Practical Software and Systems Measurement

A foundation for objective project management

Systems Engineering Leading Indicators Workshop

15 July 2008

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Objectives of this session

- Share background and latest results from academia/industry/ government collaboration on leading indicators for systems engineering programmatic and technical performance
- Kick-off and prioritize efforts to enhance/revise the SE Leading Indicators Guide
  - Additional indicators
  - Incorporate lessons learned and feedback for definitions, guidance and implementation
- Determine other support needed and get actions in place to address (e.g., Training)
- This is not intended to be a tutorial of the set of indicators

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Systems Engineering Leading Indicators Project

"SE Leading Indicators Action Team" formed under Lean Aerospace Initiative (LAI) Consortium in support of Air Force SE Revitalization

The team is comprised of engineering measurement experts from industry, government and academia, involving a collaborative partnership with INCOSE, PSM, and SSCI

- Co-Leads: Garry Roedler, Lockheed Martin & Donna Rhodes, MIT ESD/LAI Research Group
- Leading SE and measurement experts from LAI member companies, INCOSE and PSM 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.

PSM (Practice Software and Systems Measurement) has developed foundational work on measurements under government funding; this effort uses the formats developed by PSM for documenting the leading indicators

A Collaborative Industry Effort

LAI LEAN AEROSPACE INITIATIVE

INCOSE International Council on Systems Engineering

LOCKHEED MARTIN

NORTHROP GRUMMAN DEFINING THE FUTURE

Raytheon

BOEING

PSM

BAE SYSTEMS

SEARI Systems Engineering Advancement Research Initiative

Objectives of the project

1. Gain common understanding of DoD needs and drivers of this initiative – yet be in tune to industry needs
2. Identify information needs underlying the application of SE effectiveness
   – Address SE effectiveness and key systems attributes for systems, SoS, and complex enterprises, such as robustness, flexibility, and architectural integrity
3. Identify set of leading indicators for systems engineering effectiveness
4. Define and document measurable constructs for highest priority indicators
   – Includes base and derived measures needed to support each indicator, attributes, and interpretation guidance
5. Identify challenges for implementation of each indicator and recommendations for managing implementation
6. Establish recommendations for piloting and validating the new indicators before broad use

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Define Systems Engineering

- INCOSE Definition:
  – An interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then then proceeding with design synthesis and system validation while considering the complete problem.
- "Big Picture" perspective
- Includes
  – System Definition (mission/operational requirements, system requirements, architectural design)
  – Interfaces and interactions
  – Engineering management
  – Analysis, simulation, modeling, prototyping
  – Integration, verification, and validation
- Standards that focus on SE activities and tasks
  – ISO/IEC 15288, System Life Cycle Processes
  – EIA 632, Engineering of a System
  – IEEE Std 1220, Application and Mgt of the SE Process

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SE Leading Indicator Definition

- A measure for evaluating the effectiveness of a how a specific SE activity is applied on a program in a manner that provides information about impacts that are likely to affect the system performance objectives
  - An individual measure or collection of measures that are *predictive of future system performance*
    - Predictive information (e.g., a trend) is provided before the performance is adversely impacted
  - Measures factors that *may impact the system engineering performance*, not just measure the system performance itself
  - Aids leadership by providing insight to take actions regarding:
    - Assessment of process effectiveness and impacts
    - Necessary interventions and actions to avoid rework and wasted effort
    - Delivering value to customers and end users

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Problem Addressed By Leading Indicators

- Leading indicators provide insight into potential future states to allow management to take action before problems are realized
- Many leading indicators cover management aspects of program execution (e.g., earned value, etc.)
- Until this work, leading indicators for SE activities have been missing

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Difference from Conventional SE Measures

- Conventional measures provide status and historical information
  - Provide a snapshot of "where the activity has been"
- Leading indicators draw on trend information to allow for predictive analysis (forward looking)
  - Trend analysis allows *predictions of the outcomes of certain "downstream" activities*
  - Trends are analyzed for *insight into both the entity being measured and potential impacts to other entities* (interactions)
  - Decision makers have the data to make *informed decisions* and where necessary, take preventative or corrective action in a proactive manner
  - 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***

