SYSTEMS ENGINEERING LEADING INDICATORS GUIDE

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1. About this Document

This document is the beta release of the Systems Engineering Leading Indicators Guide. This project was initiated by the **Lean Aerospace Initiative** (LAI) Consortium in cooperation with the **International Council on Systems Engineering** (INCOSE). Leading measurement and systems engineering experts from government, industry, and academia volunteered their time to work on this initiative.

Government and industry organizations are encouraged to **tailor the information in this document** for their purposes, and may incorporate this material into internal guidance documents. Please cite the original source and release level (currently beta) for traceability and baseline control purposes.

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2. EXECUTIVE SUMMARY

Several policies calling for improved systems engineering on programs were released by DoD and the services during 2004[1]. During this period, the Lean Aerospace Initiative (LAI) Consortium was tasked with assisting with the systems engineering revitalization activity. In June 2004, an *Air Force/LAI Workshop on Systems Engineering for Robustness*[2] was held. The workshop established the groundwork for several initiatives in support of systems engineering revitalization. One of these initiatives focused on ***leading indicators for evaluating the goodness of systems engineering on a program***. This document describes the initial set of SE Leading Indicators. This initial set reflects the subset of possible candidate indicators that were considered to be the highest priority by the team; it is recognized that the set is not exhaustive. Additional SE Leading Indicators will be added in future updates to the document as these are identified, defined, and evolved.

What are Leading Indicators? A leading indicator is a measure for evaluating the effectiveness of a how a specific activity is applied on a program in a manner that provides information about impacts that are likely to affect the system performance objectives. A leading indicator may be an individual measure, or collection of measures, that are predictive of future system performance before the performance is realized. Leading indicators aid leadership in delivering value to customers and end users, while assisting in taking interventions and actions to avoid rework and wasted effort.

Who Developed the SE Leading Indicators? Subsequent to the June 2004 workshop, the "SE Leading Indicators Action Team" was formed under the auspices of LAI, comprised of engineering measurement experts from industry, government and academia, involving a collaborative partnership with INCOSE[3] . Mr. Garry Roedler of Lockheed Martin agreed to lead the effort, along with Dr. Donna Rhodes of LAI at MIT. Leading SE and measurement experts from LAI member companies, INCOSE, SSCI[4], and PSM[5] volunteered to serve on the team. The team held periodic meetings and used the ISO/IEC 15939 and PSM Information Model to define the indicators. To date, thirteen SE leading indicators have been developed, as summarized in Table 1.

What Problem do SE Leading Indicators Address? To effectively manage programs, leaders need access to leading indicators. Leading indicators provide insight into potential future states to allow management to take action before problems are realized. While there are some leading indicators that cover the management aspects of program execution (e.g., earned value, etc.), we lack good leading indicators specifically for systems engineering activities.

How do Leading Indicators Differ from Conventional SE Measures? Conventional measures provide status and historical information, while leading indicators use an approach that draws on trend information to allow for predictive analysis (forward looking). By analyzing the trends, predictions can be forecast on the outcomes of certain activities. Trends are analyzed for insight into both the entity being measured and potential impacts to other entities. This provides leaders with the data they need to make

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[1] Policies include Policy for Systems Engineering in the DOD, 20 Feb 04; Assistant Secretary of the Air Force for Acquisition, Dr Sambur , 9 Apr 03, Policy Memo 03A-005 titled Incentivizing Contractors for Better Systems Engineering; Memo 04A-001 titled Revitalizing AF and Industry Systems Engineering Increment 2

[2] Rhodes, D. Ed, Report on the AF/LAI Workshop on Systems Engineering for Robustness, July 2004, http://lean.mit.edu

[3] INCOSE (International Council on Systems Engineering) is the leading professional society for systems engineering. INCOSE has developed guidance materials on systems engineering measures, and both editors of document have served as former chairs of the INCOSE Measurement Working Group. INCOSE is collaborating with LAI on this effort, and is targeted as the long term owner for guidance developed under this LAI project.

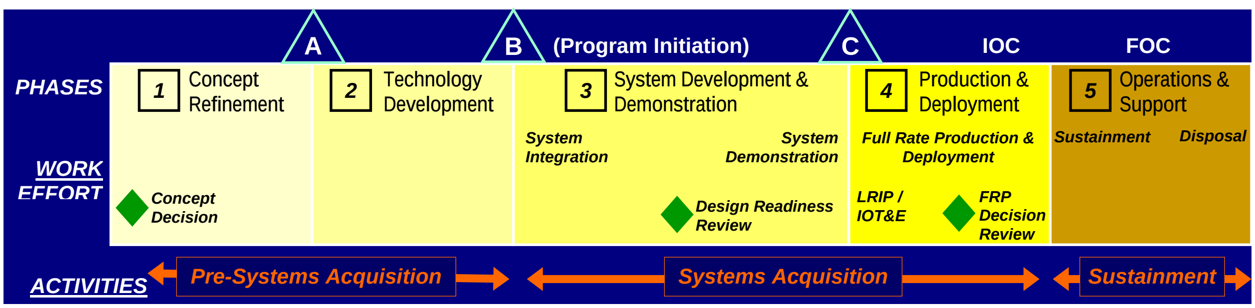
[4] SSCI (Systems and Software Consortium Inc.) is collaborating with LAI on systems engineering initiatives.

[5] PSM (Practice Software and Systems Measurement) has developed foundational work on measurements under government funding. The LAI effort is using formats developed by PSM for documenting of the leading indicators.

informed decisions and where necessary, take preventative or corrective action during the program in a proactive manner. While the leading indicators appear similar to existing measures and often use the same base information, ***the difference lies in how the information is gathered, evaluated, and used to provide a forward looking perspective*.**

How do SE Leading Indicators relate to Current Organizational SE Measurement Practices? Most organizations have an organizational measurement plan and a set of measures. These leading indicators are meant to augment the existing set of measures. For optimal efficiency these should be implemented via the organization's measurement infrastructure (typically based on CMMI® practices), thereby enabling mechanized data gathering, analysis, and evaluation. It should also be noted that leading indicators involve use of empirical data to set planned targets and thresholds. Where organizations lack this data, expert opinion may be used as a proxy until a good historical base of information can be collected, but should not be relied on as a long term solution for measurement projections. Rather, organizations must build the collection of the historical measurement data into its collection practices.

What is the Expected Impact? These leading indicators have been specifically selected to provide insight into key systems engineering activities on a defense program, across the phases of a program as illustrated in the figure below (see Defense Acquisition Guidebook for more information on phases). It should be noted that the leading indicators are also envisioned as suitable to commercial endeavors, although there may be some adaptation of the detailed measurement information specifications needed.



As can be seen in Table 1 on page 6, most of these are trend measures that have broad applicability across the life cycle phases P1 – P5, denoted in the figure above as phases 1-5.

How will the Leading Indicators be Validated? Several major aerospace contractors from the LAI Consortium[6] have agreed to participate in a six month pilot of the leading indicators on programs at their facilities running Feb – July 2006. The efforts will be monitored by the action team and used to validate the beta set of leading indicators. Based on results of the pilots, leading indictors will be adjusted as required, with an update of this beta release document in 3Q2006 timeframe. Additionally, recommendations will be developed regarding which leading indicators are most effective for particular types of programs.

What are the Plans for Improvement? In support of the continuing validation and refinement activity, MIT graduate level academic research is planned to analyze the effectiveness and adequacy of the measures in support of improved enterprise performance. As lessons are learned in the validation process, the action team will be providing briefings to and seeking input from selected government forums and systems engineering societies/associations. The longer term plan includes transition of this activity and the guidance document from LAI to the INCOSE Measurement Working Group. This action provides additional exposure of these measurement concepts to a broader cross section of systems engineering practitioners worldwide.

[6] Validation efforts will be conducted at BAE Systems, Boeing, Lockheed Martin, Northrop Grumman, Raytheon and other interested organizations.

TABLE 1. SYSTEMS ENGINEERING LEADING INDICATORS OVERVIEW						
Leading Indicator	**Insight Provided**	**P1**	**P2**	**P3**	**P4**	**P5**
Requirements Trends	Rate of maturity of the system definition against the plan. Additionally, characterizes the stability and completeness of the system requirements which could potentially impact design and production.	●	●	●	●	●
System Definition Change Backlog Trend	Change request backlog which, when excessive, could have adverse impact on the technical, cost and schedule baselines.			●	●	●
Interface Trends	Interface specification closure against plan. Lack of timely closure could pose adverse impact to system architecture, design, implementation and/or V&V any of which could pose technical, cost and schedule impact.	●	●	●	●	●
Requirements Validation Trends	Progress against plan in assuring that the customer requirements are valid and properly understood. Adverse trends would pose impacts to system design activity with corresponding impacts to technical, cost & schedule baselines and customer satisfaction.	●	●	●	●	●
Requirements Verification Trends	Progress against plan in verifying that the design meets the specified requirements. Adverse trends would indicate inadequate design and rework that could impact technical, cost and schedule baselines. Also, potential adverse operational effectiveness of the system.	●	●	●	●	●
Work Product Approval Trends	Adequacy of internal processes for the work being performed and also the adequacy of the document review process, both internal and external to the organization. High reject count would suggest poor quality work or a poor document review process each of which could have adverse cost, schedule and customer satisfaction impact.	●	●	●	●	●
Review Action Closure Trends	Responsiveness of the organization in closing post-review actions. Adverse trends could forecast potential technical, cost and schedule baseline issues.	●	●	●	●	●
Risk Exposure Trends	Effectiveness of risk management process in managing / mitigating technical, cost & schedule risks. An effective risk handing process will lower risk exposure trends.	●	●	●	●	●
Risk Handling Trends	Effectiveness of the SE organization in implementing risk mitigation activities. If the SE organization is not retiring risk in a timely manner, additional resources can be allocated before additional problems are created.	●	●	●	●	●
Technology Maturity Trends	Risk associated with incorporation of new technology or failure to refresh dated technology. Adoption of immature technology could introduce significant risk during development while failure to refresh dates technology could have operational effectiveness/customer satisfaction impact.		●	●	●	●
Technical Measurement Trends	Progress towards meeting the Measures of Effectiveness (MOEs) / Performance (MOPs) / Key Performance Parameters (KPPs) and Technical Performance Measures (TPMs). Lack of timely closure is an indicator of performance deficiencies in the product design and/or project team's performance.			●		
Systems Engineering Staffing & Skills Trends	Ability of SE organization to execute total SE program as defined in the program SEP or SEMP. Includes quantity of SE personnel assigned, the skill and seniority mix and the time phasing of their application throughout the program lifecycle.	●	●	●	●	●
Process Compliance Trends	The quality and consistency of the project defined SE process as documented in the program's SEP / SEMP. Poor/inconsistent SE processes and/or failure to adhere to SEP / SEMP, increase program risk.	●	●	●	●	●

3. LEADING INDICATOR DESCRIPTIONS

The following subsections provide a very brief description of the leading indicators, along with the leading insight provided by this indicator. The detailed description for each of the indicators is provided in Section 4, where each leading indicator has an associated *information measurement description*. For each leading indicator in Section 3, the reader should refer to the associated information in Section 4 in order to fully understand the leading indicator.

The format of the leading indicators information has been developed to be consistent with other measurement guidance in use in systems engineering and software organizations.

