Quality Assurance Terms and Formulas Series 0000

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General Specification

Corporate Quality Division of Universal Instruments
Automation in Electronic Assembly

Quality Assurance Terms and Formulas Series 0000

Contents

All specifications are subject to periodic review and may be changed without notice.

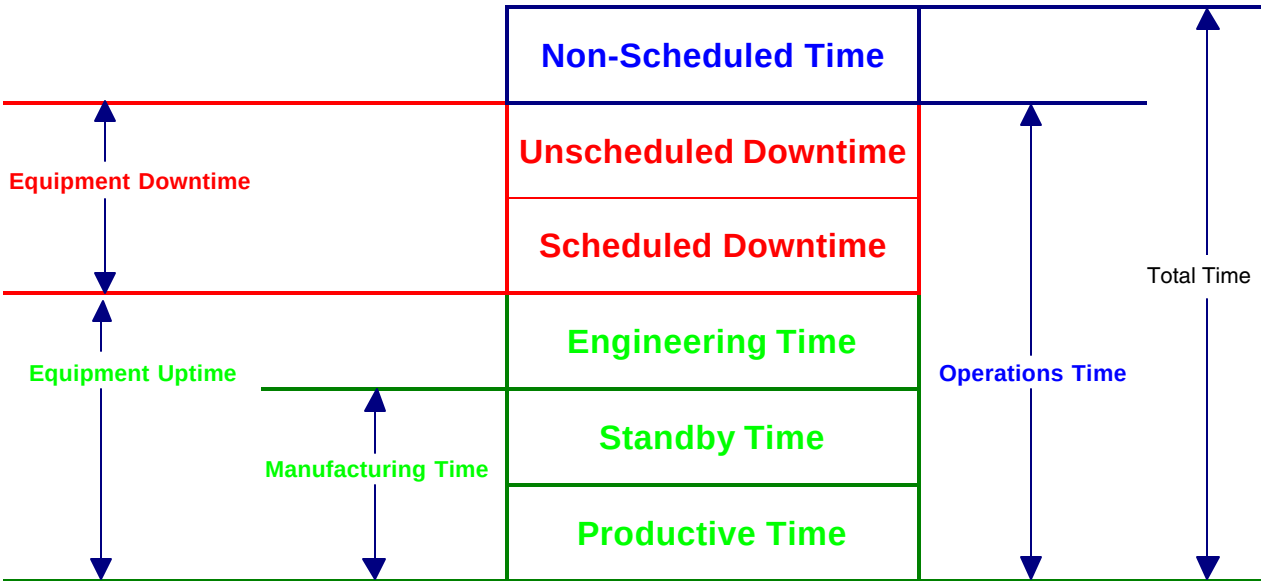
Introduction

This document defines the terms and formulas utilized in product measurement at Universal Instruments Corporation.

Terms and Formulas

Machine Utilization and Performance Terms and Formulas

These terms and formulas are intended to be identical to, or compatible with *SEMI Standard E10 Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)*, 1996 release.



Equipment States Stack Chart
Ref: SEMI Standard E10-96

Terms

Ball to Pad Coverage - Percent of total ball area that falls on the pad, as estimated for the worst case ball on the component. Analogous to lead to pad coverage, where the component has solder balls instead of leads.

Cycle - An equipment cycle is defined as one complete operational sequence of processing, manufacturing, or testing steps for a system or subsystem. In the case of Universal's equipment, a cycle coincides with the steps required to place, insert, or sequence one component.

Cycle Time - The inverse of tact time. It is the number of components that can be placed in a specified period of time.

Engineering Time - A period of time when the equipment is in condition to perform its intended function, but is operated to conduct engineering experiments.

Facilities-Related Downtime - A period during which the equipment cannot perform its intended function due to the lack of a required utility, such as power, or a vacuum line.

Insert Error - The failure of a product to insert components in the functional mode, in accordance with the tolerances defined in the product general specification.

Lead to Pad Coverage - In situations where the component lead is smaller than the printed circuit board pad, it is the fraction of total lead area that falls on the pad for the lead that is offset the most of all leads on a component by the combination of x,y, and theta errors. For situations where the pcb pad is smaller than the component lead, coverage is the fraction of total pad area that is covered by the component lead. Coverage is computed for the component most impacted by the combination of x, y and theta errors.

Machine Speed - The maximum number of components per hour that a machine can place for a particular product. Machine speed varies from product to product (which means that it should not be specified generically), and is less for products with larger components and larger space between placement sites. Excludes fiducial reads and board transfer time.

Maintenance Delay - A period during which the equipment cannot perform its intended function because it is waiting for either user or supplier personnel or parts associated with maintenance. It may also be due to an administrative decision to leave the equipment down and postpone maintenance.

Non-Scheduled Time - A period of time when the equipment is not scheduled to be used in production, such as unworked shifts, weekends, and holidays.

Outgoing Quality - The outgoing placement, insertion or taping defect rate. Usually measured in PPM.

Out-of-Specification Input Downtime - A period during which the equipment cannot perform its intended function due to the attempted use of input to the equipment which is out of specification.

Placement/Insertion Rate (Speed) - The actual components per hour that a machine places, for a particular product.

Practical (Actual) Performance - The actual throughput of a piece of equipment for a particular product.

Productive Time - A period of time when the equipment is performing its intended function. This includes regular production (including loading and unloading of product), rework, work for third parties, and engineering runs done in conjunction with production.

Recovery Time - The actual time to bring the system back to a condition to perform its intended function after an assist. It does not include maintenance delays.

Repair Time -The actual time to repair a failed system and bring it back to a condition to perform its intended function. It does not include maintenance delays.

Scheduled Downtime - A period of time when the equipment is not available to perform its intended function due to planned downtime events. These include maintenance delay (delay after an interrupt is reported, but before anyone arrives to repair it), production test, preventive maintenance, change of consumables, setup, and facilities-related downtime.

Standby Time - A period of time, other than non-scheduled time, when the equipment is in a condition to perform its intended function, facilities are available, but it is not operated. This includes time when no operator is available, time when no product is available (no boards or components), and waiting on upstream or downstream equipment.

Tact Time - The time required to pick and place a single component then return to a state ready to pick the next component. This metric is typically expressed in seconds per component. It is the inverse of maximum machine speed (and multiplied by 3600 to convert from seconds to hours).

Theoretical Performance - The maximum throughput that can be obtained for an optimized piece of equipment, performing its intended function, under ideal conditions.

Throughput (Production) Rate - The number of boards produced in a particular amount of time. Often expressed in boards per hour or boards per day. It is a measure of equipment productivity while the equipment is in a state capable of performing its intended function. This rate encompasses the time required to transfer a board into a machine, become populated, and transfer out.

