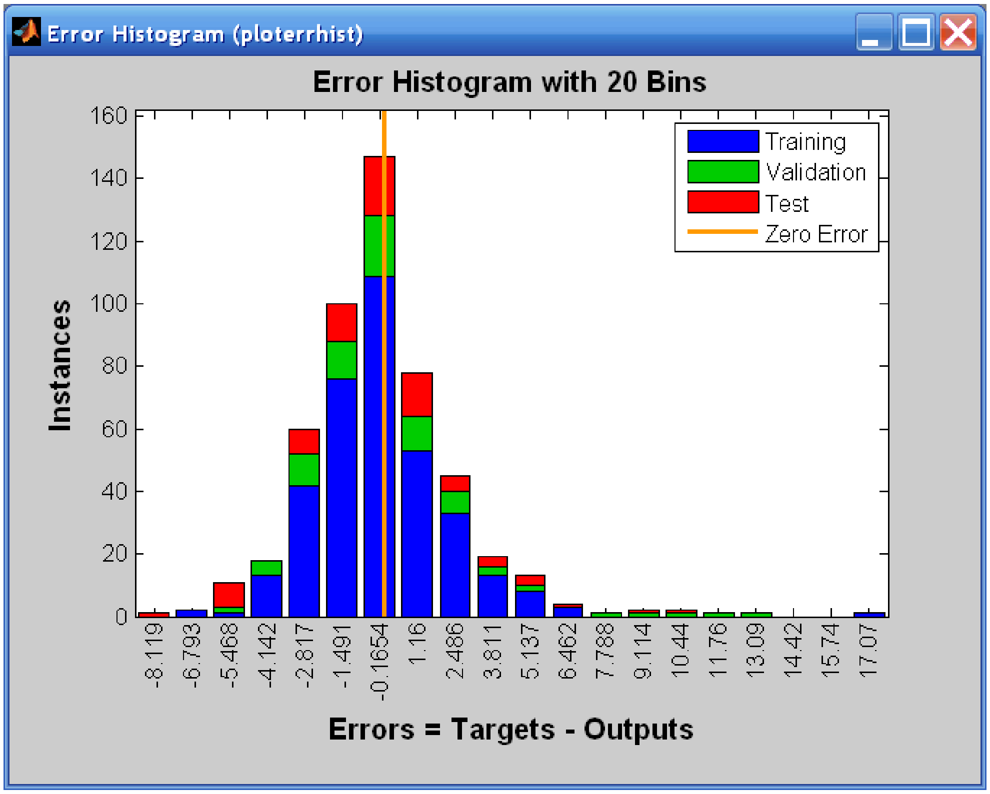

Figure C 1-5. Histogram Example

C 1.6 Pareto Diagrams

A Pareto diagram is a form of bar charting used to illustrate the relative contributions of a number of causes to an observed problem. As a metric display, it identifies the problems to be worked and is used as a lead-in for solving the problem. It can be used to identify the root cause of the problem, show the impact of the problem, and monitor the problem as measures are taken to bring the problem under control. It allows a view of all of the causes or conditions at once in order to choose a starting point. The height of the bar represents the number of instances of that condition or cause that were observed during the analysis of the problem. By convention, the cause contributing most to a problem is represented on the left, with other causes sorted in descending order of occurrence. A line graph shows cumulative contribution of the causes to the total problem. The example shown in Figure C 1-6 charts primary causes for schedule impact or deviation versus number of tasks affected by each.