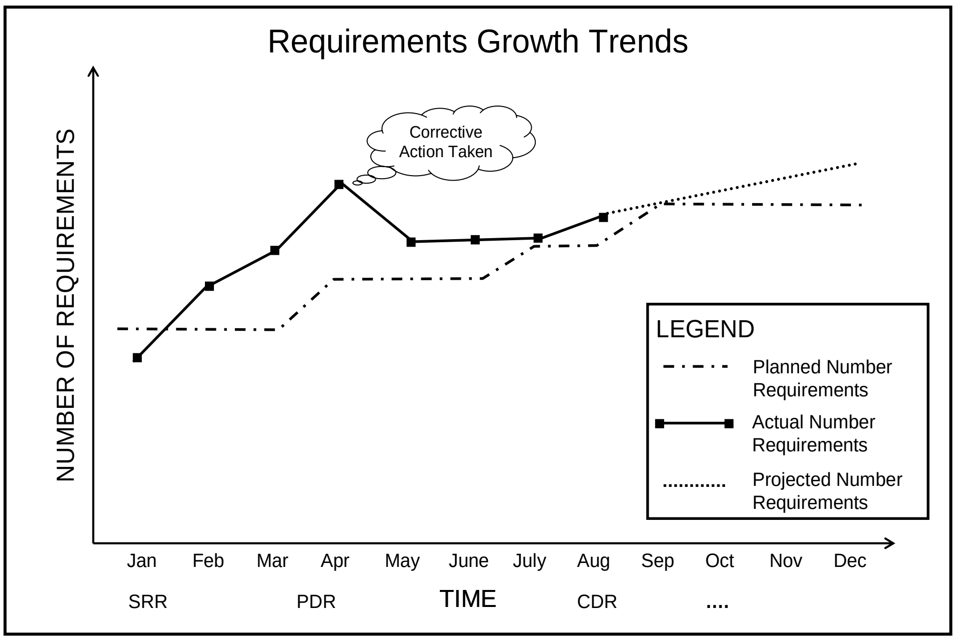
Important Note: *The graphics in this document are intended for basic illustrative purpose only, and may represent only one aspect of the overall indicator. These are prototype graphs and do not contain actual data. It is expected each organization will develop its own format for graphics. Underlying the information in the graphs, an organization will need to investigate root causes and related information to fully understand what is being flagged by the indicator. The concepts for the graphs will be refined after the pilot period and additional graphs will be used to provide insights into other aspects of the indicators.*

3.1. Requirements Trends

This indicator is used to evaluate the trends in the growth, change, completeness and correctness of the definition of the system requirements. This indicator provides insight into the rate of maturity of the system definition against the plan. Additionally, it characterizes the stability and completeness of the system requirements which could potentially impact design and production. The interface trends can also indicate risks of change to and quality of architecture, design, implementation, verification, and validation, as well as potential impact to cost and schedule.

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.1 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

Requirements Trends



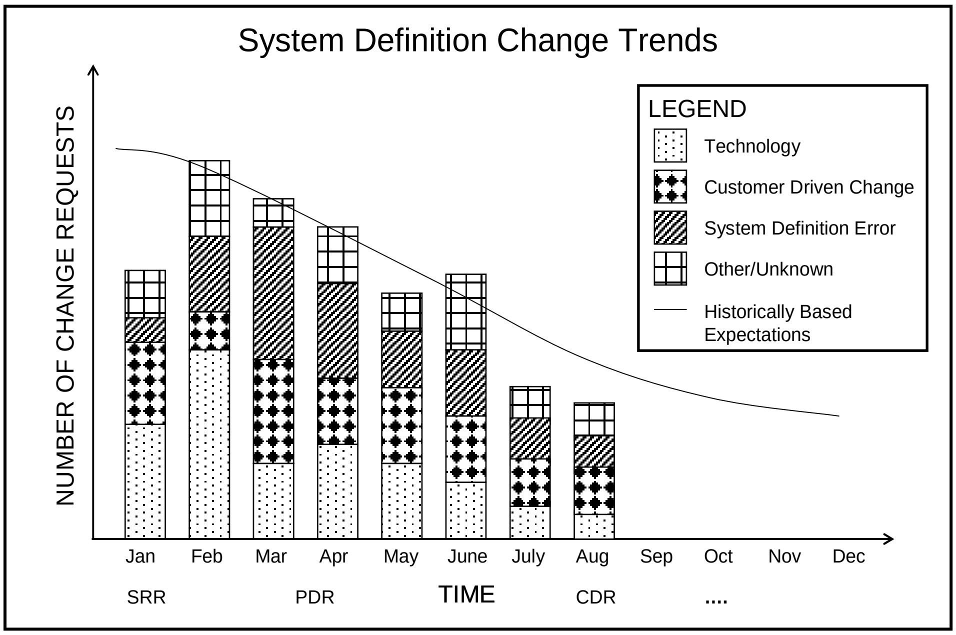
Requirements Trends. The graph illustrates growth trends in the number of requirements in respect to planned number of requirements (which is typically based on expected value based on historical information of similar projects as well as the nature of the program). Based on actual data, a projected number of requirements will also be shown on a graph. In this case, we can see around PDR that there is a significant variance in actual versus planned requirements, indicating a growing problem. An organization would then take corrective action – where we would expect to see the actual growth move back toward the planned subsequent to this point. The requirements growth is an indicator of potential impacts to cost, schedule, and complexity of the technical solution. It also indicates risks of change to and quality of architecture, design, implementation, verification, and validation.

3.2. System Definition Change Backlog Trends

This indicator is used to evaluate the trends in system definition change backlog, indicating whether the change backlog is impeding system definition progress or system development quality/schedule. It may also provide an indication of potential rework due to changes not being available in a timely manner.

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.2 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

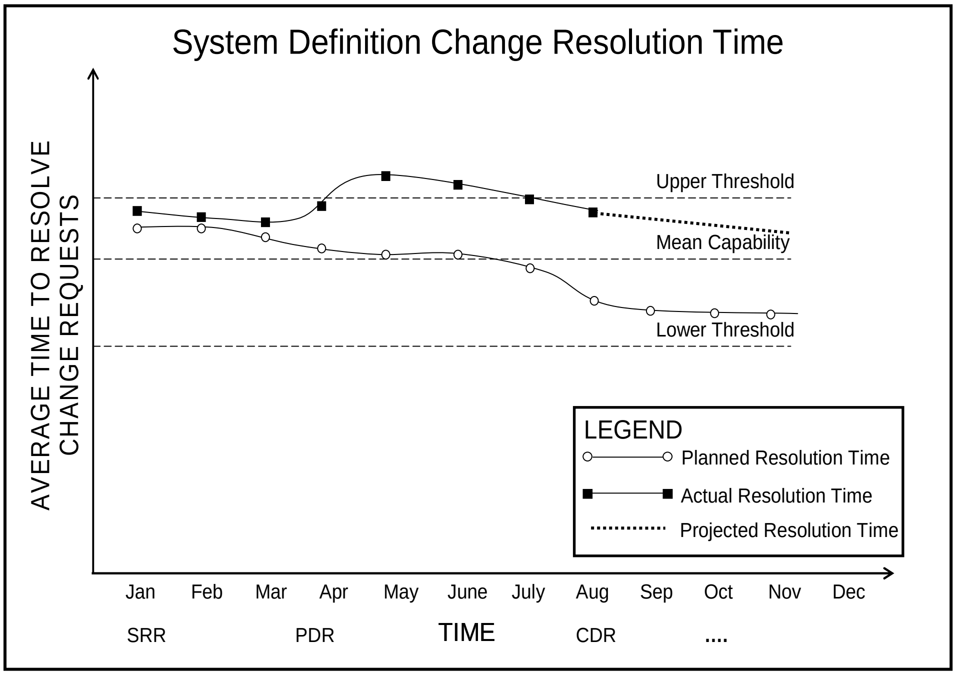
System Definition Change Trends



System Definition Change Backlog Trends. The graph illustrates the actual system definition change trend in respect to the historically based expected trend of changes. In this case for example, we see at SRR there are actually less changes than expected, and the program will need to investigate the factors for this to determine if this is a concern, and perhaps may lead to higher levels of change later in the program. The organization may find it useful to categorize changes according to what caused these, and a very mature organization might have expected trend lines for each type of change.

In addition to the change data itself, the average time to resolve the change requests provides additional leading information, as shown in the example graphs below.

System Definition Change Trends



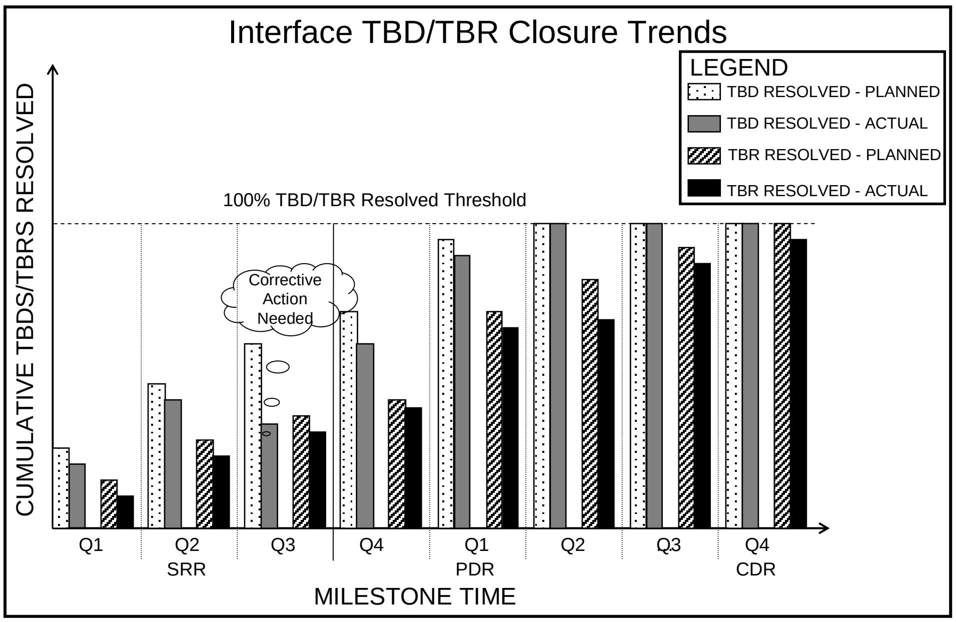
System Definition Change Trends/Resolution Time. The graph illustrates the actual average time to resolve change requests versus what is planned for the program based on historical data and nature of the program. Based on actuals to date, a projection is made for the future. Mature organizations will be able to identify lower and upper thresholds for the resolution times rather than a more simplified planned resolution time.

3.3. Interface Trends

This indicator is used to evaluate the trends related to growth, change, completeness, and correctness of the definition of system interfaces. This indicator provides insight into the rate of maturity of the system definition against the plan. It also assists in helping to evaluate the stability and adequacy of the interfaces to understand the risks to other activities towards providing required capability, on-time and within budget. The interface trends can also indicate risks of change to and quality of architecture, design, implementation, verification, and validation, as well as potential impact to cost and schedule.

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.3 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practice.

Interface Trends



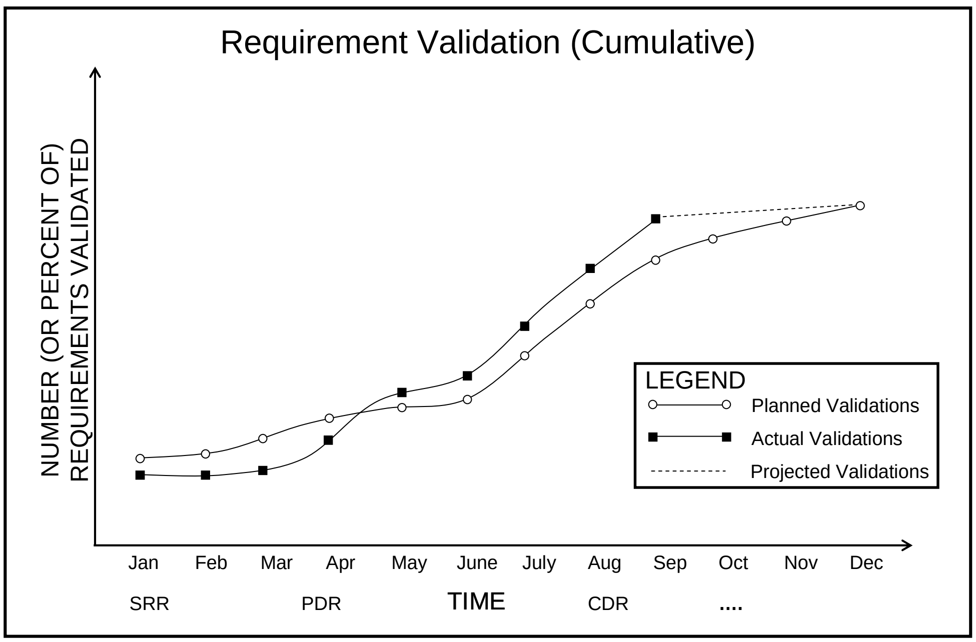
Interface TBD/TBR Closure Trends. The graph illustrates the actual cumulative number of TBDs and TBRs that have been resolved compared to what is planned to be resolved based on historical data and expectations given the program characteristics. It can be seen that in Q3 after SRR, the actual TNDs are significantly lower than planned, and corrective action is then taken.