Total Time - All time during the period being measured (at the rate of 24 hours per day, seven days per week). Also equal to the sum of time spent in all six equipment time categories.

Unscheduled Downtime - A period of time when the equipment is not available to perform its intended function due to unplanned downtime events. These include maintenance delay, repair, change of consumables, out-of-specification input, and facilities-related downtime.

Yield - The proportion of good parts exiting a process, as compared to the number of input parts. Usually expressed as a percent.

Formulas

Equipment Dependent Uptime (%) - The percent of time the equipment is in a condition to perform its intended function during the period of operations time minus the sum of all the maintenance delay, out-of-specification input downtime, and facilities-related downtime. This calculation is intended to reflect equipment reliability and maintainability based solely on equipment merit.

$$\text{Equipment Dependent Uptime} = \frac{\text{Equipment Uptime} \times 100\%}{\text{Oper.Time} - (\text{all Maint. Delay} + \text{out-of-spec input DT} + \text{fac. related DT})}$$

Intrinsic Availability (%) - The percentage of time that a machine operates based on down time attributed to relevant interrupts and active repair or recovery time only.

$$IA = \frac{\text{Productive Time}}{\text{Productive Time} + \text{Repair Time}} \text{ X } 100\%$$

Intrinsic Throughput - The product production rate based on downtime attributed to machine failure and active repair time only.

$$IT = \frac{\text{Total Placements}}{\text{Productive Time+Repair Time}}$$

Overall Equipment Effectiveness (OEE) - A measure of the overall performance and efficiency of a piece of equipment. Includes throughput, yield and utilization.

$$OEE = \frac{\text{Actual Throughput}}{\text{Ideal Throughput}} \text{ x \% Yield x \% Utilization}$$

Utilization – The fraction of theoretical production rate that a resource attains during a specified period of time. It is the product of:

1. the amount of time that a resource is in a condition capable of producing product,
2. the effectiveness of an organization in utilizing this resource during the time it is available (e.g. line balancing),
3. the theoretical efficiency of the resource.

The word "resource" is used in a generic sense and may refer to a production line or single pieces of equipment.

$$\text{Equipment Utilization} = \frac{\text{Actual Output}}{\text{Operations Time} \times \text{Theorectical Production Rate}}$$

Statistical Terms and Formulas

Terms

Alpha Level (a**)** - Probability of declaring a statistically significant result when none exists. Also (in sampling) the probability that a lot of material of acceptable quality will be rejected (producer's risk).

Analysis of Variance (ANOVA) - The analysis of variance (ANOVA) is similar to regression in that it is used to investigate and model the relationship between a response variable and one or more independent variables. However, analysis of variance differs from regression in two ways: the independent variables are discrete (categorical), and no assumption is made about the nature of the relationship (that is, the model does not include coefficients that quantify the amount of change in y associated with a change of one unit in x). In effect, analysis of variance extends the two-sample t-test for testing the equality of two population means to a more general null hypothesis of comparing the equality of more than two means, versus them not all being equal.

Attributes Data - Qualitative discrete data that can be counted, as in good/not good, present/not present, pass/fail.

Beta Level (b**)** - Probability of failing to detect with a particular test a significant difference when one exists. Also (in sampling) the probability that an unacceptable lot of material will be passed (consumer's risk).

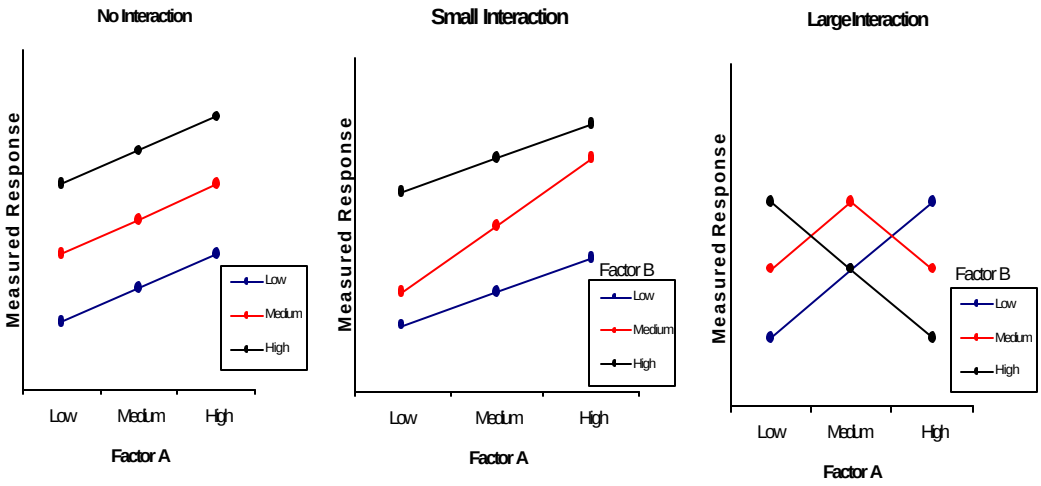
Confidence Intervals - An interval within which the parameter or parameters of interest are expected to lie, based on the estimate of the parameter and some assumptions about its sampling distribution. A confidence interval encloses an unknown parameter with a given confidence (usually called a confidence coefficient and expressed as a percent).

DOE - Statistical Design of Experiments - The process of planning experiments so that appropriate data will be collected and then analyzed by statistical methods, resulting in valid and objective conclusions. One of the goals is to be able to clearly differentiate the effects of multiple, independent factors on a dependent factor. DOE's are often classified in one of three categories: Screening Designs, which are intended to identify which main effects (factors) are the vital few important factors that require further study (usually a fractional factorial); Characterization Designs, which are used to gain some quantitive understanding of the relationships among the factors, including interactions, on the response variable (usually a factorial); and Optimization Designs, which are used to gain a precise understanding of the mathematical relationships that is sufficient to allow prediction and optimization throughput the experimental region (central composite designs are common for this). Analysis of the experimental results is done with regression or ANOVA techniques.

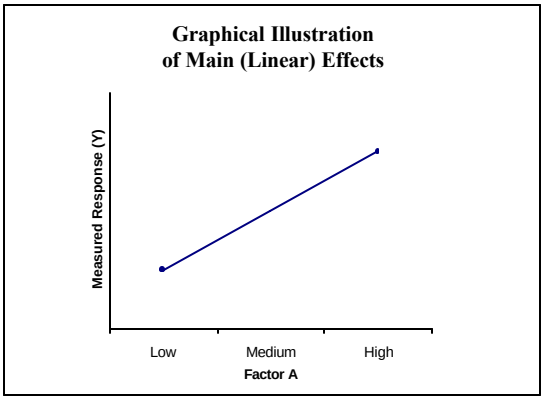
Hypothesis Test - Method for acceptance or rejection of statistical hypothesis, based on what is observed in a sample of the population of interest.