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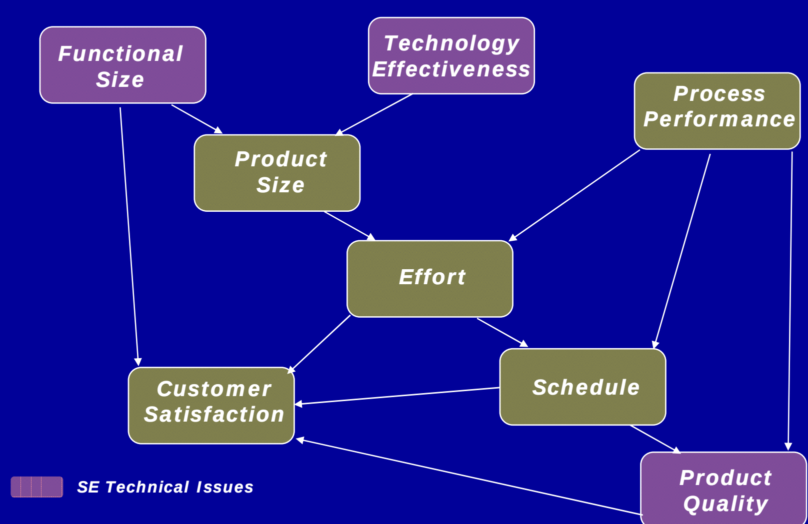
Interactions Among Factors



Adapted from J. McGarry, D.Card, et al., *Practical Software Measurement*, Addison Wesley, 2002

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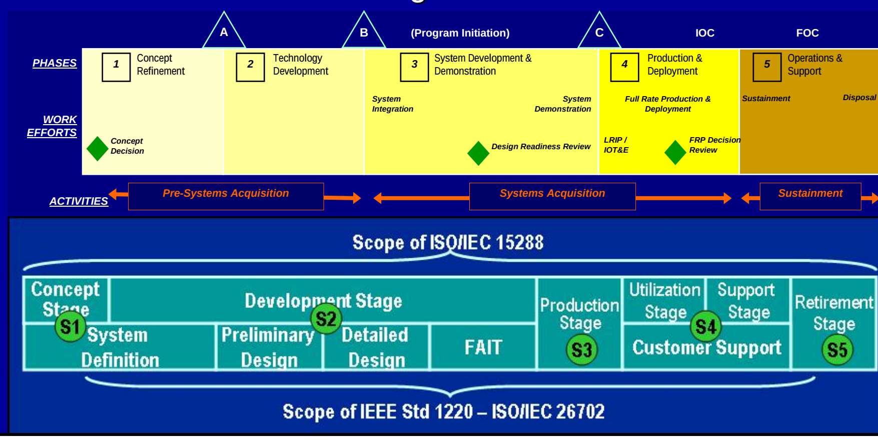
Application Across the Life Cycle

- Intended to provide insight into key systems engineering activities on a *defense program*, across the phases
- Also can be suitable to *commercial endeavors*
- Table 1 in the document identifies the applicable phases for each candidate leading indicator



Criteria of Leading Indicators

- Early in activity flow
- In-process data collection
- In time to make decisions
  - Actionable
  - Key decisions
- Objective
- Insight into goals / obstacles
- Able to provide regular feedback
- Can support defined checkpoints
  - Technical reviews, etc.
- Confidence
  - Quantitative (Statistical)
  - Qualitative
- Can clearly/objectively define decision criteria for interpretation
  - Thresholds
- Tailorable or universal

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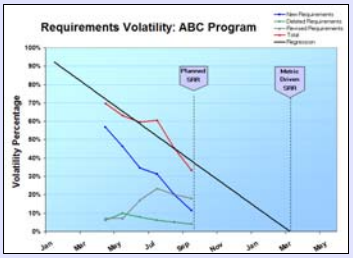
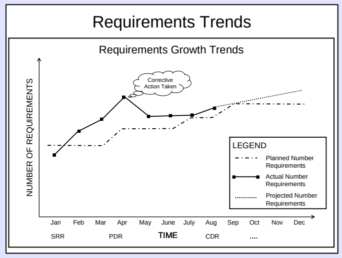
Systems Engineering Leading Indicators

- Thirteen leading indicators defined by SE measurement experts
- Developed by a working group sponsored by Lean Aerospace Initiative (LAI) collaboratively with INCOSE, PSM, and SEARI
  - Supported by 5 leading defense companies and 3 DoD services
- Beta guide released December 2005; pilot programs conducted in 2006; Version 1.0 released in June 2007
- Additional leading indicators being defined for future update
- Several companies tailoring the guide for internal use