3.4. Requirements Validation Trends

This indicator is used to evaluate the trends in the rate and progress of requirements validation activity. It provides early insight into the level of understanding of customer/user needs. It indicates risk to system definition due to inadequate understanding of the customer/user needs. It may also indicate risk of schedule/cost overruns, post delivery changes, or user dissatisfaction

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.4 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

Requirements Validation Trends



Requirements Validation Trends. The graph illustrates the actual number of (or it could also be shown as the percent of) requirements validated versus the planned validation based on historical data and the nature of the project. A projection will also be made based on the actual validation trend. In this case, we see at CDR that the actual validated requirements in higher than planned, indicating that the validation activity is on track.

3.5. Requirements Verification Trends

This indicator is used to evaluate the trends in the rate and progress of requirements verification. It provides early insight into the ability to meet customer/user requirements. The measure indicates possible risk to system definition due to inadequate ability to meet the customer/user requirements. It may indicate risk of schedule/cost overruns, potential for post delivery post delivery changes, or customer/user dissatisfaction.

An example of how such an indicator might be reported would be similar to the graph shown for requirements validation (see section 3.4).

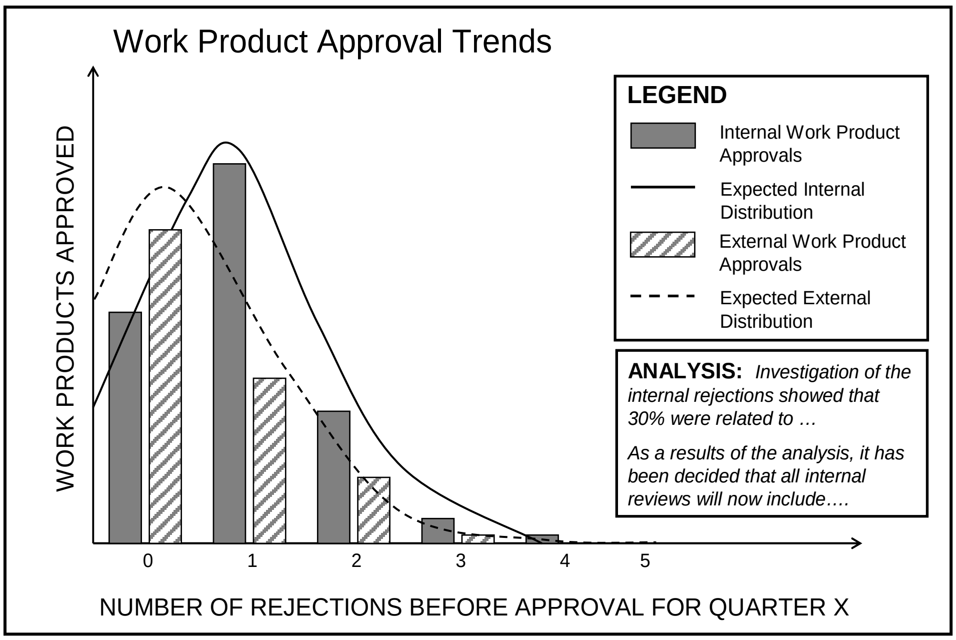
Refer to the measurement information specification in Section 4.5 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

3.6. Work Product Approval Trends

This indicator is used to evaluate the trends in the internal and external approvals of work products. It may indicate a problem with identification of needs or transformation into requirements/design. It may also indicate that the end product is not of high enough quality and may result in rework or need for changes in plan. It may also be the case that the review process definition or implementation may be inadequate. On the positive side, the measure will indicate readiness for entry into review milestones.

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.6 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

Work Product Approval Trends



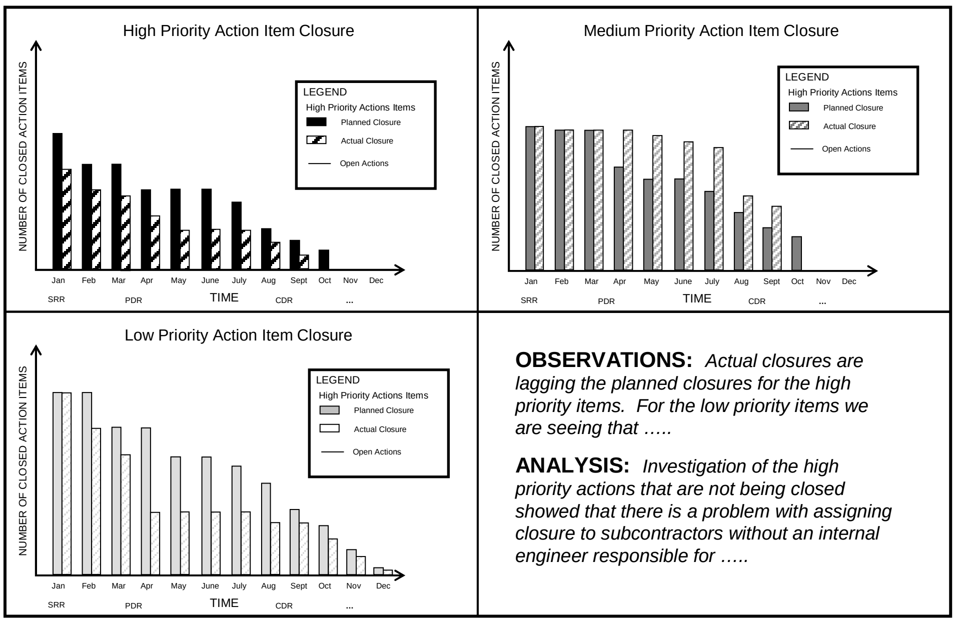
Work Product Approval Trends. The graph illustrates success of the work product approvals for Quarter X in respect to how many rejections there were for work products before approval for both internal work product approvals and external work product approvals. Actual rejections are shown with an overlay of the expected internal and external approvals based on historical data and the nature of the project. Analysis will be needed to understand why rejections are happening, and the graphic could include a breakdown of the root causes as stacked bars, for example, rather than just the single bar.

3.7. Review Action Closure Trends

This indicator is used to evaluate the trends in the closure of review action items. Review actions items may be technical or management/ communication related. Large deviations for the planned closure may be indicative of larger, more complex tasks ahead or potentially is a sign of challenging personnel interfaces. In either case, this indicator reveals project risk in terms of rework and/or infeasible schedule. Positive trends will provide insight into readiness to move to the next step/stage/phase.

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.7 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

Review Action Item Closure Trends



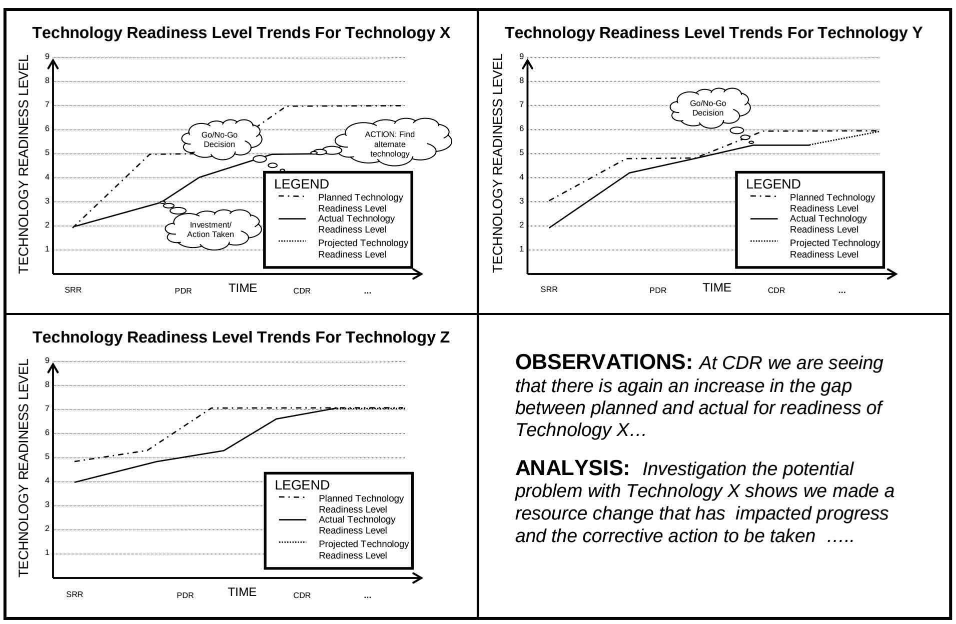
Review Action Item Closure Trends. The graph illustrates the number of review action items that are closed in each month, in respect to the number that is planned for closure in that month, based on historical information and nature of the project. The graphic shows the high priority, medium priority, and low priority actions on separate quadrants. A measurement analyst would be able to make observations that would require additional detailed analysis to decide if corrective action was required, and the nature of such action.

3.8. Technology Maturity Trends

This indicator is used to evaluate the trends in technology maturity trends, including readiness and obsolescence, of specific technologies that are under development. The measure may indicate that technology opportunities exist that need to be examined and may warrant product changes. It may also indicate when a technology is becoming obsolete and may be a candidate for replacement. Trend of obsolescence exposure gives an indication of when to take action due to obsolescence risk. This should help avoid surprises from obsolescence and plan for right timing of technology insertion of new technologies

An example of how such an indicator might be reported is show below for the readiness trends for selected technologies. Refer to the measurement information specification in Section 4.8 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

Technology Maturity Trends



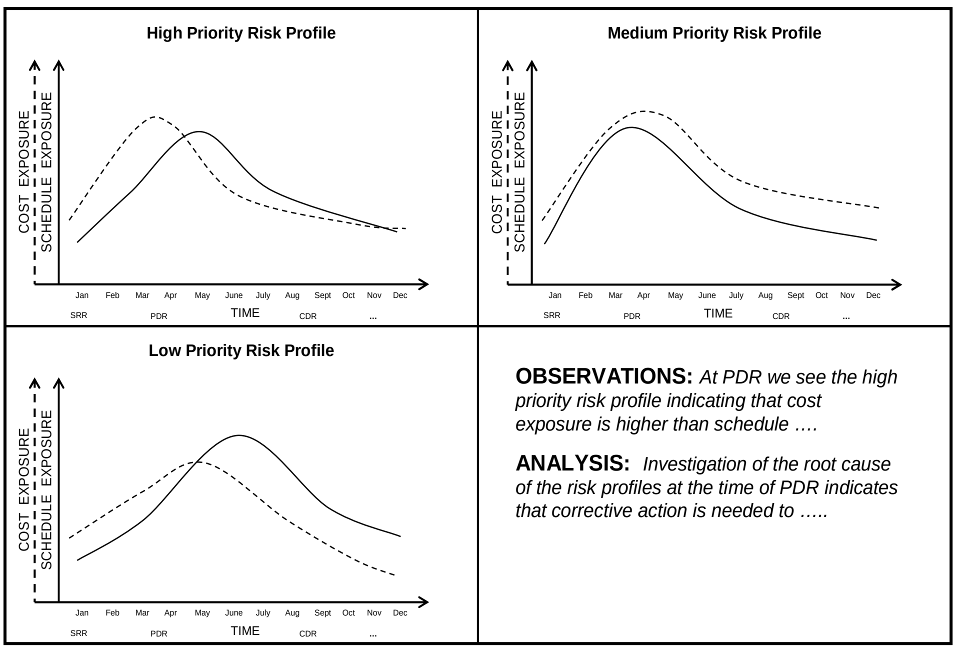
Technology Readiness Trends. The graph illustrates the actual readiness level of each of three technologies (X, Y, Z) in respect to the planned readiness level. The planned readiness would be determined by factors such as technology investment, availability of component technologies, and other factors. Observations are made on the graphs, with further analysis needed to understand underlying issues and causes where a potential problem is seen. For example, for Technology X, we see that just prior to PDR that there is a significant gap in the actual versus planned readiness, and that addtional investment action was taken which post PDR brought the actual readiness much closer to planned, allowing for a go/no-go decision.

3.9. Risk Exposure Trends

This indicator is used to evaluate the risk exposure over time in terms of cost and schedule, and in context of the level of risk. It indicates whether the program is effectively managing the program risks as shown by predicted exposure ratings over time. If the risk exposure continues to grow or not be reduced, the customer satisfaction will be negatively impacted due to resulting cost, schedule, or technical impacts.