Ideal Function - An equation that mathematically represents the relationships amongst several variables when there is no noise or variation of any kind. It represents nominal performance, and the terms in the equation are usually driven by the physics of what is taking place in the system.

Interactions - The situation where the rate of change in a response variable (its slope) associated with a change in an independent factor itself varies depending on the level of one or more other factors.



Main Effect - The linear change in response produced by a change in the level of an adjustment factor.



Monte Carlo Simulation - An experiment performed on a computer rather than an engineering laboratory in an attempt to emulate reality. With an equation/model derived from experimentation, random numbers are generated in a controlled way to determine the most likely outcomes of a response variable. Often simulation, rather than direct computation, is used due to the mathematical complexity of the relationships among the variables of interest.

Orthogonal Array - A method of setting up in such a way that the factors assigned to hte array columns are independent. This means that the impacts of these factors on the response variable can be mathematically isolated, since the factors are not correlated with each other.

Parts Per Billion (PPB) - usually measures a defect rate in defects per billion opportunities. One PPM is equal to 1000 PPB.

Parts Per Million (PPM) - usually measures a defect rate in defects per million opportunities. One percent is equal to 10,000 PPM.

Regression - A statistical method that determines the mathematical relationship between a response variable of interest and one or more independent factors. The equation, based on empirical data rather than theoretical (phenomenological) derivation, has the form: $y=\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_m x_m + \varepsilon$, where y is the response (dependent variable), there are m independent variables (these could be a linear effect, interactions, or higher order effects), and is the random error term to account for the fact that the model doesn't full account for all the variability observed in y.

Response Surface Experiment - A statistically designed experiment that analyzes the relationship between input parameters and output variables, with the intent to optimize product design. It combines factorial design methodology with regression analysis techniques; usually the resulting model has main effects, 2 factor interactions, and quadratic terms.

Statistical Hypothesis - An assertion or conjecture about one or more parameters of a population.

Variables Data - Quantitative data, where measurements are used for analysis, such as weight, length, diameter, or coordinate placement deviations.

Wald's SPRT (sequential probability ratio test) Sampling Plan - A sequential sampling plan which uses a specified *good quality level* (p_1), *bad quality level* (p_2), and alpha and beta risks to generate an accept, reject, and continue sampling region for any given sample size. This allows the total amount of sampling to be minimized while providing defined protection for both producer and consumer.

Formulas

Mean - The sample mean is the arithmetic average of a set of measurements. The sample mean estimates the population mean, and represents the expected value of the population mean under most circumstances.

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{x_1 + x_2 + \ldots + x_n}{n}$$

where $x_i = x_1, x_2, \ldots x_n$ and n = sample size

Median - The median refers to the point at which half the values are larger than X, and half the values are smaller than X. Its precise definition is a random variable X, say median(X), which satisfies $P[X \leq \text{median}(X)] \geq 1/2$ and $P[X \geq \text{median}(X)] \geq 1/2$.

Range - The difference between the largest and smallest measured values in a data set.

Root Sum of Squares - $RSS = \sqrt{\sum x_i^2}$ The square root of the sum of the square of each value in a sample.

Standard Deviation - A measure of the spread or dispersion of the values of a random variable. It is defined on a sample by the formula given here. Alternatively, the standard deviation is the expected distance any one observation would fall from the mean.

$$S = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \overline{x})^2}{n-1}} = \sqrt{\frac{(x_1 - \overline{x})^2 + (x_2 - \overline{x})^2 + \ldots + (x_n - \overline{x})^2}{n-1}}$$

where $x_i = x_1, x_2, \ldots x_n$ and n = sample size

Process Control and Capability Measures Terms and Formulas

Terms

Baseline - The current level of performance at which an entity or process is performing.

Bias (Accuracy) - The difference between the average of observed measurements (or a single observed value) and the target value (typically the target value is centered between the upper and lower specifications).

Capability Growth Index - A formula by which the performance of subsystem critical functional responses (CFRs) can be linked to requirements. It measures what percentage of CFRs have CPs of 2 or above, with partial credit being given to those with CPs between 0 and 2.

$$CGI = \sum_{i=1}^{n}\left[\frac{100}{n}\left(\frac{Cp}{2}\right)_i\right]$$

Grand Average ($\overline{\overline{X}}$) - The average of the sample averages. This estimates the mean of the process distribution and is plotted as the center line of the chart.

Out of Control Condition - occurs when the pattern of points plotted on a control chart indicates that the process distribution has changed.

R Chart - A control chart on which sample ranges (largest minus smallest value) are plotted in order to detect changes in process variability.

Repeatability - The variation in measurements obtained with one measurement instrument while measuring the identical characteristic on the same part when used several times in the same manner by a single appraiser. It is a component of measurement error, and is expressed as a standard deviation.

Note: In some industries, it is measured by three standard deviations.

Reproducibility - The variation in the average of the measurements made by different appraisers using the same measuring instrument when measuring the identical characteristic on the same part in the same manner. It is a component of measurement error, and is expressed as a standard deviation.

S-bar ($\overline{S}$) - The average of the sample standard deviations. This estimates the standard deviation of the process distribution and is plotted as the center line of the S chart.

S Chart - A control chart on which sample standard deviations are plotted, in order to detect changes in the process variability.

Specification Limits - are generally determined by an engineering analysis of the process requirements, and indicate the range of values for a measurement under which good product must be made.

Statistical Process Control (SPC) - A method of tracking critical functional responses over time during production in an effort to minimize the impact of noise factors, so that product is consistently made to spec.

Upper Control Limit (UCL), Lower Control Limit (LCL) - Limits calculated from process data, usually located three standard deviations above and below the mean of the parameter being plotted, indicating the expected range of plotted points if the process has not shifted.

X-Bar Chart ($\overline{X}$) - A control chart on which sample averages are plotted, in order to detect shifts in the process average.

Formulas

Cp - A process capability index: $Cp = \frac{USL - LSL}{6s}$, where USL = Upper Spec Limit, LSL = Lower Spec Limit, and s is the sample standard deviation. It is a ratio of allowable process variation to actual process variation. It is sometimes referred to as $\frac{\text{Voice of the Customer}}{\text{Voice of the Process}}$.