Objective: Develop a set of SE Leading Indicators to assess if program is performing SE effectively, and to enhance proactive decision making





List of Indicators

- Requirements Trends (growth; correct and complete)
- System Definition Change Backlog Trends (cycle time, growth)
- Interface Trends (growth; correct and complete)
- Requirements Validation Rate Trends (at each level of development)
- Requirements Verification Trends (at each level of development)
- Work Product Approval Trends
  - Internal Approval (approval by program review authority)
  - External Approval (approval by the customer review authority)
- Review Action Closure Trends (plan vs actual for closure of actions over time)
- Technology Maturity Trends (planned vs actual over time)
  - New Technology (applicability to programs)
  - Older Technology (obsolesence)
- Risk Exposure Trends (planned vs, actual over time)
- Risk Handling Trends (plan vs, actual for closure of actions over time)
- SE Staffing and Skills Trends: # of SE staff per staffing plan (level or skill - planned vs. actual)
- Process Compliance Trends
- Technical Measurement Trends: MOEs (or KPPs), MOPs, TPMs, and margins

Current set has 13 Leading Indicators

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Fields of Information Collected for Each Indicator

- Information Need/Category
- Measurable Concept
- Leading Information Description
- Base Measures Specification
  - Base Measures Description
  - Measurement Methods
  - Units of Measure
- Entities and Attributes
  - Relevant Entities (being measured)
  - Attributes (of the entities)
- Derived Measures Specification
  - Derived Measures Description
  - Measurement Function
- Indicator Specification
  - Indicator Description and Sample
  - Thresholds and Outliers
  - Decision Criteria
  - Indicator Interpretation
- Additional Information
  - Related SE Processes
  - Assumptions
  - Additional Analysis Guidance
  - Implementation Considerations
  - User of the Information
  - Data Collection Procedure
  - Data Analysis Procedure

Derived from measurement guidance of PSM and ISO/IEC 15939, Measurement Process

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Indicator's Usefulness for Gaining Insight to the Effectiveness of Systems Engineering (1 of 3)

Indicator	Critical	Very Useful	Somewhat Useful	Limited Usefulness	Not Useful	Usefulness Rating *
Requirements Trends	24%	35%	11%	3%	3%	4.1
System Definition Change Backlog Trend	7	11	7	3	1	3.9
Interface Trends	14	12	4	0	1	4.3
Requirements Validation Trends	22	16	4	0	1	4.4
Requirements Verification Trends	37	23	6	2	1	4.4
Work Product Approval Trends	7	19	21	2	0	3.9
Review Action Closure Trends	5	33	21	5	0	3.9
Risk Exposure Trends	14	37	6	1	0	4.3
Risk Handling Trends	6	25	11	1	0	4.1
Technology Maturity Trends	6	6	7	0	0	4.1
Technical Measurement Trends	21	27	6	0	0	4.4
Systems Engineering Staffing & Skills Trends	11	27	15	0	0	4.2
Process Compliance Trends	6	14	11	1	0	4.0

** Defined on the Slide . Somewhat Useful Very Useful*

Percentages shown are based on total survey responses. Not all indicator responses total to 100% due to round-off error or the fact that individual surveys did not include responses for every question.

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Indicator's Usefulness for Gaining Insight to the Effectiveness of Systems Engineering (2 of 3)

- Usefulness Ratings defined via the following guidelines:
  - 4.6-5.0 = Critical: Crucial in determining the effectiveness of Systems Engineering
  - 4.0-4.5 = Very Useful: Frequent insight and/or is very useful for determining the effectiveness of Systems Engineering
  - 3.0-3.9 = Somewhat Useful: Occasional insight into the effectiveness of Systems Engineering
  - 2.0-2.9 = Limited Usefulness: Limited insight into the effectiveness of Systems Engineering
  - Less than 2.0 = Not Useful: No insight into the effectiveness of Systems Engineering

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Looking Forward – What Next?

The following charts include ideas for further work to support and enhance the guide and implementation.

Includes results from SE LI Workshop at PSM Users Group Conference and from presentation at GEIA Engineering and Technical Management Conference

Your insights and opinions are needed!