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.9 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

Risk Exposure Trends



Risk Exposure Trends. The graph illustrates risk profiles of the program in regard to cost and schedule exposure over the life cycle. In this case, profiles for high, medium, and low priority risks are shown separately. The analyst can make certain observations which will require additional analysis to understand what the graphic is showing. For illustrative purposes, cost and schedule exposures are included in this graph. While not included, technical exposure would be another element of this indicator.

3.10. Risk Handling Trends

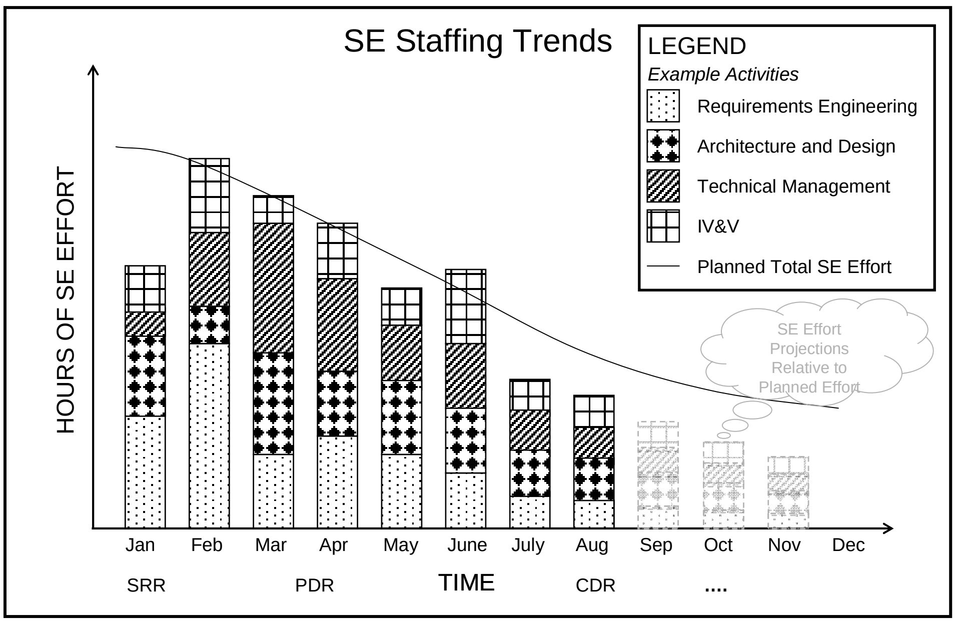
This indicator is used to evaluate effectiveness of handling risks. It indicates whether the program is proactively handling/treating potential problems or risks at the appropriate times in order to minimize or eliminate their occurrence and impacts to the program. If the actions are not closing per plan, then there is a higher probability that risks will be realized. This insight can identify where additional action may be needed to avoid preventable problems or reduce impacts. This indicator may also identify that the program does not have an iterative or continuous process implementation for risk mgt. Thus, new risks may not be identified and handled, and may affect the program and technical effectiveness/success. Refer to the measurement information specification in Section 4.10 for details regarding the indicator.

3.11. Systems Engineering Staffing and Skills Trends

This indicator is used to evaluate the staffing and skills mix trends in accordance with plans and expectations. It indicates whether the expected level of SE effort, staffing, and skill mix is being applied throughout the life cycle based on historical norms for successful projects and plans. It may also indicate a gap or shortfall of effort, skills, or experience that may lead to inadequate or late SE outcomes. The planned staffing can be compared to projected availability through the life cycle to provide an earlier indication of potential risks.

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.11 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

Systems Engineering Staff/Skill Trends



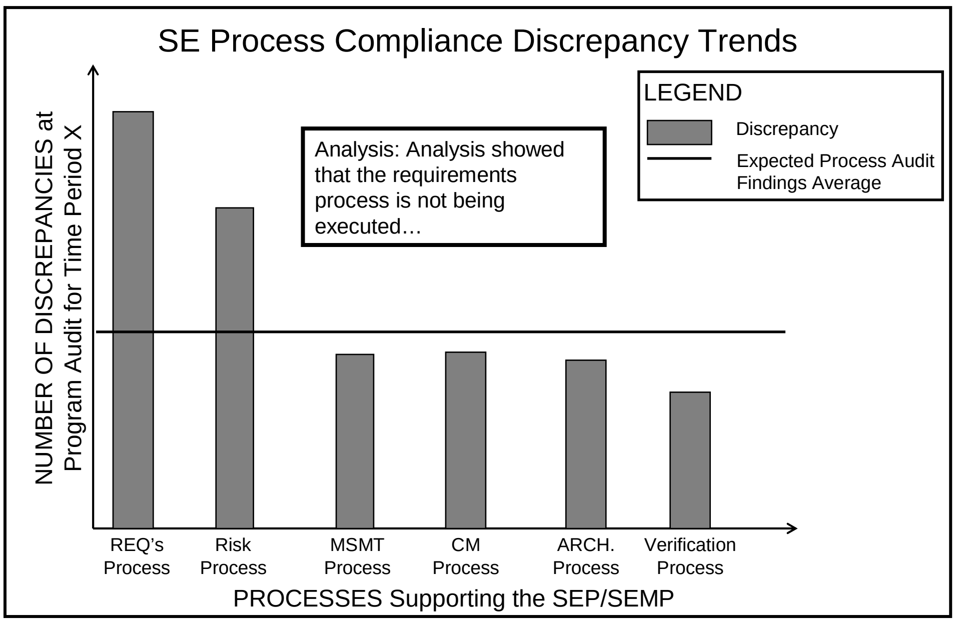
Systems Engineering Staffing Trends. The graph illustrates the systems engineering effort versus the planned effort based on historical data and nature of the project. The actual effort is shown in regard to several key categories of systems engineering activities. We can see that at SRR the data would have shown that the actual effort was well below the planned effort, and that corrective action must have been taken to align actual with planned in the next month of the project.

3.12. Process Compliance Trends

This indicator is used to evaluate the trends in process compliance discrepancies to ensure that the program is within expected range for process compliance. It indicates where process performance may impact other processes, disciplines, or outcomes of the project. General non-compliance indicates increased risk in ongoing process performance and potential increases in variance. Non-compliance of individual processes indicates a risk to downstream processes.

An example of how such an indicator might be reported is show below. Refer to the measurement information specification in Section 4.12 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

SE Process Compliance Trends



Systems Engineering Process Compliance Trends. The graph illustrates the number of discrepancies for each major process area, along with the expected process audit findings based on historical program audit information. In this case, it can be seen that there are indicators that there are issues with the requirements process and the risk process. Further investigation will be needed to determine the root causes – it could be that processes are not being followed, but there could also be cases where there are opportunities for improvement of the process that are needed.

3.13. Technical Measurement Trends

This indicator is used to evaluate the trends in progress toward achieving technical performance requirements. It aids in understanding the risk, progress, and projections regarding a system element or system of interest achieving the critical technical performance requirements.

Refer to the measurement information specification in Section 4.13 for the details regarding this indicator; the specification includes the general information which would be tailored by each organization to suit its needs and organizational practices.

4. INFORMATION MEASUREMENT SPECIFICATIONS

4.1. Requirements Trends

Requirements Trends	
Information Need Description	
Information Need	• Evaluate the stability and adequacy of the requirements to understand the risks to other activities towards providing required capability, on-time and within budget. • Understand the growth, change, completeness and correctness of the definition of the system requirements.
Information Category	1. Product size and stability – Functional Size and Stability 2. Also may relate to Product Quality and Process Performance (relative to effectiveness and efficiency of validation)
Measurable Concept and Leading Insight	
Measurable Concept	Is the SE effort driving towards stability in the System definition (and size)?
Leading Insight Provided	• Indicates whether the system definition is maturing as expected. • Indicates risks of change to and quality of architecture, design, implementation, verification, and validation, as well as schedule and cost shortfalls. • Greater requirements growth, changes, or impacts than planned or lower closure rate of TBDs/TBRs than planned indicate these risks.
Base Measure Specification	
Base Measures	1. # Requirements 2. # Requirement TBDs/TBRs 3. # Requirement defects 4. # Requirements changes by type (e.g., added, deleted, modified) 5. # Requirements changes by cause (e.g., error, customer request, external, etc.) 6. Impact of each requirement change (in estimated effort hours or range of hours) 7. Start/complete times of change
Measurement Methods	1. Count the number of requirements 2. Count the number of requirements TBDs/TBRs 3. Count the number of Requirements defects found during reviews 4. Count the number of requirements changes per change type 5. Count the number of requirements changes per change cause 6. Based on engineering judgment and documented in the change request. 7. Record from actual dates & times of requirements complete in the CM system
Unit of Measurement	1. Requirements 2. TBDs/TBRs 3. Defects 4. Changes (added deleted, modified) 5. Causes 6. Effort Hours 7. Date, Hour, Minute
Entities and Attributes	
Relevant Entities	• Requirements

Requirements Trends	
Attributes	• Requirement TBDs/TBRs • Requirement Defects • Requirement Changes • Time interval (e.g., monthly, quarterly, phase)
Derived Measure Specification	
Derived Measure	1. % Requirements approved 2. % Requirements Growth 3. % TBDs/TBRs not closed per plan 4. % Requirements Modified 5. Estimated Impact of Reqts Changes for time interval (in Effort hours) 6. Defect profile 7. Defect density 8. Defect leakage 9. Cycle time for requirement changes (each and average)
Measurement Function *	1. (# requirements approved / # requirements identified and defined)*100 as a function of time 2. ((# requirements in current baseline - # requirements in previous baseline) / (# requirements in previous baseline) * 100 3. ((# TBDs/TBRs planned for closure – # TBDs/TBRs closed) / # TBDs/TBRs planned for closure) * 100 4. (# Requirements modified / Total # requirements) * 100 as a function of time 5. Sum of estimated impacts for changes during defined time interval during defined time interval 6. Number of defects for each selected requirement attribute 7. # of requirements defects / # of requirements as a function of time 8. Subset of defects found in a phase subsequent to its insertion 9. Elapsed time (difference between completion time and start times) or total effort hours for each change
Indicator Specification	
Indicator Description and Sample **Also see 3.1**	Line or bar graphs that show trends of requirements growth and TBD/TBR closure per plan. Stacked bar graph that shows types, causes, and impact/severity of changes. Show thresholds of expected values based on experiential data. Show key events along the time axis of the graphs. 1. Line or bar graphs that show growth of requirements over time 2. Line or bar graphs that show % requirements approved over time 3. Line or bar graphs that show % TBDs/TBRs not closed per plan 4. Line or bar graphs that show % requirements modified, 5. Line or bar graphs that show estimated impact of changes for time interval (in effort hours) 6. Line or bar graphs that show defect profile 7. Line or bar graphs that show defect density 8. Stacked bar graph that shows types, causes, and impact/severity of changes on system design
Thresholds and Outliers	Organization dependent.
Decision Criteria	Investigate and, potentially, take corrective action when the requirements growth, requirements change impact, or defect density/distribution exceeds established thresholds <fill in organization specific threshold> or a trend is observed per established guidelines <fill in organizational specific>.

