SE Effectiveness Leading Indicators Project

Description, Objectives, and Status

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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?

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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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Description of Initiative

Initiative

•Leading Indicators for Evaluating Goodness of Systems Engineering on a Program

Program leaders evaluating whether their programs are doing good systems engineering need to have access to a set of leading indicators. Today, we have **many good leading indicators for the programmatic aspects of engineering, but lack good leading indicators of the more engineering aspects of a program.**

Action Plan

A "Leading Indicators Action Team" has been formed, comprised of experts on engineering measures and measurement processes. Some leading indicators are included in the AF Guide on Engineering for Robustness; this team will develop and propose an expanded set of leading indicators for systems engineering. The leading indicators should be piloted and validated through several studies before broad use.

Action Team Structure

Collaborative team under the oversight of LAI, including DoD, INCOSE, PSM, SSCI, and industry.

Deliverable

Recommendations for Leading Indicators for Systems Engineering, Version 1.0

Additional Recommendations: Using the action team's recommendations, the Air Force should establish **pilot programs for these leading indicators to validate and assess usefulness to leadership in government and industry**. Based on results of pilot programs, the leading indictors need to be adjusted as required and recommendations developed regarding which leading indicators are most effective for particular types of programs.

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Objectives

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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SE Effectiveness Leading Indicator Definition

- A measure for Evaluating Goodness of Systems Engineering on a Program in a manner that it *provides information about impacts that are likely to affect the system performance objectives*
- An individual measure or collection of measures that may be 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

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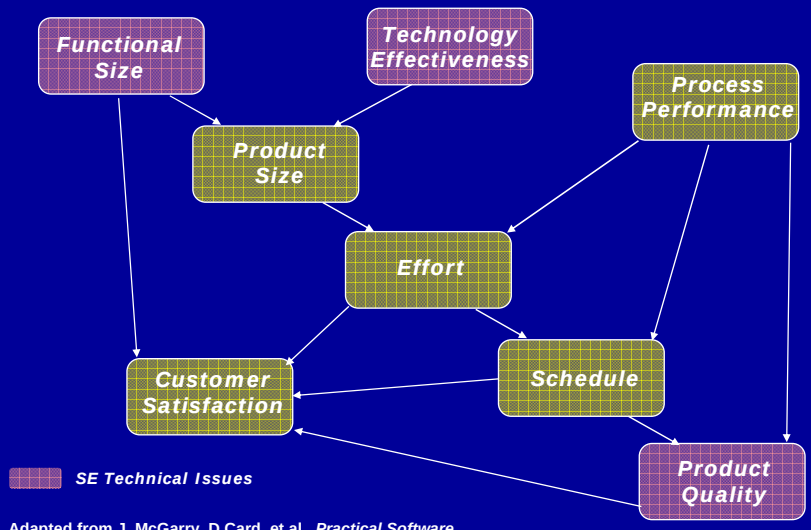
Interactions Among Factors



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

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Action Team Participants

- Donna Rhodes, MIT – Co-Lead *
- Garry Roedler, LMC – Co-Lead *
- Dave Card, SSCI – Workshop Facilitator
- Mark Wilson, Air Force
- Danny Abbott, Air Force
- Jeff Loren, Air Force
- Mike Ucchino, Air Force *
- Michael Winter, LAI, Pratt & Whitney
- Bill Miller, Stevens Institute
- Paul Robitaille, LMC *
- Lori Pajerek, LMC
- Sarah Sheard, SSCI *
- Chris Miller, SSCI *
- John Rieff, Raytheon *
- Sheree Havlik, Raytheon
- Rick Nuepert, Boeing *
- Mark Mithers, Northrop Grumman *
- Cheryl Jones, PSM Project Manager **
- Ricardo Valerdi, MIT/LAI **

• Team spans defense and aerospace leaders, as well as Air Force and academia
• The results should be applicable to all SE

**** Sub-team working on defining the indicators***
***** Recently added to the team***

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Approach for Identifying and Defining the Candidate Indicators

- Collaborative project established under lead of Lean Aerospace Initiative
  - Other participants include PSM, SSCI, AF, and industry
  - Discussing cooperation with NDIA
- Workshop held in August 2004 to identify the information needs and an initial list of candidate indicators
- Smaller team formed to define the indicators
  - Periodic meetings; both face-to-face and telecons
  - Used ISO/IEC 15939 or PSM Information Model for defining the indicators
  - Completed initial draft of 12 indicators in June 2005 and distributed to a larger group for preliminary review
    - Indicator examples to be added after initial feedback
  - Will provide for wide review after comment incorporation and addition of example graphs, tables, etc.
- Will present and work during PSM User Conference in July
- Follow-on workshop being set up by LAI at MIT in SEP
- Expect release Beta version for usage in the OCT timeframe
  - Product will be available through LAI, INCOSE, and PSM