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SE Leading Indicator Definition

- **Questions were raised about the focus of the definition**
  - **System Process vs. System Performance**
  - **Is this a valid concern?**
- A measure for evaluating the effectiveness of a how a specific SE activity is applied on a program in a manner that provides information about impacts that are likely to affect the system performance objectives
  - An individual measure or collection of measures that are *predictive of future system performance*
    - Predictive information (e.g., a trend) is provided before the performance is adversely impacted
  - Measures factors that *may impact the system engineering performance*, not just measure the system performance itself
  - Aids leadership by providing insight to take actions regarding:
    - Assessment of process effectiveness and impacts
    - Necessary interventions and actions to avoid rework and wasted effort
    - Delivering value to customers and end users

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Guide Contents

1. About This Document
2. Executive Summary
   - Includes Table 1 with overview of indicators and mapping to life cycle phases/stages
3. Leading Indicators Descriptions
   - Includes a brief narrative description of each indicator, description of the leading information provided and example graphics
4. Information Measurement Specifications
   - Detailed definitions of each indicators, including all fields of information

SYSTEMS ENGINEERING
LEADING INDICATORS
GUIDE

Adobe Acrobat 7.0 Document

Version 1.0

June 15, 2007

Supersedes Beta Release, December 2005

Some feedback indicates that the separation of the information in Sections 3 and 4 makes it harder to use.

INCOSE Technical Product Number: INCOSE-TP-2005-001-02

<http://www.incose.org/ProductsPubs/products/seleadingIndicators.aspx>

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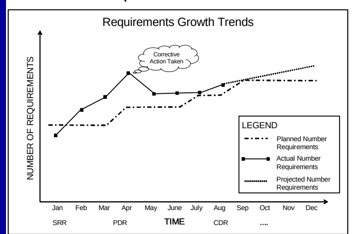
Example of Section 3 Contents

3.1. Requirements Trends

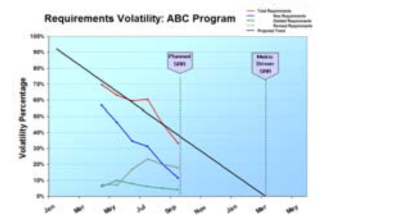
This indicator is used to evaluate the trends in the growth, change, completeness and correctness of the definition of the system requirements. This indicator provides insight into the rate of maturity of the system definition against the plan. Additionally, it characterizes the stability and completeness 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.

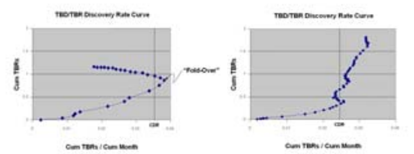
Requirements Trends



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.



Requirements Volatility. The graph illustrates the rate of change of requirements over time. It also provides a profile of the types of change (new, deleted, or revised) which allows root-cause analysis of the change drivers. By monitoring the requirements volatility trend, the program team is able to predict the readiness for the System Requirements Review (SRR) milestone. In this example, the program team initially selected a calendar date to conduct the SRR, but in subsequent planning made the decision to have the SRR be event driven, resulting in a new date for the review wherein there could be a successful review outcome.



TBD/TBR Discovery Rate. The graphs show the cumulative requirement TBDs/TBRs vs. the ratio of cumulative TBDs/TBRs over cumulative time. The plot provides an indication of the convergence and stability of the TBDs/TBRs over the life cycle of the project. The graph on the left shows a desirable trend of requirement TBD/TBR stability; as the ratio of decreases and the cumulative number of TBDs/TBRs approaches a constant level. This "fold-over" pattern is the desirable trend to look for, especially in the later stages of project life cycle. In contrast, the graph on the right shows an increasing number of TBDs/TBRs even as the program approaches later stages of its life cycle; this is a worrisome trend in system design stability. An advantage of this plot is that, by shape of the graph (without having to read

Graphics are for illustrative purposes only – may reflect a single aspect of the indicator.