Requirements Trends	
Indicator Interpretation	Used to understand impact on system definition and impact on production. Analyze this indicator for process performance and other relationships that may provide more "leading perspective". - Ops Concept quality may be a significant leading indicator of the requirements stability (may be able to use number of review comments; stakeholder coverage in defining the Ops Concept).
Additional Information	
Related Processes	Stakeholder requirements, Requirements Analysis, Architectural Design
Assumptions	Reqts DB, Change Control records, and defect records are maintained & current.
Additional Analysis Guidance	
Implementation Considerations	Usage is driven by the stability of requirements. Lower stability means higher risk, thus it would be reviewed more frequently. Applies throughout the life cycle, based on risk. - Right quantity and quality of SEs. - Adequate infrastructure - Process maturity (acquirer and supplier) - Adequacy of pre-acquisition SE -- ICD, AoA, AMA (Number of review comments; adequate coverage of alternatives in the solution space) - Stakeholder collaboration across life cycle - Adequate funding by customer; financial challenge by the program mgt
User of Information	• Program Manager (PM) • Chief Systems Engineer (CSE) • Product Managers • Designers
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.2. System Definition Change Backlog Trends

System Definition Change Backlog Trends	
Information Need Description	
Information Need	Evaluate the backlog trends of the system definition to understand whether the changes are being made in a timely manner
Information Category	1. Schedule and Progress – Work Unit Progress 2. Also may relate to Process Performance - Process Efficiency
Measurable Concept and Leading Insight	
Measurable Concept	Are changes to the baseline being processed in a systematic and timely manner?
Leading Insight Provided	Indicates whether the change backlog is impeding system definition progress or system development quality/schedule. Also, an indication of potential rework due to changes not being available in a timely manner.
Base Measure Specification	
Base Measures	1. # of Request For Change (RFC) 2. Times of change: Start/interim/ approval/incorporated 3. # changes by type (e.g., added, deleted, modified) 4. # changes by cause (e.g., error, customer request, external, etc.) 5. # changes by approval disposition 6. Impact of each change (in estimated effort hours or range of hours)
Measurement Methods	1. Count the number of RFCs 2. Record from actual dates & times in the CM system 3. Count the number of changes per change type 4. Count the number of changes per change cause 5. Count the number of changes per approval disposition 6. Based on engineering judgment and documented in the change request.
Unit of Measurement	1. RFC 2. Day, hour, minute 3. Changes (added, modified, deleted) 4. Changes (by cause) 5. Changes (by disposition) 6. Effort hours
Entities and Attributes	
Relevant Entities	• Requests for Change (RFCs)
Attributes	• Requirement Changes • Time interval (e.g., monthly, quarterly, phase)
Derived Measure Specification	
Derived Measure	1. Approval rates 2. Cycle time statistical measures per attributes (e.g., mean, mode, min/max, dev.)
Measurement Function	1. (# RFCs approved / # RFCs submitted) * 100 [per time interval] 2. Cycle time = Time approved – Time submitted (per attribute)
Indicator Specification	

System Definition Change Backlog Trends	
Indicator Description and Sample **See 3.2**	• Line graphs that show trends of RFC cycle time and backlog status over time. • Pareto graph or stacked bar graph that shows types, causes, and impact/severity of changes. • Line graphs that show projections of when the current backlog will be closed (using rate of arrivals, plus rate of closure) • Show thresholds of expected values based on experiential data.
Thresholds and Outliers	User defined.
Decision Criteria	Investigate and, potentially, take corrective action when the change backlog exceeds established thresholds <fill in organization specific threshold> or a trend is observed per established guidelines <fill in organizational specific>.
Indicator Interpretation	Used to understand impact on system definition and development progress, and impact on time to market.
Additional Information	
Related Processes	Stakeholder requirements, Requirements Analysis, Architectural Design
Assumptions	Requirements Database and Change Control records are maintained & current.
Additional Analysis Guidance	• Also provides useful lagging information: Indicates that the SE processes are not being implemented effectively.
Implementation Considerations	• Use whenever there are multiple changes in the approval queue, after baseline has been established. More frequent review needed when backlog increases, especially if changes have interdependencies. • Do not sample - collect all RFC data. • Analyze this indicator for other relationships that may provide more "leading perspective". • Relationship between open/unresolved changes needs to be considered.
User of Information	• Program Manager (PM) • Chief Systems Engineer (CSE) • Configuration Management Manager
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.3. Interface Trends

Interface Trends	
Information Need Description	
Information Need	• Evaluate the stability and adequacy of the interfaces to understand the risks to other activities towards providing required capability, on-time and within budget. • Understand the growth, change, completeness and correctness of the definition of the system interfaces.
Information Category	1. Product size and stability – Functional Size and Stability 2. Also may relate to Product Quality and Process performance (relative to effectiveness and efficiency of validation)
Measurable Concept and Leading Insight	
Measurable Concept	Is the SE effort driving towards correctness and completeness (i.e., approved) of the definition and design of interfaces?
Leading Insight Provided	• Indicates whether the system definition is maturing as expected. Unfavorable trends indicate high risk during design, implementation and/or integration. • Indicates risks of change to and quality of architecture, design, implementation, verification, and validation, as well as schedule and cost shortfalls. • Greater interface growth, changes, or impacts than planned or lower closure rate of TBDs/TBRs than planned indicate risks to the system definition and flow-down.
Base Measure Specification	
Base Measures	1. # Interfaces 2. # Interface TBDs/TBRs 3. # Interface defects 4. # Interface changes by type (e.g., added, deleted, modified) 5. # Interface changes by cause (e.g., error, customer request, external, etc.) 6. Impact of each interface change (in estimated effort hours or range of hours) 7. Start/complete times of change
Measurement Methods	1. Count the number of interfaces identified and defined 2. Count the number of interface TBDs/TBRs among those interfaces identified and defined 3. Count the number of interfaces defects found during reviews 4. Count the number of interface changes per change type 5. Count the number of interface changes per change cause 6. Estimate the effort hours or range of effort hours expected for each change 7. Record from actual dates & times of interfaces complete in the CM system

Interface Trends	
Unit of Measurement	1. Interfaces 2. TBDs/TBRs 3. Defects 4. Changes (added, deleted, modified) 5. Causes 6. Effort hours 7. Date and time (Hours, minutes)
Entities and Attributes	
Relevant Entities	• Interfaces
Attributes	• Interface TBDs/TBRs • Interface Defects • Interface Changes • Time interval (monthly, quarterly, and phase)
Derived Measure Specification	
Derived Measure	1. % Interfaces approved 2. % Interfaces growth 3. % TBDs/TBRs not closed per plan 4. % Interfaces modified 5. Estimated Impact of Changes for time interval (in effort hours), 6. Defect profile 7. Defect density 8. Defect leakage 9. Cycle time for interface changes (each and average) 10. Rate of convergence of interfaces
Measurement Function	1. (# interfaces approved / # interfaces identified and defined)*100 as a function of time 2. ((# interfaces in current baseline - # interfaces in previous baseline) / (# interfaces in previous baseline) * 100 3. ((# TBDs/TBRs planned for closure – # TBDs/TBRs closed) / # TBDs/TBRs planned for closure) * 100 4. (# Interfaces modified / Total # interfaces) * 100 as a function of time 5. Sum of estimated impacts for changes (in effort hours) during defined time interval 6. Number of defects for each selected interface attribute 7. # of interface defects / # of interfaces as a function of time 8. Subset of defects found in a phase subsequent to its insertion 9. Elapsed time (difference between completion time and start times) or total effort hours for each change 10. Number of interfaces as a function of time
Indicator Specification	

Interface Trends	
Indicator Description and Sample **See 3.3**	Line or bar graphs that show trends of interface approval rates and TBD/TBR closure per plan. Stacked bar graph that shows types, causes, and impact/severity of changes. Show thresholds of expected values based on experiential data. Show key events along the time axis of the graphs. 1. Line or bar graphs that show growth of interfaces over time 2. Line or bar graphs that show % interfaces approved over time 3. Line or bar graphs that show % TBDs/TBRs not closed per plan 4. Line or bar graphs that show % interfaces modified, 5. Line or bar graphs that show estimated impact of changes for time interval (in effort hours) 6. Line or bar graphs that show defect profile 7. Line or bar graphs that show defect density 8. Stacked bar graph that shows types, causes, and impact/severity of changes on system design
Thresholds and Outliers	Organization dependent.
Decision Criteria	Investigate and, potentially, take corrective action when the interfaces are faulty and incomplete, interfaces change impact, or defect density/distribution exceeds established thresholds <fill in organization specific threshold> or a trend is observed per established guidelines <fill in organizational specific>.
Indicator Interpretation	• Used to understand impact on system definition, design, and system integration. • Analyze this indicator for process and system definition performance and progress, and impact to architecture, design, implementation, verification, and validation, as well as schedule and cost shortfalls. • Unfavorable trends indicate high risk during design, implementation and/or integration. • Greater interface growth, changes, or impacts than planned or lower closure rate of TBDs/TBRs than planned indicate risks to the system definition and flow-down.
Additional Information	
Related Processes	Stakeholder requirements, Requirements Analysis, Architectural Design
Assumptions	Requirements database, change control records, and defect records are maintained and current.
Additional Analysis Guidance	• May also be helpful to track trends based on severity/priority of changes
Implementation Considerations	• Usage is driven by the correctness and stability of interfaces definition and design. • Applies throughout the life cycle, based on risk. • Track this information per baseline version to track the maturity of the baseline as the system definition evolves. • Appropriate quantity and quality of Systems Engineers • Adequate infrastructure • Process maturity (acquirer and supplier) • Interface design capability • Stakeholder collaboration across life cycle • Adequate funding by customer; financial challenge by the program management

Interface Trends	
User of Information	• Program Manager (PM) • Chief Systems Engineer (CSE) • Interface Managers • Designers
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.4. Requirements Validation Trends

Requirements Validation Rate Trends	
Information Need Description	
Information Need	Understand whether requirements are being validated with the applicable stakeholders at each level of the system development.
Information Category	1. Product size and stability – Functional Size and Stability 2. Also may relate to Product Quality and Process performance (relative to effectiveness and efficiency of validation)
Measurable Concept and Leading Insight	
Measurable Concept	The rate and progress of requirements validation.
Leading Insight Provided	Provides early insight into level of understanding of customer/user needs: • Indicates risk to system definition due to inadequate understanding of the customer/user needs • Indicates risk of schedule/cost overruns, post delivery changes, or user dissatisfaction
Base Measure Specification	
Base Measures	1. # of requirements 2. # of requirements validated for time interval (planned) 3. # of requirements validated for time interval (actual) 4. Time (in months or hours) used for validation with the customer/end user
Measurement Methods	1. Count total # of requirements 2. Record # of requirements planned for validation for the time interval 3. Count # of requirements validated for the time interval 4. The start time and end time of the requirement validation process
Unit of Measurement	1-3. Requirement 4. Hours or person months
Entities and Attributes	
Relevant Entities	• Requirements
Attributes	• Time Interval (e.g., monthly, quarterly, phase, or event) • Stakeholder • Level of the architecture
Derived Measure Specification	
Derived Measure	1. Requirements validation rate (Rate at which requirements are validated with the customer/end user) 2. % requirements validated
Measurement Function	1. (# of requirements validated/unit time) 2. (# of requirements validated/total # requirements)*100
Indicator Specification	
Indicator Description and Sample See 3.4	1. Line graphs that show trends of validation rates per plan during a validation activity. 2. Table or graph showing time interval or events versus number or percent requirements validated (actual and planned).
Thresholds and Outliers	Organization dependent. Thresholds are phase dependent.

Requirements Validation Rate Trends	
Decision Criteria	Investigate and potentially take corrective action when the validation rate is lower than the established thresholds <fill in organization specific threshold> or a trend is observed per established guidelines <fill in organizational specific>.
Indicator Interpretation	• Investigation is driven by deviation of actual rate, percentage or quantity from plan. • Lower validation rate means higher risk, thus it would be reviewed more frequently. If actual validation (rate) lags planned validation (rate), there may be a need to increase staffing, increase review time with customer/end user, and/or review effectiveness of mission/requirements analysis processes pending causal analysis. This can in turn affect quality of system definition, validation, and customer satisfaction. • If the actual validation rate is exceeding the planned validation rate significantly, there may still be risk to consider. The planning process should be reviewed or the quality of the requirement validation method should be analyzed to ensure adequacy, if no process improvement was the reason for the deviation. If planning uses too low of validation rate, then efficiency may be lost. If validation process does not ensure adequate customer/user review, then there may be surprises during system validation.
Additional Information	
Related Processes	Stakeholder requirements, Requirements Analysis, Architectural Design.
Assumptions	Requirements database is maintained and validation rates can be obtained from project timeline.
Additional Analysis Guidance	The timing for validation may be driven by large project reviews/events such as the PDR or CDR. These should be considered in the planning and analysis.
Implementation Considerations	• Usage is driven by the requirements validation rate. • Applies throughout the life cycle, based on risk. • Could apply any time the project has requirements validation scheduled. • If the requirements validation rate is lagging, then there may be a need to collect "just-in-time" data to determine what this issue/root cause is. • May also want to consider using "Requirements Validation Results Trends" that looks at causes of validation rejections, etc.
User of Information	• Chief Systems Engineer • V&V Lead • Program Manager
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.5. Requirements Verification Trends

Requirements Verification Trends	
Information Need Description	
Information Need	Understand whether requirements are being verified to the requirements at each level of the system development.
Information Category	1. Product size and stability – Functional Size and Stability 2. Also may relate to Product Quality and Process performance (relative to effectiveness and efficiency of verification)
Measurable Concept and Leading Insight	
Measurable Concept	The rate and progress of requirements verification.
Leading Insight Provided	Provides early insight into ability to meet customer/user requirements: • Indicates risk to system definition due to inadequate ability to meet the customer/user requirements • Indicates risk of schedule/cost overruns, post delivery changes, or customer/user dissatisfaction
Base Measure Specification	
Base Measures	1. # of requirements 2. # of requirements verified for time interval (planned) 3. # of requirements verified for time interval (actual) 4. Time (in months or hours) used for verification with customer/end user
Measurement Methods	1. Count total # of requirements 2. Record # of requirements planned for verification for the time interval 3. Count # of requirements verified for the time interval 4. The start time and end time of the requirement verification process
Unit of Measurement	1-3. Requirement 5. Hours or person months
Entities and Attributes	
Relevant Entities	• Requirements
Attributes	• Time Interval (e.g., monthly, quarterly, phase, or event) • Stakeholder • Level of the architecture
Derived Measure Specification	
Derived Measure	1. Requirements verification rate (Rate at which requirements are verified) 2. % requirements verified
Measurement Function	1. (# of requirements verified/unit time) 2. (# of requirements verified/total # requirements)*100
Indicator Specification	
Indicator Description and Sample **See 3.5**	1. Line graphs that show trends of verification rates per plan during a verification activity. 2. Table or graph showing time interval or events versus number or percent requirements verified (actual and planned).
Thresholds and Outliers	Organization dependent. Thresholds are phase dependent.