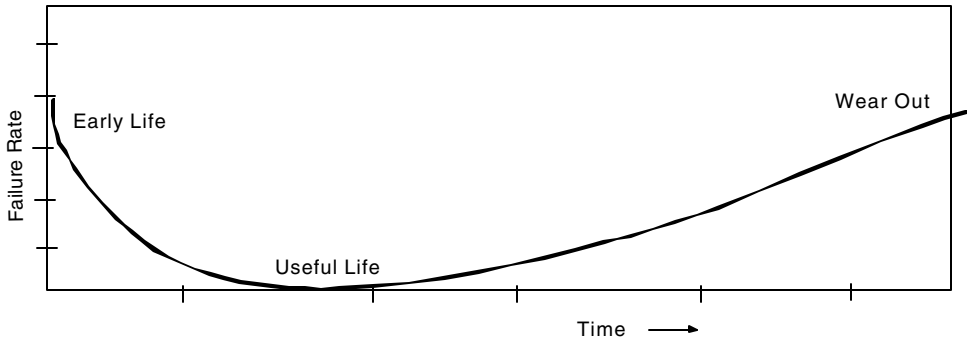
In instances where the target is zero and is halfway between the LSL and the USL, CP is a measure of how many sets of three standard deviations lie between the target and the (upper or lower) spec.

Cp_k - A process capability index: $Cp_k = \min\left[\frac{USL - \overline{X}}{3s}, \frac{\overline{X} - LSL}{3s}\right]$, where $\overline{X}$ is the sample average. It is similar to Cp, but Cpk accounts for both the mean shift and the lack of perfect repeatability. In instances where the target is zero and is halfway between the LSL and the USL, Cpk is a measure of how many sets of three standard deviations lie between the mean and the closest spec limit. In this case, the equation reduces to $Cpk = \frac{USL - \bar{x}}{3s}$

Precision to Tolerance Ratio - $P/T = \frac{6s_{R\&R}}{USL - LSL}$ For a measurement system the p/t ratio is a ratio of the total measurement uncertainty, $6s_{R\&R}$, divided by the product tolerance. It represents the proportion of the tolerance taken up by measurement uncertainty. If the P/T ratio is greater than 25%, the gage is typically considered to be inadequate to verify the product's ability to meet its specifications.

Hardware Reliability Terms and Formulas

Product Reliability Cycle



Terms

Accelerated Life Test - Testing that intentionally increases the level of stress, or the duty cycle, on a system or subsystem in an effort to gain wear or failure data.

Accessibility - A technique designed to optimize maintainability by making all parts of the system easy to reach and easy to work on.

Assist - An unscheduled downtime event where no parts are replaced other than parts which are known to wear out quickly as an inherent part of the process (specified as consumables), and the equipment is returned to an in-specification condition.

Burn-In - The operation of an item under running conditions to stabilize its characteristics. This activity is intended to filter defective product before shipment to customer. The purpose is to minimize a customer's exposure to early life failures.

Corrective Maintenance - All actions performed, as a result of failure, to restore an item to a specified condition.

DFMECA (Design Failure Modes and Effects Criticality Analysis) - The consideration of each mode of failure for every component of a system (or subsystem) during the design phase to ascertain the effects on system operation of each failure mode, classified in relation to the severity of the effect.

Dependent Failure - A failure which is caused by the failure of an associated item or items. Not independent.

Derating - Using an item in such a way that applied stresses are below rated values.

Duane Plot - A method of displaying reliability growth over time. It graphs the Mean Time Between Service Calls (MTBSC) over time.

Durability Analysis - A theoretical verification based on load calculations for wear-out and fatigue components such as belts, bearings, and springs.

Early Life - The stage in the life of a product where manufacturing defects and residual design defects are detected and corrected.

Failure Analysis - Subsequent to a failure, the logical systematic examination of an item—its construction, application, and documentation—to identify the failure mode and determine the failure mechanism and its root cause.

Failure Mechanism - The physical, chemical, electrical, thermal, or other process which results in failure.

Failure Mode - The consequence of the mechanism through which the failure occurs, that is, short, open, fracture, or excessive wear.

Failure Mode Effect and Criticality Analysis (FMECA) - The consideration of each mode of failure of every component of a system to ascertain the effects on system operation of each failure mode, classified in relation to the severity of the effect.

Failure Reporting and Corrective Action System (FRACAS) - A closed loop system of data collection, analysis and dissemination to identify and correct failures of a product or process.

Hardware Failure - An unscheduled downtime event that involves either the replacement of one or more parts, or a software power cycle. This definition does not apply to parts that are known to wear out quickly as an inherent part of the process (specified as consumables).

Highly Accelerated Life Testing (HALT) - Testing that involves the use of every stimulus, such as voltage cycling, broad-range thermal cycling, vibration, and everything else that may enable the discovery of the weak links in the design that would lead to system breakdown in a very short period of time.

Highly Accelerated Stress Testing (HAST) - Similar to HALT, except that the emphasis is on quantifying the amount of degradation in performance, rather than all out failure.

Independent Failure - Failure which occurs without being caused by the failure of any other item. Not dependent.

Interrupt - Any assist or failure.

Relevant Interrupts - An interrupt that can be shown to be caused by defects in the design or manufacture of the machine; piece-parts and their suppliers are included in this category. Examples of relevant interrupts include:

- An interrupt caused by a defect in the design of the equipment, either hardware, software, or firmware.
- An interrupt caused by a defect in the manufacturing processes used to make the equipment.
- An interrupt caused by a defect originating in the design or manufacture of the components, piece-parts, materials purchased, or supplied to the equipment manufacturer.
- An interrupt caused by human errors (and determined to be related to machine design).
- An interrupt caused by a defect due to shipping damage.

Non-Relevant Interrupts - An interrupt that can be shown to be caused by defects not related to machine design or manufacture. Examples of non-relevant interrupts include:

- An interrupt caused by a defect due to installation damage.
- An interrupt caused by a defect due to an accident or mishandling.
- An interrupt caused by a defect due to facilities, out-of-specification input, unskilled operators or technicians.
- Normal operation adjustments.
- An interrupt caused by defects caused by secondary failures within the equipment.
- An interrupt caused by human errors (and determined to not be related to design).

Maintainability - A characteristic of the design, which when achieved contributes to fast, easy maintenance at the lowest level life-cycle cost. Good maintainability is most likely to be achieved when incorporated into the earliest stages of design.

Maintenance Allocation - The apportionment of time for system maintenance activity down to the subsystem components.

Maintenance Concept - The procedures, resources, and time needed to, retain equipment in, or restore equipment to, a state in which it can perform its required functions. Wear items are identified. Assemblies or processes are identified for which the company only supports maintenance by field engineering.

Preventive Maintenance - All actions performed in an attempt to retain an item in a specified condition by providing systematic inspection, detection, and prevention of incipient failures.