Example of Section 4 Contents

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. • Indicates schedule and cost risks. • Greater requirements growth, changes, or impacts than planned or lower closure rate of TBDs/TBRs than planned indicate these risks. • May indicate future need for different level or type of resources/skills.
Base Measure Specification	
Base Measures	1. # Requirements 2. # Requirement TBDs/TBRs (by selected categories: interval, milestone) 3. # Requirement defects (by selected categories; e.g., type, cause, severity) 4. # Requirements changes (by selected categories; e.g., type, cause) 5. Impact of each requirement change (in estimated effort hours or range of hours) 6. 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 per category 4. Count the number of requirements changes per category 5. Estimate the effort hours or range of effort hours expected for each change. 6. Record from actual dates & times of requirements complete in the CM system
Unit of Measurement	1. Requirements 2. TBDs/TBRs 3. Defects 4. Changes 5. Effort Hours 6. Date and Time (Hours, Minutes)
Entities and Attributes	
Relevant Entities	• Requirements
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 closure variance per plan 4. % Requirements Modified 5. Estimated Impact of Requirements Changes for time interval (in Effort hours) 6. Defect profile 7. Defect density 8. Defect leakage (or escapes) 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 defect categorization 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 (by types, causes, severity, etc.) 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>.

Example of Section 4 Contents (Cont'd)

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).
	• Care should be taken that the organization does not create incentives driving perceptions that all requirements change is undesirable. Note: Requirements changes may be necessary to accommodate new functionality.
	• Review of this indicator can help determine the adequacy of:
	  o Quantity and quality of Systems Engineers
	  o Infrastructure
	  o Process maturity (acquirer and supplier)
	  o Interface design capability
	  o Stakeholder collaboration across life cycle
	Funding by customer; financial challenge by the program management

Additional Information	
Related Processes	Stakeholder Requirements, Requirements Analysis, Architectural Design
Assumptions	Requirements Database, Change Control records, and defect records are maintained & current.
Additional Analysis Guidance	• May also be helpful to track trends based on severity/priority of changes • Defect leakage - identify the phases in which defect was inserted and found for each defect recorded.

Implementation Considerations	• Requirements that are not at least at the point of a draft baseline should not be counted.
	• Usage is driven by the correctness and stability of interfaces definition and design.
	  o Lower stability means higher risk of impact to other activities and other phases, thus requiring more frequent review.
	  o Applies throughout the life cycle, based on risk.
	  o Track this information per baseline version to track the maturity of the baseline as the system definition evolves.

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

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PSM Information Need Categories

- Schedule and Progress
- Resources and Cost
- Product Size and Stability
- Product Quality
- Process Performance
- Technology Effectiveness
- Customer Satisfaction

- Most information needs roll up into one of these categories
- These aid identification of more specific information needs of the program or business
- Can help to identify other valuable SE Leading Indicators

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ISO/IEC 15288: 2008*

- Primary question: Are there information needs specific to other technical processes that need to be included?
- We need to look at the PSM information categories for these processes.

* ISO/IEC 15288:2008 is a revision that was published in FEB 2008.

Technical
Stakeholder Reqts Definition Process
Requirements Analysis Process
Architectural Design Process
Implementation Process
Integration Process
Verification Process
Transition Process
Validation Process
Operation Process
Maintenance Process
Disposal Process

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Looking at Additional Information Needs and Questions

Information Need	***Measurable Concept (Question)***	***Candidate Indicator***
Product Quality of Work Products	Is the level of rework acceptable?	Rework trends per work product type (include attributes of causes)
Functional /Product Size (Scope/ Completeness)	Is the architecture complete WRT the problem statement?	Trends of Known Unknowns and Unknown Unknowns
Product Quality WRT to Requirements	Does the system architecture and functionality cover all requirements adequately?	Trends of requirements mapping to architecture and test
Functional Size/Stability	Are the capabilities for the enterprise understood?	Capabilities definition trends
Stakeholder/Team Involvement	Is the level of involvement adequate to effectively ensure customer satisfaction?	??

Other Indicators for Consideration? - 1

- Looked at some indicators to consider in future
  - Need further analysis to relate to key information needs & prioritize
- Additional indicators considered (Viewed as useful)
  - Concept Development (?)
    - Need an indicator to provide feedback very early in life cycle
  - SoS Capabilities Trends
    - Similar to Requirements Trends
    - Could provide insight early in the life cycle
  - Architecture Trends
    - Similar to Requirements Trends
  - Algorithm Trends and Scenario Trends
    - Similar to Requirements Trends
    - Addresses remaining system size drivers used in COSYSMO
  - Baseline Management
    - May be a derived indicator from change trends, requirements trends, and/or interface trends
  - Complexity Change Trends (e.g., system, organization, etc.)
    - Changes in complexity that could impact cost, schedule, quality
  - Resource Volatility
    - Amount of change in the resources required to support SE
    - May be in place of SE Skills or as a supplement

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Other Indicators for Consideration? - 2