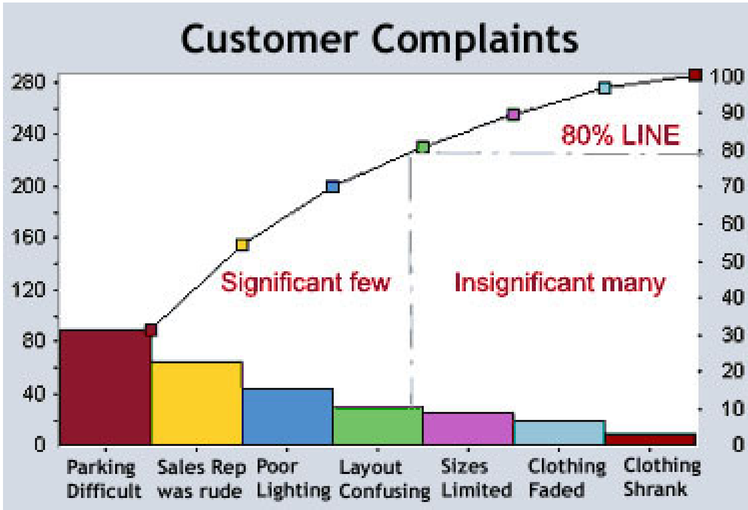

Figure C 1-6. Pareto Chart Example

C 1.7 Scatter Diagrams

Scatter diagrams are typically used for problem analysis and can assist in identifying potential metrics. The scatter diagram illustrates relationships between two variables and testing of those relationships. When one variable's changes affect the relating variable, this confirms that a relationship exists and indicates the strength of that relationship.
Direction and tightness of the clustering in Figure C 1-7 show the strength of the relationship between variable A and variable B. The more the cluster resembles a straight line, the stronger the relationship between the variables. Scatter Charts are also useful to compare effort versus duration or size, time versus size, or faults versus size.

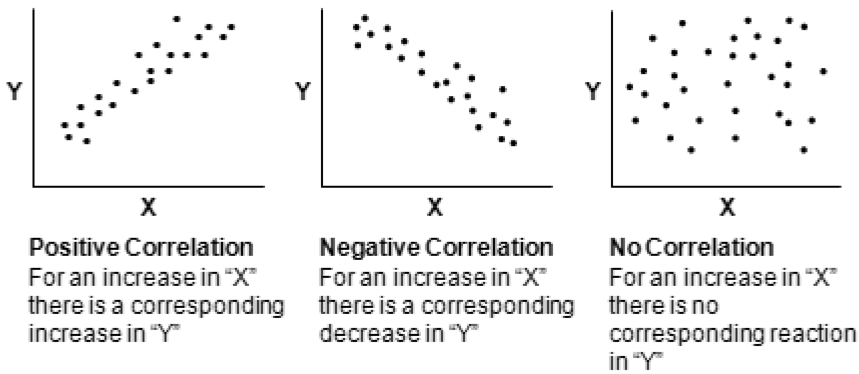

Figure C 1-7. Scatter Diagram Example

C 1.8 Check Sheets

Check Sheets are often used for counting and stratifying. This particular chart is appropriate to use for several metrics as a data collection and classification tool, but does not work well as a graphical display. The example in Figure C 1-8 shows the number of defects per type over a series of design inspections. Sample observations are gathered in order to detect patterns. This is a logical starting point in most problem solving cycles.

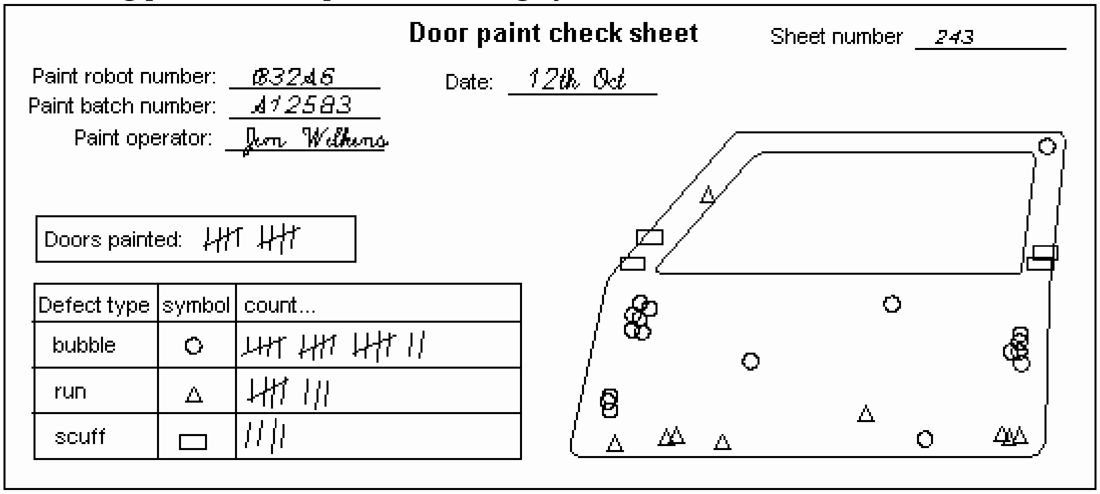

Figure C 1-8 Number of defects per type over a series of design inspections.