Reliability - The ability of an item to perform a required function under stated conditions for a stated period of time. Typically stated in terms of an allowable failure rate.

Reliability Allocation (Apportionment) - the process of subdividing the system reliability goal into subsystem and component goals.

Reliability Block Diagram - A graphical representation of how reliability is distributed within a system or subsystem. Relationships from block to block, and how each block affects the overall system should be shown in the layout of the diagram.

Reliability Growth - The positive improvement of the reliability of equipment through the systematic and permanent removal of failure mechanisms.

Reliability Prediction - A method of determining *probable* product reliability (of a proposed product) by reliability calculations using known, estimated, or extrapolated component failure rates and the appropriate probability laws and distributions.

Risk Assessment (service) - A risk assessment of the system and each of the major subsystems. The risk assessment should include an analysis of the likelihood that the subsystem will require unusual field service or user intervention, the severity of such a failure, and the possible recovery methods that would need to occur to eliminate the source of failure.

Root Cause - The underlying primary reason for the symptom; the problem cause location may differ from the symptom location; for example, bulb filament broken.

Symptom - The initial observed manifestation of a problem; for example, light not working.

System Useful Life - Definition of the intended design life of a particular system, in terms of cycles or years of operation.

Useful Life - The period between early life and wear out where random failures occur and the failure rate is constant.

Wear-out - The last stage in product life, after useful life, characterized by an increase in failures (wear-out defects).

Formulas

MCBA - Mean Cycles Between Assists - the average number of equipment cycles between assists; total equipment cycles divided by the number of assists during those cycles (includes both product and non-product cycles).

$$MCBA = \frac{\text{Total Equipment Cycles}}{\text{\# of Assists}}$$

MCBF - Mean Cycles Between Failures - the average number of equipment cycles between failures; total equipment cycles divided by the total number of failures during those cycles (includes both product and non-product cycles).

$$MCBF = \frac{\text{Total Equipment Cycles}}{\text{\# of Failures}}$$

MedianTTR_a - Median Time to Recover Assists - is an estimate of the 50% point of a lognormal distribution of assist recovery times. See the formula.

$$MedianTTR_a = \text{EXP}\left[\frac{\sum_{i=1}^{n} \ln x_i}{n}\right]$$

where x_i = recovery times = $x_1, x_2, \ldots x_n$

n = the number of assists

$MedianTTR_f$ - Median Time to Repair Failures - is an estimate of the 50% point of a lognormal distribution of failure repair times. See the formula.

$$MedianTTR_f = \text{EXP}\left[\frac{\sum_{i=1}^{n} \ln x_i}{n}\right]$$

where x_i = repair times = $x_1, x_2, \ldots x_n$

n = the number of failures

$MTBA_p$ - Mean (Productive) Time Between Assists - the average time the equipment performed its intended function between assists; productive time divided by the number of assists during that time.

$$MTBA_p = \frac{\text{Productive Time}}{\text{\# of Assists During Productive Time}}$$

$MTBF_p$ - Mean (Productive) Time Between Failures - the average time the equipment performed its intended function between failures; productive time divided by the number of failures during that time.

$$MTBF_p = \frac{\text{Productive Time}}{\text{\# of Failures During Productive Time}}$$

$MTBI_p$ - Mean (Productive) Time Between Interrupts - the average time the equipment performed its intended function between interrupts; productive time divided by the number of interrupts during that time.

$$\text{MTBI}_p = \frac{\text{Productive Time}}{\text{\# of Interrupts During Productive Time}}$$

$MTTR_a$ -Mean Time to Recover Assists; the average time to correct an assist and return the equipment to a condition where it can perform its intended function; the sum of all repair time (elapsed time, not necessarily total man hours) incurred during a specified period (including equipment and process test time, but not including maintenance delay), divided by the number of assists during that period.

$$MTTR_a = \frac{\text{Total Recovery Time}}{\text{\# of Assists}}$$

$MTTR_f$ - Mean Time to Repair (failures) - the average time to correct a failure and return the equipment to a condition where it can perform its intended function; the sum of all repair time (elapsed time, not necessarily total man hours) incurred during a specified period (including equipment and process test time, but not including maintenance delay), divided by the number of failures during that period.

$$MTTR_f = \frac{\text{Total Repair Time}}{\#\ \text{of Failures}}$$

Software Reliability Terms and Formulas

Terms

Defects by Severity - Tells us either the raw number or the percent of defects classified by the five severity categories.

Defects per Subsystem - Identifies the breakdown of defects by the subsystem affected.

Failure Reporting and Corrective Action System (FRACAS) - A closed loop system of data collection, analysis and dissemination to identify and correct failures of a product or process.

High Level Design Document or Drawing - Document that shows how the software system will be structured to satisfy the requirements**.**

High Severity Defects - Defects of severity one and two.

Major Causes of High Severity Defects - Identifies the proportion of high severity defects attributed to various root causes.

MTSWR - Mean Time to Software Restore; the average time to return the equipment to a condition where it can perform its intended function. If the failure is not repeatable (does not happen every time) restoration involves rebooting and/or reloading software and/or databases. If the failure is repeatable (happens every time) restoration also involves determining a workaround and/or waiting for a fix that permanently corrects the failure mechanism.

Percent of High Severity Defects introduced by Phase - Identifies in which phase of the product development process that the defect was inserted into the code.

Prototype Screens - A graphical representation of the screen. The software has not yet been developed for the functionality.

Root Cause - Underlying reason that a defect has occurred. Root causes used in system testing are listed below.

0 None.
100 Communications between development team members.
101 Communications between product team.
102 Creeping elegance.
103 Did not understand how existing SW/HW functions.
104 Did not understand how new SW/HW functions.
105 Documentation incorrect.
106 Education - Lack of education in programming language logic, engineering discipline.
107 Education - Lack of training in department procedures/ policies, methodologies software.
108 Expectations - Conflicting Views.
109 Expectations - Went beyond specifications.
110 Last Minute Addition - Customer commitment.
111 Oversight - Programming, Logic, Syntax error.
112 Oversight - Not an issue when originally developed.
113 Purposely left out - Did not consider all cases.
114 Unknown.
115 Complexity.
116 Tester expectations/Error.
117 Missed due to risk assessment.
118 Missed due to time constraints.
119 Missed - Did not consider all cases, not thorough enough.
120 Hardware not capable of meeting specifications.
121 Vendor hardware/software does not work as expected.

Software Block Diagram - A software block diagram is a representation of the major software subsystems and their relationship to each other in terms of invocation and communication.