- Additional indicators considered (Viewed as less useful)
  - SE Product Quality
    - Quality of the system definition products and other products
    - Already have TPMs and Approval Trends for quality
    - May not be able to define indicator that is leading
  - Team Cohesion
    - Important to understand, but difficult to be objective or leading
  - Stakeholder Participation
    - Important to understand, but difficult to be objective or leading
  - Overarching SE Effectiveness Index (summarizing the SE LIs)
    - Concern about potential masking and temptation to make decisions from a single number
  - SE Productivity
    - Low utility other than historical
    - Productivity measures often are biased or misused

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Recent SE Measurement Survey Results

- Survey conducted by Don Reifer across industry
- Included questions about the SE Leading Indicators
- Identified the following:
  - Deficient in the area of systems test.
    - Measures establishing trends relative to systems test completeness, systems test coverage and defect/error trends need to be added to increase their usefulness.
    - Test completeness can be measured in terms of the performance threads that originate in the operational concepts document, get tied to requirements via scenarios, and terminate when the scenarios are automated and accepted as part of systems testing.
    - Test completeness measures relate to ensuring requirements are satisfied in operational settings where deployment considerations are accounted for and baselines are established.
  - Other areas of need:
    - Deploying operational concepts.
    - End-measures for systems deployment.
    - SE Productivity
      - Most notable need that the community surveyed agreed upon
      - Benchmarks to compare organizational performance against

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Priorities for the Revision

- New indicators

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Potential Future Matrices to Include

- Consider Matrices for:
  - Cost-effective sets of Base Measures that support greatest number of indicators
    - Strong utility
    - Not likely to be a one-size-fits-all
      - May differ by type of program (requiring multiple tables)
  - Indicators vs. Program Profile
    - Attributes should include size, customer type, contract type, application type (e.g., R&D, development, O&M, service mgt)
  - Indicators vs. SE Activities
    - Most valuable at process level (use ISO/IEC 15288)
    - Concern about making too large if lower level
  - Insight provided from indicators per phase
    - Can provide some insight, but somewhat covered by table in section 1 of guide
    - Would need to cover some other aspect for value (see concept on next chart)
- SoS Appendix explaining how to use the indicators for SoS (including an example)

Concept for Mapping SE Leading Indicators

DoD 5000 PHASE / ISO 15288 STAGE	CONCEPT DEVELOPMENT (R&D) ??		CONCEPT REFINEMENT / TECH DEVELOPMENT ??		SYSTEM DEVELOPMENT & DEMONSTRATION ??		PRODUCTION & DEPLOYMENT ??		OPERATIONS & SUPPORT ??	
INDICATOR \ APPLICATION	System	SoS / Architecture / Enterprise	System	SoS / Architecture / Enterprise	System	SoS / Architecture / Enterprise	System	SoS / Architecture / Enterprise	System	SoS / Architecture / Enterprise
REQUIREMENTS DEFINITION										
(growth, correctness/completeness)										
SYSTEM DEFINITION CHANGE RATE	0	0	1	2	3	3	3	2	1	3
REQUIREMENTS VALIDATION										
REQUIREMENTS VERIFICATION										
INTERFACE DEFINITION internal										
external										
REVIEW ACTION CLOSURES	0	1	2	2	3	2	3	2	1	1
APPROVALS internal										
external (customer)	0	1	1	1	3	3				
TECHNOLOGY MATURATION new	2	2	3	3	3	3				
old (obsolescence)					2	2				
RISK EXPOSURE	0	1	1	2	3	3	3	3	3	3
RISK HANDLING										
STAFFING / WORK EFFORT headcount										
work package completion					3	1	3	1	1	1
PROCESS COMPLIANCE	0	0	1	1	2	1	1	1	1	2
TECHNICAL MEASURES	1	1	2	2	3	3	3	3	2	3

Table entries:
0 - not applicable
1 - low
2 - nominal
3 - high

current values are notional

- Concept resulting from workshop at PSM User Conference
- Map SE Leading Indicators:
  - To DoD 5000 phases and ISO/IEC 15288 stages
  - For Systems and SoS/Enterprise
  - Show level of applicability

Priorities for the Revision

- Matrices to show specific relationships

1.
2.
3.