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List of Indicators

- Requirements Trends (growth; correct and complete)
- System Definition Change Backlog Trends (cycle time, growth)
- Interface Trends (correct and complete)
- Trends of Requirements Validation Rate (at each level of development)
- Approval Trends
  - Internal Approval (approval by program review authority)
  - External Approval (approval by the customer review authority)
- Design Review Action Item Closure (plan vs actual for closure of actions over time)

Current set has 13 leading Indicators

- Technology Maturity Trend (planned vs actual over time)
  - New Technology (applicability to programs)
  - Older Technology (obsolesence)
- Risk exposure trends (planned vs, actual over time)
- Risk handling action trends (plan vs, actual for closure of actions over time)
- Effort Indicator: % SE effort through the life cycle (planned vs. actual)
- Staffing Indicator: # of SE staff per staffing plan (level or skill - planned vs. actual)
- Process compliance though the life cycle
- Trends of Technical Measures: MOEs (or KPPs), MOPs, TPMs, and margins

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Fields of Information Collected for Each Indicator

- Goal
- SE Processes for Which Insight is Provided
- Measurable Concept
- Relationships to (Cost Schedule, Product Quality, etc.)
- Indicator
- Leading Information Description
- Usage Concept
- Base Measures
- Attributes
- Potential Source of Base Measures
- Function
- Derived Measures
- Analysis Model
- Decision Criteria
- Description of the Indicator
- Considerations

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What we need from YOU

- Reviewers of the next update
  - Expect in AUG/SEP
- Pilots project s to try some or all of the indicators
  - Plan to pilot late 2005/early 2006
- Additional candidate measures, especially if used successfully
  - Preferably prior to release of the Beta version
  - Request a draft of all fields of data
- Example indicator graphics of the current candidate set

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Overview of Indicators

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Indicator: Requirements Trends (growth; correct and complete)

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Is the SE effort driving towards stability in the System definition (and size)?
- Leading Information:
  - 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.
- Usage:
  - When: 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.
  - Who: Chief SE, Product Mgr.
  - Scope: Impact on system definition, impact on production.
- Description of the Indicator:
  - 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.

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Indicator: System Definition Change Backlog Trends (cycle time, growth)

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Are changes to the baseline being processed in a systematic and timely manner?
- Leading Information:
  - Indicates whether the change backlog is impeding system definition progress or system development quality/schedule.
  - Indicates potential rework due to changes not being available in a timely manner.
- Usage:
  - When: Use whenever there are multiple changes in the approval queue. More frequent review needed when backlog increases, especially if changes have interdependencies.
  - Who: Chief SE, CCB Chair, Product Mgr.
  - Scope: Impact on system definition and development progress, impact on time to market.
- Description of the Indicator:
  - Line graphs that show trends of RFC cycle time and backlog status over time.
  - Stacked bar graph that shows types, causes, and impact/severity of changes.
  - Show thresholds of expected values based on experiential data.

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Indicator: Interface Trends (correct and complete)

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Is the SE effort driving towards fidelity and completeness (i.e., approved) of the interfaces?
- Leading Information:
  - 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.
- Usage:
  - When: Usage is driven by the status of interface closure. Lower closure means higher risk, thus it would be reviewed more frequently. Applies throughout the life cycle, based on risk. Begin to apply by the time when Interface Control Docs are expected to be reaching closure.
  - Who: Chief SE, Product Mgr.
  - Scope: Impact on system definition, impact on production.
- Description of the Indicator:
  - 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.

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Indicator: Trends of Requirements Validation Rate (at each level of development)

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Are the requirements being validated with the applicable stakeholders at each level of the system development?
- Leading Information:
  - Indicates risks of post delivery changes or user dissatisfaction.
  - Indicates whether there is a risk to further system definition due to inadequate understanding of the customer/user needs.
- Usage:
  - When: Usage is driven by the requirements validation rate. Lower validation rate means higher risk, thus it would be reviewed more frequently. Applies throughout the life cycle, based on risk.
  - Who: Chief SE, V&V Lead
  - Scope: Impact on system definition, delivery, and support, impact on stakeholder satisfaction.
- Description of the Indicator:
  - Line graphs that show trends of validation rates per plan during a validation activity.
  - Table showing events and % requirements validated.

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Indicator: Approval Trends

  - Internal Approval (approval by program review authority)
  - External Approval (approval by the customer review authority)
- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Are the system definition work products being approved as planned?
- Leading Information:
  - Indicates that there may be a problem with identification of needs or transformation into reqts/ 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.
- Usage:
  - When: Use when there are numerous work products going through review and approval. 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.
  - Who: Chief SE, PM, Process Owners, Approval Authority
  - Scope: Impact on system definition, delivery, and stakeholder satisfaction.
- Description of the Indicator:
  - Graphs that show trends of approval rates per plan during system definition.
  - Chart showing approval rate distribution by work product type.

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Indicator: Design Review Action Item Closure (plan vs actual for closure of actions over time)

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Are early design review action items being closed according to plan?
- Leading Information:
  - 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
    - challenging personnel interfaces
  - In either case, this indicator reveals project risk in terms of rework and/or infeasible schedule.
- Usage:
  - When: 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.
  - Who: Chief SE, Product Mgr.
  - Scope: Impact on system definition, impact on production.
- Description of the Indicator:
  - 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).