Software Change Control Board (SCCB) - A group consisting of a Software Quality representative, Software Engineering representative and Product Team representative. The group is responsible for evaluating and approving or disapproving proposed changes to the software**.**

Software Complexity Matrix - The Software Development Complexity Matrix is a tool used to help determine the size of a new project. All required software modules are identified, with each given a complexity score. An overall complexity score is generated, and may be used to assess the relative size of this project versus another approach or project.

Software Configuration Management Plan - The Software Configuration Management Plan (SCMP) specifies the procedures whereby Software Configuration Management (SCM) concepts are applied in support of the Universal Instruments Corporation (UIC) Central Engineering software development effort. Responsibility of the Lead Software Engineer on the project.

Software Development Process Plan - Identifies the software outputs from a project requiring development from SM Software Engineering. Responsibility of the Lead Software Engineer on a project.

Software Failure (Defect) - An unscheduled downtime event that requires a software power cycle. Such events are logged as severity 1 or 2 software failures.

Software Problem Tracking/Change Request Reports - Views available in the Software Problem Tracking Database. These views identify defects in the software, the severity of the defect and identify the root cause of the defect, the status, and the phase when the defect was introduced. Change requests are also tracked in this database.

Software Project Planning Guideline - Provides a guideline, for the Software Engineering Technical Managers, to be used when estimating work content for a particular project.

Software Quality Assurance Plan - The Software Quality Assurance Plan (SQAP) identifies the planned and systematic pattern of actions necessary to provide adequate confidence that a software work product (deliverable) conforms to established technical requirements. Developed by the Software Quality representative on the project.

Software Subsystem Interface Documents - Document that describes how software subsystems interact with one another.

Software Validation Plan - The validation plan describes the method of validation, resources, and schedule. Validation is a process whereby a subset of the verification activities are conducted by SW Quality to validate the product. Validation will be conducted at the system level and may be conducted at the subsystem level where appropriate.

SWIM Release Plan - The SWIM Release Plan specifies the procedures to be used to release a software product.

System Test Severity Levels - The severity levels range from 1 to 5 with 1 being the most severe and 5 merely a suggestion. Following are the definitions of the severity levels.

- **Severity 1 - No Ship** - No readily acceptable work-around is available to the user. *Defect that prevents the user from performing an essential function.* To be fixed prior to shipment.
- **Severity 2 - Very Serious Defect** - Only to be considered for shipment if there is a work around for the problem. *Defect that adversely affects the accomplishment of an essential function.* There are acceptable work-arounds, however every effort should be made to fix this defect prior to shipment.
- **Severity 3 - Defect** - *Defect that affects the accomplishment of functions*. There are acceptable work-arounds including other means of accomplishing the task.
- **Severity 4 - Software Enhancement** - Causes *minor inconvenience* from customer's standpoint.
- **Severity 5 - Suggestion** - An *aesthetic defect*; for example, color, placement of screen or a *suggestion for an additional function* or *better way* to accomplish a function.

Total Defects - Counted for each software release. A defect occurs when there is a difference between what was specified or expected to happen, and what really happened.

Transition Documentation - Documentation identified in the Validation Plan that must be given to Software Quality at prior to validation. Examples of this documentation are verification results, products run during verification etc.

Use Case Models - Approach to the analysis and design of software using Use Cases. This method provides a systematic and structured approach to analyzing requirements, defining the architecture and doing detailed design. The Use Cases are elaborated on and decomposed into more detailed scenarios as the design progresses.

Formula

Failure Rate (Defect Density) - The defect density tells us how many new problems are introduced into the code for every hour spent writing it.

$$\text{Defect Density} = \frac{\text{Total \# of defects}}{\text{Development hours} + \text{Rework hours}}$$

Quality Assurance Terms

Terms

Design Verification - Design verification is the process of ensuring the design conforms to specification. Design verification may include: alternate calculations, design reviews, comparison to similar designs, inspection, system test, first production test, and quality acceptance criteria test.

Flow Chart - A schematic representation of a sequence of events.

Gage Repeatability and Reproducibility (R&R) Study - A statistically designed experiment that studies the measurement uncertainty of a gage, where a gage is any device used to obtain measurements. Repeatability is the variation in measurements obtained with one gage when used several times by one appraiser while measuring a characteristic on one part. Reproducibility is the variation in the average of the measurements made by different appraisers using the same gage when measuring a characteristic on one part. See Precision to Tolerance ratio.

House of Quality (HOQ) - A diagram that lays out how a product will deliver customer requirements, as well as other related information. It includes the Customer requirements and importance ratings, the customer perceptions of performance against these (UIC & competitors), engineering characteristics, a matrix linking engineering characteristics to quality attributes, a triangle showing the relationships among the engineering characteristics, scores on engineering lab metrics, and a data matrix for evaluating trade-offs and design decisions.

Measurement System - The collection of operations, procedures, gages and other equipment, software, and personnel used to assign a number to the characteristic being measured; the complete process used to obtain measurements.

Measurement Systems Analysis (MSA) - A collection of procedures used to assess the repeatability, reproducibility, bias, stability, and linearity of a measurement system. Gage studies are a subset of MSA studies.

Milestone Plan - From the resource loaded/linked Integrated Project Plan, a product's development cycle is time phased. Each task/deliverable within the plan has a schedule start date. The cumulation of these planned start dates can be plotted on a histogram with time as the x-axis. This histogram is the milestone plan. When actual starts from the tasks/deliverables are plotted on the same histogram a trend/quick analysis can be made as to whether the project is on schedule or not.

PPAP - Production Part Approval Process

Product Specification - Defines the product from the customer perspective. This specification may eventually become the General Specification for the product. It typically includes: the Product Tree or configuration requirements, a list of functions and features, performance criteria, reliability criteria, product cost budget, code/standard compliance, environmental requirements, and recommended kill criteria.

Quality Acceptance Criteria (QAC) - The process used to determine that the performance of a production machine meets specification is called the quality acceptance criteria. The Quality Acceptance Test is defined as part of the QAC.

Test Plan - A test plan is composed of the test requirements (with test designs and resources), a test schedule and estimated test costs. As the test process progresses the test plan is revised to include test cases.

Verification Plan - The verification plan describes the method of verification, resources, and schedule. Verification may include, but is not limited to alternate calculations, comparison to a previous design, inspection, or test. Verification may encompass both the sub-system and system level.

Design for Six Sigma Terms

Terms

Concept of Operation - The concept of operation is a description of the behavior of a subsystem or a system from the perspective of a user. It may be clarified beyond the use of text with the use of mock-ups, prototypes, demos, and/or storyboards.

Control Block Diagram - Diagrammatic representation of the flow of information and the functions performed by each component in a system.

Control Factor - See Critical Adjustment Parameters.