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SE Leading Indicator Training

- Need to develop accompanying training that can be provided by user organizations
  - 1-hour introduction to brief program and business management teams
    - Provide understanding of:
      - What SE Leading Indicators are
      - Utility provided SE Leading Indicators
      - Resources needed to implement
  - 4-6 hour tutorial
    - Practitioner is the audience
    - Not a general measurement tutorial
    - Focus on:
      - Selecting the right SE Leading Indicators
      - How to obtain “leading insight” rather than “lagging insight”
      - Detailed discussion of each of the indicators in the guide
      - Short exercises

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Other Ideas/Needs Raised

- Consider effects of external influences on the system in appropriate indicators
  - Requirements/architecture changes are often driven by external interfaces
- Revise the definition of SE Leading Indicators to focus more on SE *Process* performance than system performance
  - Understand that there is a relationship
- Need to analyze extensibility to SoS and consider adding appropriate guidance to indicators in Additional Analysis or Interpretation sections
- Include both Thresholds and Targets
  - May be within threshold, but still not meeting target
  - Adds another level of insight
  - However, targets often depend on mgt objectives more than process capability
- Develop an version of the PSM Analysis Model that is specific to the SE Leading Indicators – could be a useful tool
- Need to expand the set of indicators and/or their specifications to better address Concept, Operations, and Support phases
  - Currently have more focus on development phase

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Priorities for the Revision

- Other changes

1.
2.
3.
4.

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Support for the Revision?

- Interested team members and role? (contributor or reviewer)
  - Garry Roedler (LMC)
  - Donna Rhodes (MIT)
  - Howard Schimmoller (LMC)
  - Cheryl Jones (PSM)
  - Ricardo Valerdi (MIT)
  - Greg Niemann (LMC)
  - Ron Carson (Boeing)
  - Jim Stubbe (Raytheon)
  - Gan Wang (BAE Systems)
  - John Rieff (Raytheon)
  - Paul Frenz (GD)
  - Tom Huyhn (NPG)

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Team rhythm and operations

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QUESTIONS?

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Back-up Charts

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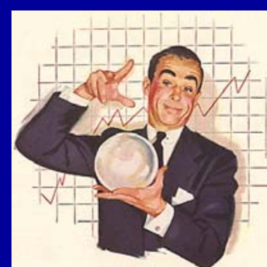
SE Effectiveness

- A few questions to think about:
  - Do you perform Systems Engineering (SE), SoS SE, or SW SE to any extent?
  - Are those SE activities effective?
  - How do you know?

We need leading indicators to provide the necessary insight to proactively manage SE



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Growing Interest in SE Effectiveness

- Questions about the effectiveness of the SE processes and activities are being asked
  - DoD
  - INCOSE
  - Others
- Key activities and events have stimulated interest
  - DoD SE Revitalization
  - AF Workshop on System Robustness
    - Questions raised included:
      - ***How do we show the value of Systems Engineering?***
      - ***How do you know if a program is doing good systems engineering?***
    - Sessions included SE Effectiveness measures and Criteria for Evaluating the Goodness of Systems Engineering on a Program

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Informed Decision Making

Popular Practice

"Informed decision-making comes from a long tradition of guessing and then blaming others for inadequate results" Scott Adams

Best Practice

"Measurement can help recognize the 'best' course of action available...and assist in making predictions about likely program outcomes given different scenarios and actions" Practical Software and Systems Measurement (PSM)

"Without the right information, you're just another person with an option" Tracy O-Rourke, Allen-Bradley

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Measurement is Used To...

Characterize

Gain understanding of processes, products, resources, and environments

Evaluate

Determine status with respect to plans

Predict

Support planning, prepare new proposals, and anticipate issues

Control

Support decisions to implement control action

Improve

Identify root causes, deficiencies, inefficiencies, and opportunities for improvement

It is not enough to use measurement for characterization and evaluation

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Sources for Defining and Prioritizing Information Needs

- Risk Analysis Results
- Project Constraints and Objectives
- Leveraged Technologies
- Product Acceptance Criteria
- External Requirements
- Experience
- Planned-Decision Points

X

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Systems Engineering Leading Indicators Application to Life Cycle Phases/Stages

Table 1 - SYSTEMS ENGINEERING LEADING INDICATORS OVERVIEW

Leading Indicator	Insight Provided	Phases / Stages									
		P 1	P 2	P 3	P 4	P 5	S 1	S 2	S 3	S 4	S 5
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.	•	•	•	•	•	•	•	•	•	•