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Indicator: Technology Maturity Trend (planned vs actual over time)

  - New Technology (applicability to programs)
  - Older Technology (obsolesence)
- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: What is the potential impact of Technology changes on the horizon?
- Leading Information:
  - 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 obsolesence exposure gives an indication of when to take action due to obsolesence risk.
  - Should help avoid surprises from obsolescence and plan for right timing of technology insertion.
- Usage:
  - When: Use when 1) products have technological difficulties or long lives compared to technology refresh times; 2) there is a risk of technology obsolescence that may impact the system; or 3) critical technologies are in development.
  - Who: Chief SE, Chief Architect, Program Manager, Customer, Research and development (R&D groups)
  - Scope: Impact on system, architecture, components
- Description of the Indicator:
  - A graph showing trend of technology opportunity exposure, obsolescence exposure and impact of change.

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Indicator: Risk exposure trends (planned vs actual over time)

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Is the risk exposure going to impact the system solution? Is the SE effort managing the exposure successfully?
- Leading Information:
  - Indicates whether the program is effectively managing the program risks as shown by predicted exposure ratings over time.
- Usage:
  - When: Aligned with scheduled reviews (e.g., Risk, IPT, SE, and program)
  - Who: PM, Chief SE, Risk Mgr
  - Scope: Impact on program execution in meeting Cost, Schedule, Performance, Quality
- Description of the Indicator:
  - Risk magnitude/reduction line graph over time that shows trends for each risk category/rating
  - Table of planned vs. actual risk exposure

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Indicator: Risk handling action trends (plan vs actual for closure of actions over time)

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Is the risk exposure going to impact the system solution? Is the SE effort driving the closure of risks?
- Leading Information:
  - Indicates whether the program is proactively handling potential problems or risks 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.
- Usage:
  - When: Applies to all tasks (i.e., PM, SE, SW, …) throughout the program life cycle. Aligned with scheduled reviews (e.g., Risk, IPT, SE, and program).
  - Who: PM, Chief SE, Risk Mgr
  - Scope: Used to identify whether effort is being adequately applied to risk handling activities. Impact on staffing, planning, development progress, and product delivery.
- Description of the Indicator:
  - A graph showing the planned vs actual risk action item closure.
  - A Risk Reduction Chart (or line graph) showing the reduction of risk over time for each risk requiring a mitigation plan.

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Indicator: Effort & Staffing Indicators

- Effort Indicator: % SE effort through the life cycle (planned vs. actual)
- Staffing Indicator: # of SE staff per staffing plan (level or skill - planned vs. actual)

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: Is SE effort with the appropriate skill being applied to the project activities consistent with proven organizational or industry practice?
- Leading Information:
  - Indicates whether the expected level of SE effort or staffing is being applied throughout the life cycle based on historical norms for successful projects and plans.
  - Indicates risk of inadequate or late SE outcomes of all types.
  - Lack of meeting planned staffing may result in missed milestones or reduced quality.
  - In addition, planned staffing can be compared to projected availability through the life cycle to provide an earlier indication of potential risks.
- Usage:
  - When: Applies to all SE tasks throughout the life cycle. Used to flag when appropriate level of SE effort may not be applied.
  - Who: Chief SE
  - Scope: Impact on staffing, planning, development progress.
- Description of the Indicator:
  - Line graphs that show trends of SE effort applied and SE staffing per plan.
  - Bar chart or stacked bar chart showing distribution of actual SE effort per task, activity, event or other relevant breakdown against the experiential data.
  - Bar chart showing distribution of actual SE staffing levels or skills against plan.

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Indicator: Process compliance though the life cycle

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: To what extent are the SE processes in place and being used on the program?
- Leading Information:
  - 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.
- Usage:
  - When: Usage is driven by the process audit plan.
  - Who: Program process lead, Chief SE
  - Scope: Impact on process execution and quality mgt.
- Description of the Indicator:
  - 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.

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Indicator: Trends of MOEs (or KPPs), MOPs, TPMs, and margins

- Information Need: Is the SE effort effective in providing required capabilities, on-time, within budget?
- Measurable Concept: To what extent are the performance parameters feasible and being achieved per plan?
- Leading Information:
  - Indicates whether the product performance is likely to meet the needs of the user.
  - Provides insight into whether the system definition and implementation are acceptably progressing.
  - Allows early action to be taken to address potential performance shortfalls.
- Usage:
  - When: Usage is driven by the technical measurement plan. Generally, measures are reviewed monthly; more frequent at critical decision points or when values are beyond tolerance band. Applies throughout system development.
  - Who: Chief SE, Assigned Measurement analyst,
  - Scope: Impact on System Definition, implementation, and V&V. Impact on stakeholder satisfaction.
- Description of the Indicator:
  - Graphical representation will be dependent on the specific MOP/TPM chosen.

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