C 1.9 X-t Plots

The X-t plots (Figure C 1-9) show activity over time, in this case position over time for selected milestones.

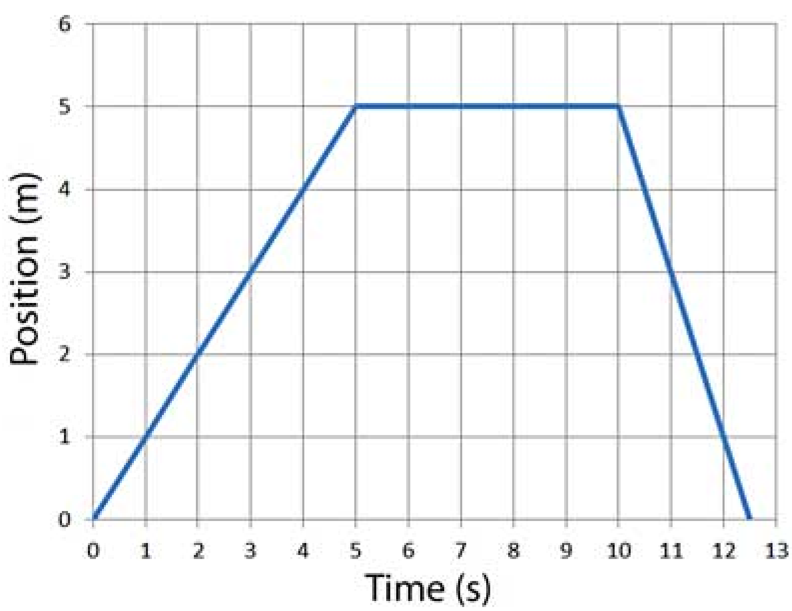

Figure C 1-9 Xt Plot Example

C 1.10 Network Diagrams

Network diagrams (also known as PERT charts), shown notionally in Figure C 1-10, are a primary output of project management. This chart shows the relationships between tasks through logical formatting. Interdependencies are shown as well as resource data, completion percentages, actual start and stop dates, and estimates and durations. Using on-line tools, the PERT chart can be customized to reflect any number of variations. The information gathered while monitoring PERT diagrams is used as a basis for a number of metrics analyses. An example is shown in Figure C 1-10.

Data on expected start and completion dates and actual start and completion dates for program tasks are collected and can be presented in both tabular and graphic form. The basic data can be analyzed in a number of ways, including comparison with plan and comparison to control limits among others. Note that information collected over time represents a valuable resource for lessons learned and trend analysis.