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Applying SE Leading Indicators

- Integrate into the organizational and program measurement plans
- Plan and perform using current PSM/CMMI compliant process
- Leading indicators involve use of empirical data to set planned targets and thresholds
  - Apply applicable quantitative management methods
  - If this data is not available, expert judgment may be used as a proxy until baseline data can be collected
  - Expert judgment is not a long term solution for measurement projections
- Evaluate effectiveness of the measures per PSM

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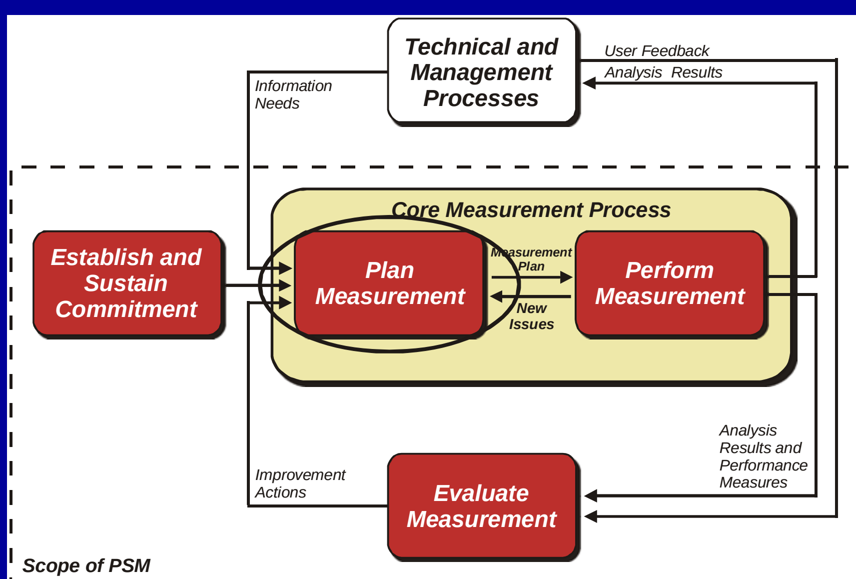
PSM Measurement Process



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Validation and Input for Release Version

- First issued as Beta version (Dec 2005)
- Pilots
  - Pilots in various companies
- Workshops
  - PSM
  - MIT
- Surveys (feedback from over 100 respondents)
  - LMC
  - INCOSE
- Feedback during briefings to key organizations and forums

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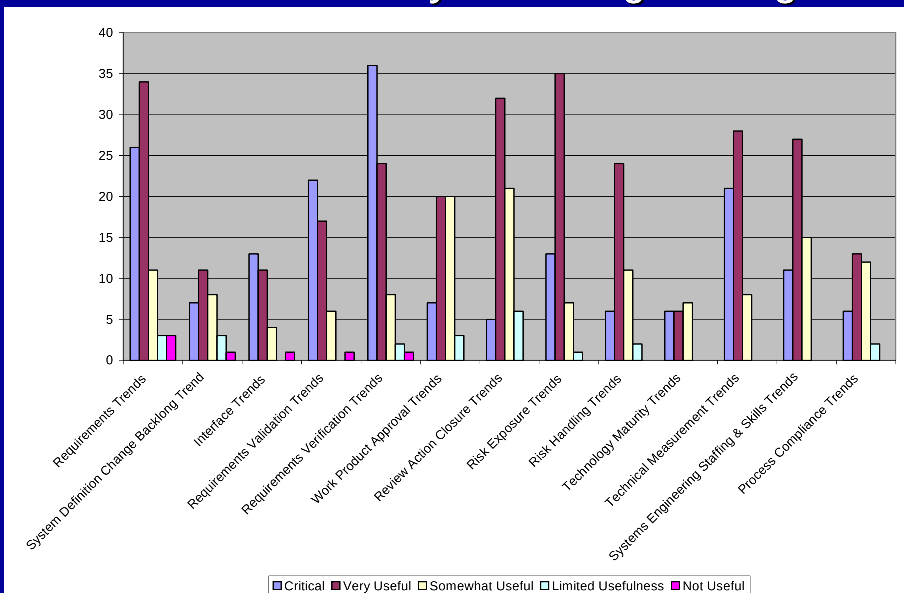
Indicator's Usefulness for Gaining Insight to the Effectiveness of Systems Engineering (3 of 3)



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- Brad Clark

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