Control Strategy - Definition of all systems for controlling parts and processes during production. The plan fully documents measurement and test methods used for assuring product and process performance.

Critical Adjustment Parameters (CAP) - Design parameters of a concept or technology that need to be optimized in order to adjust the mean value of a critical functional response (CFR) onto its target without adversely affecting the CFRs Robustness.

Critical functional manufacturing responses - Adjustable process level specifications. Manufacturing critical functional responses require the application of statistical process control to help assure proper levels of quality. (e.g., metal stamping set points, lens molding temperatures, CCD array process set points).

Critical Functional Requirements - These are the parameters (variables) that measure the fulfillment of the system and subsystem level requirements (i.e. the y's or response variables such as speed, accuracy, etc.)

Critical Functional Response (CFR) - Physical, measurable responses that enable the fulfillment of the system level requirements.

Critical to function component level specifications - These are static component level specifications which are related to an assembly, subsystem or system level critical functional response. Component CTF's are measured during or after manufacturing. (e.g., aperture diameter, image clarity, light sensor voltage)

Critical To Function Spec (CTFs) - Assembly or component level critical functional responses that, if unmet, jeopardize the subsystem and system CFR's.

Critical Parameter Management - A method for focusing on the few things that matter the most relative to cost, quality, and time-to-market goals in the product development cycle. CPM is a way of laying out inter-related variables in a structured manner (such as flowdown diagrams), preferably in a database, and incorporates quantitative information that describes the mathematical relationships amongst the parameters. Parameters that are determined to be both practically significant (as measured by the process capability index CP) and statistically significant (as measured by the F test statistic) are to be included; other variables may be included as well. For CPM to be done well, instrumentation, data acquisition, data analysis, and database management are some of the most important enabling best practices, and it is usually implemented within a scorecard-based Phase-Gate product development process.

Customer Needs Document - A composite of needs associated with VOC results. This information is used in HOQ activities and in the generation of the Systems Requirements Document (SRD).

DFx - A tool for evaluating designs to improve quality, cost and delivery and to quantify assembly times, maintainability times and manufacturability.

Gap Identification and Recovery - This is part of the Marketing Entitlement Checklist. It typically includes: a gap description and priority, and a recovery project summary.

Integrated Project Plan - A multiphase plan that details the development of a product through marketing, engineering and product launch. It links key tasks and deliverables and who is responsible for accomplishing these tasks. Integrated Project Plans include cross-functional inputs for labor, material, capital and critical test equipment needs. It is the primary vehicle of communication for a project's planned costs and time-to-market schedule. The baselined Integrate Project Plan is what the actual costs and development progress is measured against. It is the primary method for determining if a product development is on track or not from a cost and schedule perspective.

KJ method - A systematic process for assimilating a complex set of related pieces of information. It is similar to the affinity diagram process, but is more complex. It can be used to identify what requirements should become part of the house of quality.

Multi-Vari Chart - A graph that provides a visual alternative or supplement to analysis of variance. These charts are used in the preliminary steps of data analysis to help identify sources of variation. It illustrates how means vary, by factor level, and how individual data points are dispersed about their means.

Multi-Vari Studies - A passive method of observation, usually done in a production environment to identify root causes of variation. Often done to follow-up on problems identified in SPC.

Noise Diagram - A representation of how the three major forms of noise (external, unit-to-unit, and deterioration) are associated with a design element.

Noise Experiment - An experiment designed to identify noise factors that impact system variability. Noise experiments also benchmark the performance of the baseline design, both before and after the design has been robustized.

Noise Factor - Any factor that promotes variability in a product or process.

Nondeterministics - Parameters that require empirical evaluation to prove the validity of initial design assumptions.

Pugh Concept Selection - A DFSS tool used to identify the strongest solution to a given design problem. The solution chosen when using this process should be a hybrid incorporating the best aspects of multiple proposals.

Robust Design - A system or subsystem design whose critical functional responses are consistently repeatable and near the desired target, even in the presence of stressful sources of variation (noise).

Robustness Optimization - A sequence of statistically designed experiments whose purpose is to find an optimum collection of parameter set points that minimize the product's sensitivity to noise factors and put output response variables on target.

Root Sum of Squares Tolerancing method - A tolerancing method that makes use of RSS to determine the best tolerance limits. It should not be used in extremely non-linear scenarios (simulation is more appropriate).

S/N - A ratio that represents the measure of a design's insensitivity to various sources of variation (noise).

Scorecard - A summary of results vs requirements within a phase that are available at a gate review. This information may be tabular, graphical, textual, etc. Scorecards vary by project and phase and should report on critical to success objectives and requirements. Structure is at the discretion of the presenter but must anticipate questions by gate reviews.

Signal to Noise Metric - a mathematical measure of a design's ability to produce performance characteristics that are excellent, even in the presence of various types of noise. The mathematical form of this metric varies, depending upon if the Critical Functional Reponse is optimized by being as small as possible, as large as possible, or as close to target as possible. {Examples of these 3 types, in order, for our products would be component placement repeatability, machine throughput, and component placement accuracy (mean value).}

Sub-System - A sub-system is a portion of a system. Sub-systems are typically composed of components or modules either from single or multiple disciplines. Sub-systems typically do not provide a useful function independent of the system they are associated with.

Sub-System Baseline Analysis - The nominal characterization of the subsystem's performance and a baseline signal to noise evaluation.

System - A system is the entire product. Systems are composed of sets of sub-systems operating in conjunction with one another. Systems typically provide a useful function in their own right.

System Integration - The process of combining the various sub-systems and disciplines (i.e. mechanical, electrical and software) into a homogeneous working system.

Systems Requirements Document - A document that describes the system requirements in functional terms and what market needs the system will fulfill.

Taguchi Additional Model - A mathematical representation of the optimal value of the Signal-to-Noise metric that is determined by the experiment to be achievable. This optimal Signal-to-Noise value is expressed as the sum of the contributions to the overall Signal-to-Noise associated with each of the control factors that add significant improvement to robustness (insensitivity to noise). Obtaining robustness is more difficult if such an additive model can not be obtained due to the complexity and interactions of the relationships between the factors involved.

Tolerance Analysis - An analysis of the dimensional tolerances of manufactured parts. It can also be applied to other (parallel) scenarios such as locations of moving parts, error propagation, etc. In general, the component tolerances are all known or specified and the resulting assembly tolerance is calculated. But the Taguchi approach works in reverse; it optimizes tolerances by determining the impact weights of individual tolerances in an assembly and constraining only those which are critical to the overall assembly while relaxing those which are less critical. Economic compromises are also considered.

Visual factory - A methodology of bringing orderliness to the factory. It is essentially workplace organization where everything has a place and is in its place and is well marked to show when something does not conform to this expectation.