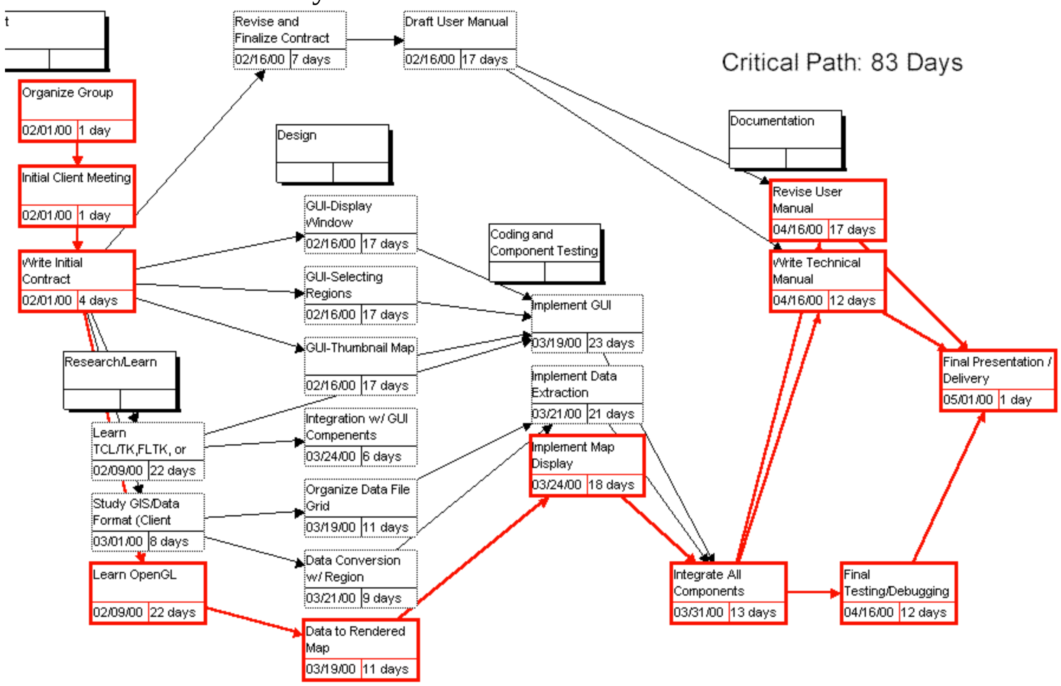

Figure C 1-10 Network (PERT) Chart Example

C 1.11 Gantt Charts

The example Gantt chart in Figure C 1-11 provides another way of looking at task durations or time scales. The length of each bar represents the relative duration of the task it represents. The bar also shows the start and end dates of each task against the time scale as well as the critical task (path). A stair-step pattern often indicates a critical path, as the end of each task matches the required start date for the next task. Overlaps in the horizontal bars may indicate negative float on a critical path. Gaps between the end of one bar and the beginning of another can be interpreted as positive float, an amount of “breathing room” in the schedule. Gantt charts may be annotated to indicate delayed tasks and actual progress to date.

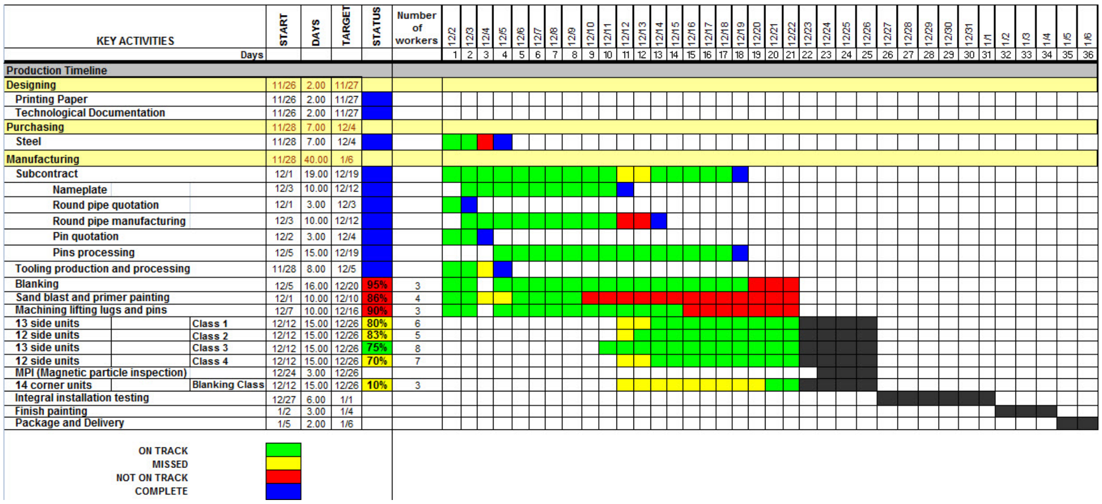

Figure C 1-11 Gantt Chart Example

C 1.12 Line Graphs

Line graphs are often used to display cost and resource information. The cost graph in Figure C 1-12 displays that the budgeted cost of work scheduled (BCWS) to be performed for the project is lower than the budgeted cost of work actually performed (BCWP) during implementation. However, the actual cost of work performed (ACWP) is higher, including unplanned expenses incurred during implementation.