Requirements Verification Trends	
Decision Criteria	Investigate and potentially take corrective action when the verification rate is lower than the established thresholds <fill in organization specific threshold> or a trend is observed per established guidelines <fill in organizational specific>.
Indicator Interpretation	• Investigation is driven by deviation of actual rate, percentage or quantity from plan. • Lower verification rate means higher risk, thus it would be reviewed more frequently. If the actual verification (rate) lags planned verification (rate), there may be a need to increase staffing, increase verification time with customer/end user, and/or review effectiveness of mission/requirements analysis processes pending causal analysis. This can in turn affect the quality of the system definition, system validation, and customer satisfaction. • If the actual verification rate is exceeding the planned verification rate significantly, there may still be risk to consider. The planning process should be reviewed or the quality of the requirement verification method should be analyzed to ensure adequacy, if no process improvement was the reason for the deviation. If planning uses too low of verification rate, then efficiency may be lost.
Additional Information	
Related Processes	Stakeholder requirements, Requirements Analysis, Architectural Design.
Assumptions	Requirements database is maintained and verification rates can be obtained from project timeline.
Additional Analysis Guidance	The timing for verification may be driven by large project reviews/events such as the PDR or CDR. These should be considered in the planning and analysis.
Implementation Considerations	• Usage is driven by the requirements verification rate. Applies throughout the life cycle, based on risk. Could apply any time the project has requirements verification scheduled. • If the requirements verification rate is lagging, then there may be a need to collect "just-in-time" data to determine what this issue/root cause is. • May also want to consider using "Requirements Verification Results Trends" that looks at causes of verification failures, etc.
User of Information	• Chief Systems Engineer • Verification & Validation Lead • Program Manager
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.6. Work Product Approval Trends

Work Product Approval Trend	
Information Need Description	
Information Need	Evaluate work product progress to plan and the approval efficiency of the work products.
Information Category	1. Schedule & Progress – work unit progress *2. Product Quality – efficiency* 3. *Process Performance – process efficiency*
Measurable Concept and Leading Insight	
Measurable Concept	Are the system definition work products being approved as planned?
Leading Insight Provided	• Indicates that there may be a problem with identification of needs or transformation into requirements/design. • Indicates that the end product is not of high enough quality and may result in rework or need for changes in plan. • Indicates that the review process definition or implementation may be inadequate. • Indicates readiness for entry into review milestones
Base Measure Specification	
Base Measures	1. Number of work products submitted, 2. Number of submitted work products for each approval disposition
Measurement Methods	1. Count the number of work products total 2. Count the number of work products per approval disposition
Unit of Measurement	1. Work Products 2. Work Products (rejected, approved, etc.)
Entities and Attributes	
Relevant Entities	• Work Products
Attributes	• Time interval (e.g., monthly, quarterly, phase) • Work Product Type • Work Product Approval Dispositions
Derived Measure Specification	
Derived Measure	1. Approval rate 2. Distribution of dispositions, 3. Approval rate performance
Measurement Function	• (number approved on first submittal) / (number submitted) 1. Number of rejected work products before approval 2. (Actual approval rate) / (Planned approval rate)
Indicator Specification	
Indicator Description and Sample **See 3.6**	• Graphs that show trends of approval rates per plan during system definition. • Chart showing approval rate distribution by work product type.
Thresholds and Outliers	Organization dependent

Work Product Approval Trend	
Decision Criteria	Investigate and, potentially, take corrective action when the approval rate is lower than established thresholds <fill in organization specific threshold> or a trend is observed per established guidelines <fill in organizational specific>. A positive trend can still indicate a risk or problem exists. E.g., a positive trend can be caused from reviews that are not effective or that there is too much effort being expended on work product preparation and review.
Indicator Interpretation	• Decreasing trends indicate greater risk in the review process or the understanding of user needs. • Increasing trends can indicate risk in thoroughness of reviews or that too much effort is being applied on work product preparation and review. • If external approval rate drops below threshold, it may indicate issue with effectiveness of Engineering Review Board, in-process reviews, and processes supporting product generation • If internal approval rate drops below threshold, it may indicate issue with effectiveness of in-process reviews, and processes supporting product generation • If internal approval rate gets close to 100%, it may indicate the internal reviews are not thorough enough. Review results together with the External Approval Rate. If external rate is lower, then the cause is probably the lack of thorough internal reviews. • If external approval rate gets close to 100%, may indicate that too much effort is being expended on KWP preparation and review. • Also can provide insight into adequacy of meeting planned/agreed-to milestones (internal and external). • Can provide insight into one influence of customer satisfaction.
Additional Information	
Related Processes	Review process
Assumptions	• Approval data for work product reviews is captured, retained, and current. • Approval rate based on 1st time submittals.
Additional Analysis Guidance	
Implementation Considerations	• Do not sample - collect all work product approval data. • Use when there are numerous work products going through review and approval. Collect data and use the indicator for both internal (submitted to internal approval authority) and external (submitted to customer approval authority) work product reviews. Not intended for use during interim, incremental, in-process internal reviews.
User Of The Data	• Chief Systems Engineer • Program Manager • Process Owners • Approval Authority
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.7. Review Action Closure Trends

Review Action Closure Trends	
Information Need Description	
Information Need	Evaluate design review action item progress to plan and closure efficiency.
Information Category	1. Schedule & Progress – milestone completion 2. Also may relate to Product Quality – efficiency; Process Performance – process efficiency; and Customer Satisfaction – customer feedback
Measurable Concept and Leading Insight	
Measurable Concept	Are early design review action items being closed according to plan?
Leading Insight Provided	• Design review actions items may be technical or management/ communication related. Large deviations for the planned closure may be indicative of larger, more complex tasks ahead or potentially is a sign of challenging personnel interfaces. In either case, this indicator reveals project risk in terms of rework and/or infeasible schedule. • May provide insight into readiness to move to the next step/stage/phase.
Base Measure Specification	
Base Measures	1. # Action Items for the time interval 2. # Action Items per disposition (opened, closed, overdue, etc.) at end of time interval 3. # Action Items per priority (e.g., critical, major, minor) at end of time interval 4. # of Action Items per Design Review event 5. Impact for each action item (e.g., high, medium, low or effort hours)
Measurement Methods	1. Count the total number of action items 2. Count the number of action items for each disposition at the end of the time interval 3. Count the number of action items for each priority at the end of the time interval 4. Count the number of action items assigned for each design review event 5. Estimate the impact of each action item using engineering judgment
Unit of Measurement	1. Action items 2. Action items 3. Action items 4. Action items 5. Assessed qualitative impact or effort hours
Entities and Attributes	
Relevant Entities	• Action items
Attributes	• Action Disposition (Open, Closed, Overdue, etc.) • Priority (e.g., Critical, Major, Minor) • Impact (e.g., High, Medium, Low) • Time interval (e.g., monthly, quarterly, phase),
Derived Measure Specification	

Review Action Closure Trends	
Derived Measure	1. Closure rates 2. Action item closure performance 3. Variance from thresholds (for number of action items assigned at design review or closure performance)
Measurement Function	1. Number of action items closed over time 2. (Action items closed over time interval) / (Action items planned for closure over time interval) 3. Difference between observed values and threshold values
Indicator Specification	
Indicator Description and Sample **See 3.7**	• Graph(s) showing trends of closure rates and action item performance. • May include bar graph showing total number of actions per review. • Show thresholds of expected values based on experiential data. • Show key events along the time axis of the graph(s).
Thresholds and Outliers	Organization dependent
Decision Criteria	Investigate and, potentially, take corrective action when the closure rate or Overdue action items exceed established thresholds <fill in organization specific threshold> or a trend is observed per established guidelines <fill in organizational specific>.
Indicator Interpretation	• Large deviations for the planned closure may be indicative of larger, more complex tasks ahead or potentially is a sign of challenging personnel interfaces. • A backlog in the action item closure indicates project risk in terms of rework and/or infeasible schedule, especially if the backlog has higher priority or impact actions. • If the backlog of action items are related to the technical solution definition, then it indicates there is additional technical risk that should be assessed before proceeding to the next phase, especially if the backlog has higher priority or impact actions. Large number of lingering action items may indicate requirements instability, immature architecture/design, or inadequate stakeholder buy-in. This may be caused by inadequate pre-acquisition systems engineering, including ICD, AoA, AMA (number of review comments; adequate coverage of alternatives in the solution space, etc.) • The backlog of action items may also be an indication of inadequate quantity or quality (experience or skill mix) of personnel, inadequate program support infrastructure, process maturity/compliance problems, or inadequate program funding. • Significantly larger number of technical actions assigned at a design review than expected (based on historical data or thresholds) may indicate unacceptable technical risks and may impact readiness.
Additional Information	
Related Processes	Review process
Assumptions	Review minutes/records are maintained & current.
Additional Analysis Guidance	Usage is driven by the status of Design Review action item closure. Lower closure than planned, or greater the number of open action items, means higher risk, thus it would be reviewed more frequently. Applies to the Design phase.

Review Action Closure Trends	
Implementation Considerations	• Includes action items from peer reviews, inspections, technical exchange meetings, in addition to those from large formal reviews/events • Do not sample - collect all Design review action item data. • Should include stakeholder collaboration across life cycle
User Of The Data	• Chief Systems Engineer • Product Manager
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.8. Technology Maturity Trends

Technology Maturity Trends	
Information Need Description	
Information Need	Determination of the readiness of new technologies and the obsolescence of currently used technologies in order to maintain a useful and supportable technology base.
Information Category	Technology Effectiveness
Measurable Concept and Leading Insight	
Measurable Concept	The potential impact (beneficial or adverse) of technology changes on the future of the program.
Leading Insight Provided	• Indicates that technology opportunities exist that need to be examined and may warrant product changes. • Indicates technology is becoming obsolete and may be a candidate for replacement. • Trend of obsolescence exposure gives an indication of when to take action due to obsolescence risk. • Should help avoid surprises from obsolescence and plan for right timing of technology insertion of new technologies.
Base Measure Specification	
Base Measures	1. Number of technology obsolescence candidates identified 2. Number of critical/beneficial technology opportunities identified 3. Technology readiness level (for each new technology opportunity) 4. Number of technology obsolescence candidates realized 5. Number of technology opportunity candidates realized 6. Expected time to realization (of technology readiness or obsolescence) 7. Actual time to realization (of technology readiness or obsolescence) 8. Expected cost for realization (of technology readiness or obsolescence) 9. Actual cost for realization (of technology readiness or obsolescence) 10. Probability of technology insertion/phase-out 11. Probable impact of technology insertion/phase-out 12. Actual impact of technology insertion/phase-out
Measurement Methods	1-3. Empirical analysis and expert opinion based on the following sources: a. Industry contacts and associations b. Technology forecast reports c. Technical staff 4. Track technology obsolescence candidates until realized 5. Track technology opportunity candidates until realized 6. Empirical analysis and expert opinion based on sources listed above 7. Record actual time to realization (of technology readiness or obsolescence) 8. Empirical analysis and expert opinion based on sources listed above 9. Record actual cost for realization (of technology readiness or obsolescence) 10. Empirical analysis and expert opinion based on sources listed above 11. Empirical analysis and expert opinion based on sources listed above 12. Empirical analysis and expert opinion based on sources listed above