Worst Case Tolerance Analysis - The assembly tolerance is determined by summing the component tolerances linearly. Each component dimension is assumed to be at its maximum or minimum limit, resulting in the worst possible assembly limits. It is not the best approach to tolerancing, due to the fact that it caters to combinations that are extremely unlikely, rather than focusing on a more probabilistic approach.

Industry Terms

Alpha Build - The intent of an Alpha build is to do an initial debug build to verify all manufacturing processes. Production's first time build with assembly procedures and associated fixtures, etc. Quantity is usually small.

Beta Plan - A Beta Plan may include the following topics associated with a proposed Beta Test: purpose, site selection criteria, agreements with the customer, data gathering, data analysis, plus a schedule and definition of responsibilities.

Beta Site - The customer installation(s) where the Beta Test is executed.

Beta Test - Production type runs of a new product at a customer installation over a significant period usage. The primary purpose is usually to obtain customer feedback on issues that cannot be satisfactorily evaluated outside of an actual customer environment.

Bill of Material (BOM) - A listing of all subassemblies, intermediates, parts and raw material that go into a parent assembly showing the quantity of each required to make it. It is used in conjunction with the master production schedule to determine the items for which purchase requisitions and production orders must be released.

Breadboard - A breadboard is an assembly of hardware and/or software for the purpose of evaluating non-determinants. It typically represents the function, but not the form, of the intended design.

CEAR - Capital Expenditure Approval Request

Cost Magnitude Estimate - An "order of magnitude" estimate of cost rather than a detailed engineering analysis.

Cost Roll-up - A review and an evaluation of actual and/or anticipated cost.

EM - Engineering Model

Engineering Change - A revision to a blueprint or design released by engineering to modify an item. Usually tracked through implementation.

Entitlement - The optimum performance level attainable by a business using its existing resources.

EP Status - Engineering Procurement. Phase two of creating and using a part number. You can purchase items at this level but not for final production.

Final Cost Roll-up - A review and an evaluation of actual cost.

Fine Pitch Components - Components (to be placed by the machine) that have a relatively small pitch (distance between the center of two adjacent terminations). For leaded devices, a pitch of 0.5 mm or less is considered fine pitch. For area array, 0.5 mm on BGAs or QFPs is considered fine pitch, and 0.2 mm on flip chips is also fine pitch.

First Pass Yield - A measure of the ability to perform a function the first time successfully, without requiring rework to complete that function. Expressed as a percentage.

Flexible Fine Pitch Machine - A placement machine that can place a large range of parts, including fine pitch components.

FR - Full Release. The highest level of control on materials and documentation. Used for all items in final production.

Kitting - The process of pulling items from stock and readying them for movement to the production area. Usually a pick list is used to determine what components to pick.

Lean Manufacturing / Lean Process Flow - Lean manufacturing provides a way to specify value, line up value creating action in the best sequence, conduct those activities without interruption and perform them more and more effectively. It allows us to get as close as possible to provide customers with exactly what they want when they want it.

Life Cycle Cost Structure Requirements - This document outlines design considerations relevant to achieving an acceptable life cycle cost model.

Logistics - Activities involving planning for the support of the product in the field, including such issues as spare parts requirements and service support.

Make/Buy Decision - A team decision on whether to build a part or assembly inside UIC versus outside. Decision criteria could include: vendor capability, core competency, expertise, proprietary technology, price, exchange rates, capacity, and lead-time.

Market Assessment - Typically a market assessment includes: market need and outlook, risk and competitor summary, product price goal, market window, market share forecast, figure of merit, and ROI.

Material Master (MM) - A set of techniques that uses options in the creation of an item number connecting it to a particular set of criteria such as lead-time, planner number, purchased or produced in house etc. The basic setup of an item number in SAP.

Materials Requirements Planning (MRP) - A set of techniques that uses bills of material, inventory data and the master production schedule to calculate requirements for material.

New Product Introduction (NPI) - Total time from initial CAD work to first board out.

NI Status - Number issued. The first phase of creating and using a part number. Material can not be purchased at NI level.

Obsolescence (OBS) - Loss of product value resulting from a model or style change or technological development. Material no longer required.

Obsolescence Exposure - The amount of inventory on-hand and contractually responsible for. Usually converted to dollars for the purpose of evaluating.

Packaging and Handling concepts - The packaging requirements, proposed packaging solution, and packaging processes for shipment preparation, crating, and shipment.

Pick list - A document that lists the material to be picked for manufacturing orders.

Pilot Build - A pilot build is the build of a final version of the hardware or software, typically with the aim of refining the manufacturing process.

PP&E - Property, Plant, and Equipment

Production Mix - The total number of unique products in a production environment that require a changeover in manufacturing equipment and/or settings. A high mix environment will have 6 or more changeovers per day, a medium mix environment will have between 3 and 5 changeovers per day, and a low mix environment will have 2 or fewer changeovers per day.

Production Order - A document authorizing the warehouse to pick material and manufacturing to produce it.

Production Planning - A monthly review of production requirements with Sales, Marketing, Manufacturing, Finance and the executive committee. It is also a vehicle to discuss and determine high-level new product introduction date and production quantities.

Product Support Information - The different types of information to be created to ensure the proper use and maintenance of UIC products. Product support information may include: traditional training course material, traditional manuals, on-line manuals, videos, job aids, electronic performance support systems, expert systems, and tutorials.

Product Support Information Plan - A product support information plan is a proposal defining the different types of information to be created to ensure the proper use and maintenance of UIC products. For each type of support information planned, the following should be created: a description, an outline of content, a list of assemblies changed, the format, resource requirements, schedules, and costs. The outline of content should include both educational goals and instructional goals.

Product Tree - A graphical description or hierarchical list of the product and it's options.

Production Volume - The total number of product units produced. Volume is a function of production mix and batch size. High volume, flexible fine pitch equipment is capable of placing 4,000 or more, fine pitch components per hour. Low volume, flexible fine pitch equipment is capable of placing less than 4,000 fine pitch components per hour.

Prototype - A prototype is an early version of the hardware and/or software that represents the form and the function of the intended design. Typically used for continuing design refinement activity.

Routing - A set of information detailing the method of manufacture of a particular item. It includes the operations to be performed, their sequence and work centers.

SAP - The brand name of a business operations software package.

Service Business Plan - A document that describes the expected Service-related revenue stream, and associated costs, derived from the equipment over it's useful life.

Variant Configurator - An option in SAP allowing an improved ordering process my consolidating standard features into one item number.

Witness Assemblies - Assemblies produced in the manufacturing area, using actual work instructions, drawings, and tools, monitored by engineering team personnel.