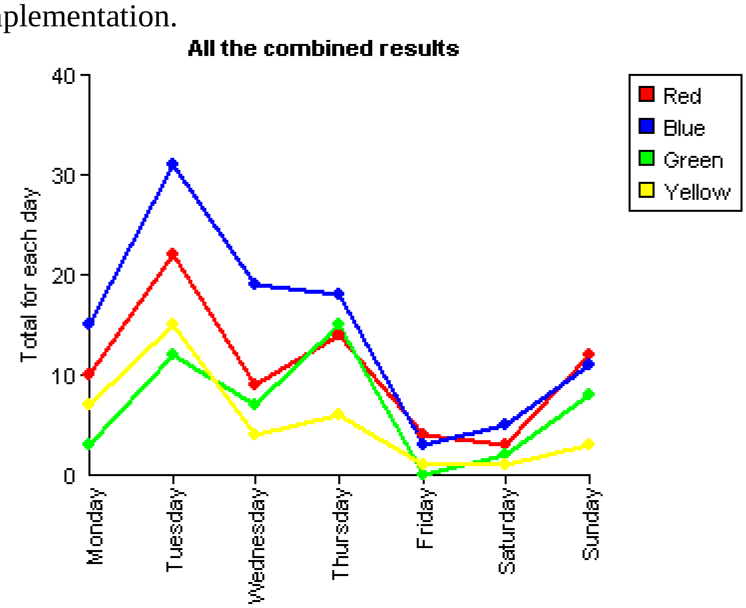

Figure C 1-12 Line Graph Example

C 1.13 Pie Charts

Pie charts provide a simple way to display percentages. The example in Figure C 1-13 illustrates the results of functional testing and the percentage of Trouble Reports written. This chart, along with a histogram (see paragraph C 1.5 for discussion of histogram) to correlate the number of tests conducted per thread will provide information about the number of bugs being found. Action on the tester's part would be to either exercise the other test scenarios more, or take a closer look at the problem areas.

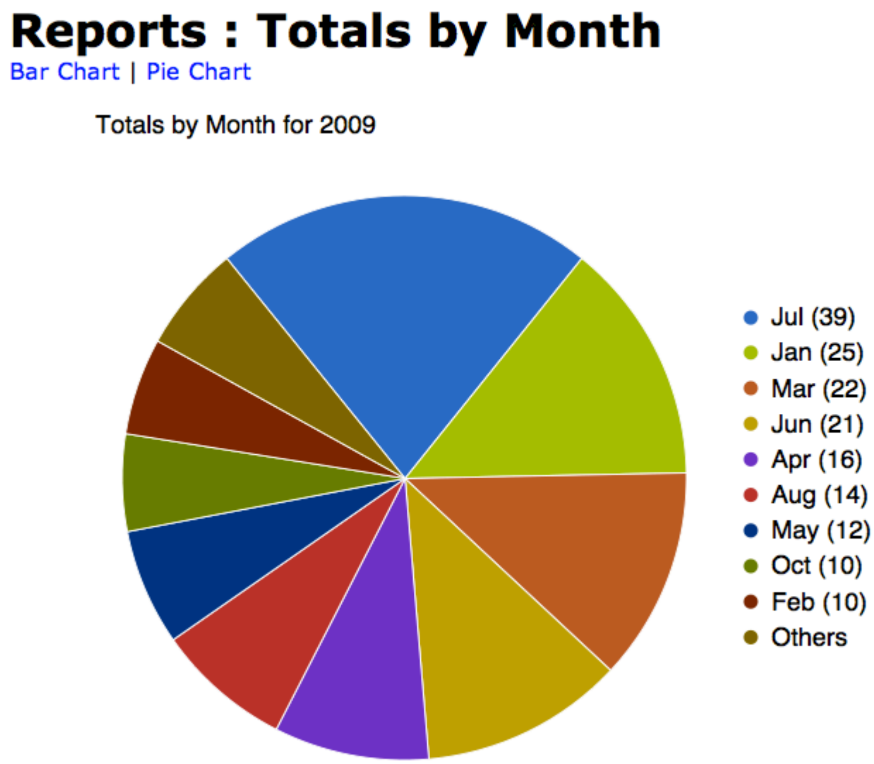

Figure C 1-13 Pie Chart Example