Technology Maturity Trends	
Unit of Measurement	1. Technology obsolescence candidates 2. Technology opportunity candidates 3. Technology readiness level 4. Technology obsolescence candidates 5. Technology opportunity candidates 6. Time 7. Time 8. Cost 9. Cost 10. Probability 11. Cost and schedule 12. Cost and schedule
Entities and Attributes	
Relevant Entities	• Technology candidates
Attributes	• New Technology opportunities • Existing technology obsolescence
Derived Measure Specification	
Derived Measure	1. Technology opportunity exposure 2. Technology obsolescence exposure 3. Mean time of impact 4. Mean error of impact estimate (cost, schedule, performance, etc.)
Measurement Function	1. Technology opportunity exposure: probability * impact * number of candidates 2. Technology obsolescence exposure: probability * impact * number of candidates 3. Empirical analysis 4. Empirical analysis
Indicator Specification	
Indicator Description and Sample **See 3.8**	• A graph showing trend of technology opportunity exposure, obsolescence exposure and impact of change. • Graph or table showing variances between estimated and actual.
Thresholds and Outliers	Organization dependent
Decision Criteria	Investigate and, potentially, take action when total technology opportunity exposure, technology obsolescence exposure, and/or impact of change exceeds organizational criteria.
Indicator Interpretation	• Provide early warning of potential obsolescence issues • Provide early assessment of impact of changes • Identify when conditions are right to take advantage of new technology opportunities
Additional Information	
Related Processes	Planning, Decision Making, Architectural Design, and Production
Assumptions	Technology opportunities and obsolescence candidates are captured. Technical staff assesses probability, impact, and timeframe of insertion or replacement.

Technology Maturity Trends	
Additional Analysis Guidance	• Collect data for each identified technology opportunity or obsolescence candidate. • Need to consider analysis based on intended life of the system/product.
Implementation Considerations	Use when 1) Products have technological difficulties or long lives compared to technology refresh times; 2) When there is a risk of technology obsolescence that may impact the system; and 3) When critical/beneficial technologies are in development. Obsolescence issues may prevent the organization from making/maintaining the product. Need to ask: 1) What can be done with the new technology? 2) How can it be incorporated into the architecture and design? 3) What risks are introduced as a result of new technology and product obsolescence?
User of Information	• Program/project Manager • Chief Systems Engineer • Chief Architect • Customer • R&D groups
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.9. Risk Exposure Trends

Risk Exposure Trends	
Information Need Description	
Information Need	Determine an estimate of the risk exposure to understand the potential impact to the quality, cost, and schedule of the system solution and the necessary SE effort to manage the exposure.
Information Category	1. Product quality 2. Schedule and progress 3. Cost and resource
Measurable Concept and Leading Insight	
Measurable Concept	Assessment of program effectiveness in managing/mitigating risks • Is the risk exposure going to impact the system solution? • Is the SE effort managing the exposure successfully?
Leading Insight Provided	Indicates whether the program is effectively managing the program risks as shown by predicted exposure ratings over time. • Assessment of risk exposure impacts to the system solution • Assessment of the SE effort in successfully managing the exposure
Base Measure Specification	
Base Measures	At each time interval: 1. Number of risks 2. Probability of occurrence 3. Impact of occurrence 4. Criticality (Urgency to address – if used in risk mgt process) 5. Planned handing actions (per risk) 6. Actual handing actions (per risk) 7. Risk dispositions (new, open, closed, etc.)
Measurement Methods	1. Count of risks in database 2. Engineering judgment influenced by historical data (if any) or risk models 3. Engineering judgment influenced by historical data (if any) or risk models 4. Engineering judgment influenced by historical data (if any) or risk models 5. Count from risk repository 6. Count from risk repository 7. Count of risks for each disposition
Unit of Measurement	1. Number (of risks, tasks, events) 2. Probability value 3. Performance value/dollar/schedule differential(s) 4. Rating corresponding to time interval 5. Number (of tasks, events) 6. Number (of tasks, events) 7. Number (of risks for each disposition)
Entities and Attributes	
Relevant Entities	• Risk candidates
Attributes	• Time interval (e.g., monthly, quarterly, phase)
Derived Measure Specification	
Derived Measure	Factored Risk Exposure *[could be in terms of $, time, or technical parameters]*

Risk Exposure Trends	
Measurement Function	1. Probability * Impact *[behavior over time]* 2. Probability * Impact * Criticality *[behavior over time - variant if criticality (or urgency) is used]*
Indicator Specification	
Indicator Description and Sample **See 3.9**	1. Risk magnitude/reduction line graph over time that shows trends for each risk category/rating. 2. Table of planned vs. actual risk exposure. • Planned vs. actual over time • Information displayed graphically • See sample charts
Thresholds and Outliers	Organization and/or program dependent.
Decision Criteria	Investigate and, potentially, take corrective action when the exposure trends predict that the risk exposure thresholds are being approached or may become out of control.
Indicator Interpretation	Impact on program execution in meeting Cost, Schedule, Performance, Quality. If the risk exposure continues to grow or not be reduced, the customer satisfaction will be negatively impacted due to resulting cost, schedule, or technical impacts.
Additional Information	
Related Processes	Risk Management, Program Management
Assumptions	Information is readily available, current, and maintained in a Risk Management repository.
Additional Analysis Guidance	May use all data or just concentrate on the highest priority risks.
Implementation Considerations	• Align with scheduled reviews (e.g., Risk, IPT, SE, and program) • Aids in identifying trouble spots in terms of performance, cost, and schedule, especially with the collection of categories and sources to share across enterprises to foster lessons learned. Note: For this indicator, the concept of risk does not include opportunities.
User of Information	• Program Manager • Chief Engineer • Risk Manager
Data Collection Procedures	• See Appendix A
Data Analysis Procedures	• See Appendix A

4.10. Risk Handling Trends

Risk Handling Action Trends	
Information Need Description	
Information Need	Evaluation of risk management program to assess whether the plan/action items have been properly executed.
Information Category	1. Product quality 2. Schedule and progress
Measurable Concept and Leading Insight	
Measurable Concept	Assess how successful the SE effort is in mitigating the risks • Are the risk handling/treatment actions being executed and closed as planned ? • Is the SE effort driving the closure of the risks?
Leading Insight Provided	Indicates whether the program is proactively handling/treating potential problems or risks at the appropriate times in order to minimize or eliminate their occurrence and impacts to the program. If the actions are not closing per plan, then there is a higher probability that risks will be realized. This insight can identify where additional action may be needed to avoid preventable problems or reduce impacts. This indicator may also identify that the program does not have an iterative or continuous process implementation for risk mgt. Thus, new risks may not be identified and handled, and may affect the program and technical effectiveness/success.
Base Measure Specification	
Base Measures	1. Number of risk handling actions 2. Risk handling action disposition (new, open, overdue, closed on time, closed after overdue, etc.) 3. Risk level of associated risks (red, yellow, green - for filtering purposes to isolate progress on actions for high priority risks)
Measurement Methods	1. Count of risk handling actions from risk management repository 2. Count of risk handling actions for each disposition 3. Count of risks for each risk level
Unit of Measurement	1. Number (of action items)
Entities and Attributes	
Relevant Entities	• Risk handling actions
Attributes	• Time interval
Derived Measure Specification	
Derived Measure	1. % risk handling actions closed on time *[per risk level]* 2. % risk handling actions overdue *[per risk level]* 3. % risks that met risk reduction plan
Measurement Function	1. ((# actions closed in time interval)/(# actions planned to close in time interval)) * 100 *[per risk level]* 2. ((# actions overdue in time interval)/(# actions planned to close in time interval)) * 100 *[per risk level]* 3. ((# of risks reduced in time interval)/(# of risks planned to be reduced in time interval)) * 100
Indicator Specification	

Risk Handling Action Trends	
Indicator Description and Sample See 3.10	1. A graph showing the planned vs actual risk action item closure. 2. A Risk Reduction Chart (or line graph) showing the reduction of risk over time for each risk requiring a mitigation plan. • Information displayed graphically
Thresholds and Outliers	Organization and/or program dependent.
Decision Criteria	Investigate and, potentially, take corrective action when risk reduction and risk handling action closure are below threshold or expectations. Objective for both is generally near 100%.
Indicator Interpretation	Used to identify whether or not effort is being adequately applied to risk handling/treatment activities. Impact on staffing, planning, development progress, and product delivery. If the actions are not closing per plan, then there is a higher probability that risks will be realized. This insight can identify where additional action may be needed to avoid preventable problems or reduce impacts.
Additional Information	
Related Processes	Risk Management, Program Management
Assumptions	Information is readily available, current, and maintained in a Risk Management Database.
Additional Analysis Guidance	• May use all data or just concentrate on the highest priority risks. • Effective closure of risk handling actions should positively affect risk exposure.
Implementation Considerations	• Applies to all tasks (i.e., PM, SE, SW, ...) throughout program life cycle. • Align with scheduled reviews (e.g., Risk, IPT, SE, and program). • The Risk and Opportunity Management process is owned by Program Management and is facilitated for execution by Systems Engineering. Not only are these indicators for Systems Engineering, but they are most likely indicators of overall program performance and health.
User of Information	• Program Manager • Chief Engineer • Risk Manager
Data Collection Procedure	• See Appendix A
Data Analysis Procedure	• See Appendix A

4.11. Systems Engineering Staffing and Skills Trends

Systems Engineering Staffing & Skills Trends	
Information Need Description	
Information Need	Evaluate the adequacy of the SE effort, skills, and experience provided on the program to meet program objectives.
Information Category	Resources and Cost – Personnel Effort
Measurable Concept and Leading Insight	
Measurable Concept	Is SE effort being applied to the project activities consistent with proven organizational or industry practice? Do the staff members have the appropriate skills and experience to achieve assigned tasks?
Leading Insight Provided	• Indicates whether the expected level of SE effort, staffing, and skill mix is being applied throughout the life cycle based on historical norms for successful projects and plans. • Indicates gap or shortfall of effort, skills, or experience that may lead to inadequate or late SE outcomes. • Planned staffing can be compared to projected availability through the life cycle to provide an earlier indication of potential risks.
Base Measure Specification	
Base Measures	1. Total effort in hours by task, activity, or event (Planned) 2. Total effort in hours by task, activity, or event (Actual) 3. SE effort in hours by task, activity, or event (Planned) 4. SE effort in hours by task, activity, or event (Actual) 5. SE effort in hours by skill and experience (Planned) 6. SE effort in hours by skill and experience (Actual) 7. # of SE Staff by task, activity, or event (Planned) 8. # of SE Staff by task, activity, or event (Actual)
Measurement Methods	1. Record effort hours from plan by task, activity, or event (may also include experience) 2. Count effort hours by task, activity, or event 3. Record effort hours from plan by task, activity, or event 4. Count effort hours by task, activity, or event 5. Record effort hours from plan by skill and experience (Novice, Junior, Senior, etc.) 6. Count effort hours by skill and experience (Novice, Junior, Senior, etc.) 7. Record the number of SE staff planned for the task, activity, or event 8. Count the number of SE staff actually applied to the task, activity, or event
Unit of Measurement	1-6. Hours 7-8. Full-time equivalent staff
Entities and Attributes	
Relevant Entities	• Effort Hours • Skills • Headcount
Attributes	• Time interval (e.g., monthly, quarterly, phase), • Task or activity • Experience level (Novice, Junior, Senior, etc.)
Derived Measure Specification	

Systems Engineering Staffing & Skills Trends	
Derived Measure	The following may be useful for both the total project and for the specific activities, tasks, or events. 1. % of SE Effort (SE effort / total effort) – Planned 2. % of SE Effort (SE effort / total effort) - Actual 3. % of SE Staffing per plan (SE staffing / total staffing) - Planned 4. % of SE Staffing per plan (SE staffing / total staffing) – Actual 5. Variance of SE Effort (per task and total) 6. Variance of SE Staffing (per task and total) 7. Variance of quantity of SE skills (per given SE skill)
Measurement Function	1. Planned SE Effort / Planned Total Effort 2. Actual SE Effort / Actual Total Effort 3. Planned SE Headcount / Planned Total Headcount 4. Actual SE Headcount / Actual Total Headcount 5. (Planned SE effort hours) – (Actual SE effort hours) 6. (Planned SE headcount) – (Actual SE headcount) 7. (Planned hours of a given SE skill) – (Actual hours of a given SE skill) [consider experience also, as applicable]
Indicator Specification	
Indicator Description and Sample **See 3.11**	1. Line graphs that show trends of actual SE effort and SE staffing versus plan across the life cycle. Show key events along the time axis of the graphs. 2. Bar chart or stacked bar chart showing the distribution of actual SE effort per task, activity, event or other relevant breakdown against the experiential data for successful projects or against plan. 3. Bar chart showing distribution of actual and planned SE staffing hours by skill. Can use a stacked bar graph to show experience distribution within a skill. 4. Line graph showing the trends of the most critical SE skills against plan. Show a plan line and actual line over time for each critical skill.
Thresholds and Outliers	Organization dependent
Decision Criteria	Based on the trend, investigate and, potentially take corrective action when the SE effort/skills for a task, event, or portion of the life cycle exceeds established thresholds (positive or negative) or a trend is observed per established guidelines.
Indicator Interpretation	• Lack of meeting planned SE effort or staffing with required skills/experience (i.e., below plan thresholds) potential missed milestones, schedule slips, and/or reduced quality. • Staff hours or headcount that is higher than plan indicates potential cost overrun. • Effort hours, skills and experience should be reviewed together against plan for tasks or activities. This indicates whether the right amount of effort is being applied with the right skills and experience. • Planned staffing can be compared to projected availability through the life cycle to provide an earlier indication of potential risks. • Provides insight into impact of the quantity of systems engineering effort (both hours and headcount) on the overall performance of the project. • Meeting planned effort hours with too few staff will likely result in longer term overtime issues, including impact on cost and quality.
Additional Information	

Systems Engineering Staffing & Skills Trends	
Related Processes	Planning, Control
Assumptions	• Time records that capture SE effort are maintained and current. • SE skill capabilities and experience of personnel are known and maintained. • The Staffing Plan identifies not only roles and quantity, but includes identification of critical skills and when they are needed.
Additional Analysis Guidance	• Can use to aid in trade-off of SE effort versus level/skills. • Should analyze the effort and skills trends together to ensure the right skill mix for the effort.
Implementation Considerations	1. Do not sample - collect all SE effort data and establish applicable distribution. 2. The SE effort is dependent on the tasks/activities the project is responsible for. The project would define the tasks/activities included and would determine whether to track at a total aggregate level or at a lower level. 3. This is most effective, if the distribution of SE skills is identified, an evaluation of personnel against the SE skill set is maintained, and the tracking is performed to ensure the personnel with the right skills are being provided.
User Of The Data	• Program Manager • Chief Systems Engineer • Other Managers
Data Collection Procedures	• See Appendix A
Data Analysis Procedures	• See Appendix A

4.12. Process Compliance Trends

Process Compliance Trends	
Information Need Description	
Information Need	Evaluate project defined SE process performance for compliance, efficiency, and effectiveness.
Information Category	Process Performance – process compliance, efficiency, effectiveness
Measurable Concept and Leading Insight	
Measurable Concept	To what extent are the SE processes in place and being used on the program?
Leading Insight Provided	• Indicates where process performance may impact other processes, disciplines, or outcomes of the project. • General non-compliance indicates increased risk in ongoing process performance and potential increases in variance. • Non-compliance of individual processes indicates a risk to downstream processes.
Base Measure Specification	
Base Measures	1. Tasks satisfied, 2. Tasks with discrepancies 3. Number of discrepancies by discrepancy severity qualifier (minor, major) 4. Number of discrepancies by discrepancy category
Measurement Methods	3. Count the number of tasks satisfied 4. Count the number of tasks with discrepancies 5. Count the number of discrepancies by severity 6. Count the number of discrepancies by category
Unit of Measurement	1. Tasks 2. Tasks 3. Discrepancies 4. Discrepancies
Entities and Attributes	
Relevant Entities	• Tasks
Attributes	• Time interval (e.g., monthly, quarterly, phase) • Discrepancy severity • Discrepancy category
Derived Measure Specification	
Derived Measure	1. % Processes with discrepancies 2. Profile of discrepancies 3. High risk processes
Measurement Function	1. Number of processes with discrepancies divided by number of processes (audited) 2. Number of minor, major discrepancies over time 3. Number of processes with major findings or with numerous minor findings
Indicator Specification	

Process Compliance Trends	
Indicator Description and Sample **See 3.12**	Pareto chart showing quantity of discrepancies for processes from highest to lowest (allows visual identification of those requiring investigation). Show thresholds of expected values based on experiential data.
Thresholds and Outliers	Organization dependent
Decision Criteria	Investigate and, potentially, take corrective action when the % of processes with discrepancies or number of discrepancies exceeds established thresholds <fill in organization specific threshold> or a trend is observed per established guidelines <fill in organizational specific>. Particularly pay attention to critical processes.
Indicator Interpretation	• General non-compliance indicates increased risk in ongoing process performance and potential increases in variance. • Non-compliance of individual processes indicates a risk to downstream processes.
Additional Information	
Related Processes	All processes
Assumptions	Process audits are conducted and records are maintained & current. Base measures data are available from process audits.
Additional Analysis Guidance	• Usage is driven by the process audit plan • Review together with the work product approval indicators • Although lagging, this indicator also identifies where additional training or quality surveillance may be needed.
Implementation Considerations	• All processes do not need to be audited during all audit periods. Audit those that are most important to success or performed most often during that period. • Need to identify the processes that are downstream from the process observed to provide a leading view. • The lack of a process audit plan is an indicator of risk in this area. • Best to have a non-advocate/independent party involved • Frequency of review is dependent on schedule duration, scope, and composition of the program. • Discrepancy categories are organization dependent • Discrepancy high risk thresholds are organization dependent
User Of The Data	• Chief Systems Engineer • Process Lead • Quality Assurance Manager
Data Collection Procedures	• See Appendix A
Data Analysis Procedures	• See Appendix A

4.13. Technical Measurement Trends

Technical Measurement Trends	
Information Need Description	
Information Need	Understand the risk, progress, and projections regarding a system element or system of interest achieving the critical technical performance requirements.
Information Category	Technology Effectiveness • Technology Suitability and Volatility Product Quality • All categories
Measurable Concept and Leading Insight	
Measurable Concept	To what extent are the performance parameters feasible and being achieved per plan?
Leading Insight Provided	Indicates whether the product performance is likely to meet the needs of the user. • Project the probable performance of a selected technical parameter over a period of time • Project the probable achievement of system balance Indicates feasibility of alternatives and impact of potential technical decisions. • Assessments of the program impact for proposed change alternatives Provides insight into whether the system definition and implementation are acceptably progressing. • Early detection or prediction of problems requiring management attention • Allows early action to be taken to address potential performance shortfalls. Where little or no negative margin exists, they provide insight into where potential trades between performance parameters or cost. Where positive margin exists, they provide a means for identifying early on where requirement flow-down may be missing or an opportunity for trades to reduce risks exists.
Base Measure Specification	
Base Measures	Specific base measures are dependent on the MOE/MOP/TPM; general base measures are: 1. Planned Values of Technical Measure (at each time interval or milestone) 2. Actual Values of Technical Measure (at each time interval or milestone) 3. Priority (e.g., critical, major, minor or High, medium, low)
Measurement Methods	1. Record planned values of the MOE/MOP/TPM 2. Record actual values of the MOE/MOP/TPM 3. Count the number of requirements for each priority
Unit of Measurement	Depends on MOE/MOP/TPM - measured values (e.g., miles, pounds, watts, MTBF, etc.)
Entities and Attributes	
Relevant Entities	• Technical Requirements
Attributes	• Time interval (e.g., monthly, quarterly, phase), • Other attributes are dependent on the MOEs/MOPs/TPMs chosen.

Technical Measurement Trends	
Derived Measure Specification	
Derived Measure	1. Delta performance (planned vs actual) 2. Delta performance to meeting thresholds and objectives
Measurement Function	1. Delta performance = Planned performance – Actual performance 2. Delta performance = Threshold performance – Actual performance
Indicator Specification	
Indicator Description and Sample **See 3.13**	Trends graphs/charts of MOEs (or KPPs), MOPs, TPMs, and margins. Graphical representation will be dependent on the specific MOE/MOP/TPM chosen.
Thresholds and Outliers	Organization and/or contract dependent.
Decision Criteria	Investigate and, potentially, take corrective action when the values of the MOEs/MOPs/TPMs exceed the tolerance bands (e.g., acceptable risk range) <fill in MOE/MOP/TPM specific tolerance band values> or a trend is observed per established guidelines <fill in specific details>.
Indicator Interpretation	• Indicates whether the product performance is likely to meet the needs of the user. • Indicates feasibility of alternatives and impact of potential technical decisions. • Provides insight into whether the system definition and implementation are acceptably progressing. Allows early action to be taken to address potential performance shortfalls. • Where little or no negative margin exists, they provide insight into where potential trades between performance parameters or cost. • Where positive margin exists, they provide a means for identifying early on where requirement flow-down may be missing or an opportunity for trades to reduce risks exists.
Additional Information	
Related Processes	Technical Risk, Requirements Analysis, Modeling, Design and Integration
Assumptions	MOE/MOP/TPM measurement records are maintained & current. This includes accurate and current measured values from analysis, prototype, and test.
Additional Analysis Guidance	See Technical Measurement Guide (PSM, INCOSE)
Implementation Considerations	• It is useful to understand the MOE/MOP/TPM sensitivity to changes in other parameters. • Solid Systems Engineering Foundation - Staff, Requirements Analysis, Architecture, Implementation, Integration, Verification, Facilities.
User Of The Data	• Chief Systems Engineer • Product Manager • Quality Assurance Manager
Data Collection Procedures	• See Appendix A
Data Analysis Procedures	• See Appendix A

5. REFERENCES

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Guidance for the Use of Robust Engineering in Air Force Acquisition Programs, Air Force Center for Systems Engineering, January 2004, http://cse.afit.edu

ISO/IEC 15939, **Software Engineering - Software Measurement Process**, ISO 2002

Measurement Primer, International Council on Systems Engineering (www.incose.org)

PSM Guide V4.0b, ***Practical Software and Systems Measurement***, Department of Defense and US Army, October 2000

APPENDIX A

The following information is very organization or project dependent and will not be defined in this guidance. It is provided in this one indicator (Requirements Growth) as an example only. The organization or project measurement plans should include this information following the guidance of PSM.

Data Collection Procedure (for each Base Measure) ***Complete this section for each base measure listed in each measurement information specification***	
Frequency of Data Collection	Collect at least monthly; more frequently during peak activity periods. Do not sample - collect all reqts data.
Responsible Individual	Measurement Analyst, Requirements Manager, CM Manager
Activity in which Collected	From concept and system definition through system deployment
Potential Sources of Data	Reqts DB, Change Board records, defect data
Typical Tools Used in Data Collection	Requirement DB, Configuration Mgt DB
Verification and Validation	Check data against CM records.
Repository for Collected Data	User defined.

Data Analysis Procedure (for each Indicator)	
Frequency of Data Reporting	Biweekly to monthly, depending on the level of activity
Responsible Individual	Measurement Analyst
Activity in which Analyzed	From concept and system definition through system deployment
Source of Data for Analysis	Reqts DB, Change Board records, defect data
Tools Used in Analysis	Spreadsheet, statistical analysis, measurement analysis
Review, Report, or User	Chief SE, Product Mgr.

APPENDIX B - Acronyms

AoA	Analysis of Alternatives
AMA	Analysis of Material Approachs
CDR	Critical Design Review
ICD	Initial Capabilities Document
INCOSE	International Council on Systems Engineering
KPP	Key Performance Parameter
LAI	Lean Aerospace Initiative
MOE	Measure of Effectiveness
MOP	Measure of Performance
PDR	Preliminary Design Review
PSM	Practical Software & Systems Measurement
RFC	Request for Change
SE	Systems Engineering
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Plan
SRR	System Requirements Review
SSCI	Systems and Software Consortium Incorporated
TBD	To Be Determine
TBR	To Be Resolved
TPM	Technical Performance Measure (ment)
V&V	Verification & Validation