Investigation of Leading Indicators for Systems Engineering Effectiveness in Model-Centric Programs

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Motivation

Studies demonstrate the value of mature measurement capability in DoD programs

State of the practice of measurement based on traditional engineering

Digital engineering is a game-changer that motivates re-examining the existing systems engineering leading indicators

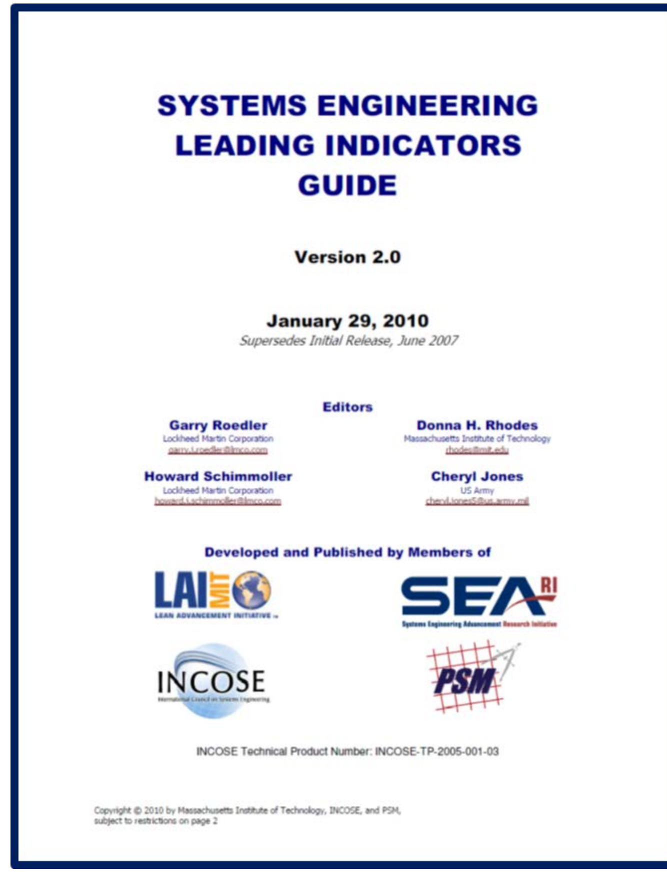
- *How can the existing systems engineering leading indicators be adapted and extended for model-centric programs?*
- *How can program leaders use these to proactively assess systems engineering effectiveness in model-centric programs?*

Background

More than a decade ago, systems experts from **industry, academia and government collaborated** to develop the SE Leading Indicators Guide, aimed at predictive assessment of SE effectiveness during a program lifecycle

Guide details **eighteen leading indicators** using the PSM measurement specification format, and provides useful measurement guidance and practitioner insights

The guide, however, was **developed under the assumptions of traditional systems engineering**



SYSTEMS ENGINEERING LEADING INDICATORS GUIDE

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LAI MIT LEAN ADVANCEMENT INITIATIVE

SEA RI Systems Engineering Advancement Research Initiative

INCOSE International Council on Systems Engineering

PSM

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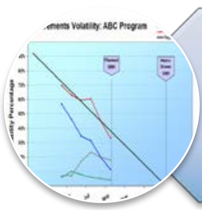
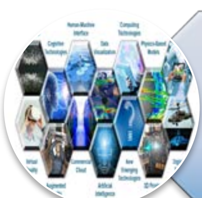
Approach

Draw on prior research and **engage systems community** in knowledge gathering

Initial step – **re-examine and augment** current set of SE leading indicators



Perform **usability evaluation** of adapted/extended leading indicators and **investigate opportunities for proactive assessment**



Define follow-on research to investigate **advanced indicators and apply newer technologies**

SE Leading Indicators (2010)

Initial set of thirteen + five

- Requirements Trends
- System Definition Change Backlog Trend
- Interface Trends
- Requirements Validation Trends
- Requirements Verification Trends
- Work Product Approval Trends
- Review Action Closure Trends
- Risk Exposure Trends
- Risk Handling Trends
- Technology Maturity Trends
- Technical Measurement Trends
- Systems Engineering Staffing & Skills Trends
- Process Compliance Trends

- Facility and Equipment Availability Trends
- Defect/Error Trends
- System Affordability Trends
- Architecture Trends
- Schedule and Cost Pressure

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Development of Leading Indicator Measurement Specifications

3.17.1 Architecture Trend Specification

Architecture	
Information Need Description	
Information Need	Evaluates the maturity of an organization with regards to implementation and deployment of an architecture process that is based on an accepted set of industry standards and guidelines
Information Category	• Product Quality • Process Performance • Technology Effectiveness • Customer Satisfaction
Measurable Concept and Leading Insight	
Measurable Concept	• Is the process definition based on industry accepted standards? • Is SE using a defined architecture process through the leadership of certified architects? • Do the architecture work products conform to an industry accepted set of standards?
Leading Insight Provided	• Indicates whether the organization has an architectural process that will assist in maturing the system design • Indicates whether the organization has the architectural skill set in order to execute an architectural process • May indicate future need for different level or type of resources / skills • Indicates whether the system definition is maturing • Indicates schedule and cost growth risk
Base Measure Specification	
Base Measures	1. Commitment 2. Capability 3. Plans and Products 4. Performance Metrics 5. Strategic Direction 6. Interfaces and Interoperability 7. Data 8. Security
Measurement Methods	Self-assessment or independent appraisal
Unit of Measurement	Each Base Measure has an associated unitless level.
Entities and Attributes	
Relevant Entities	• Assessment levels
Attributes	• Assessor contact information • Time Interval (e.g., date, time, monthly, quarterly, phase, etc.) • Objective evidence that support the assessment levels selected • Objective evidence meta-data • Associated attributes (e.g., status, maturity - identified and defined, interval, milestone, type, cause, severity, etc.)

Architecture	
Derived Measure Specification	
Derived Measure	1. Number of base measures failing to improve over time 2. Combined base measure scores 3. Certified architects
Measurement Function	1. Number 2. Weighted average 3. Number
Indicator Specification	
Indicator Description and Sample	Line chart depicting base measures at discrete review points in time.
Thresholds and Outliers	Organization-dependent experience is needed to identify the thresholds and outliers based on comparison to historic project and system performances.
Decision Criteria	Investigate and potentially take corrective action when the base measures do not all improve over time. All measures are expected to exceed level 3 by the time that design begins.
Indicator Interpretation	Lack of progress in any base measures over several periods indicates weakness in the architecting process.
Additional Information	
Related Processes	• Technical Risk • Requirements Analysis • Modeling • Design
Assumptions	Self-assessment is performed by experts with adequate breath of experience and proven judgment.
Additional Analysis Guidance	• System architects must work with leadership, subject matter experts, and stakeholders to build an integrated view of a system's structure, strategy, processes, and information assets to perform the assessment. • Assessment experience will aid in applying the measures in a consistent manner. • Singular assessors are to be avoided whenever possible.
Implementation Considerations	• Record the metadata and examples of objective evidence that supports the base measure level selected. (This might include architecture views, and products, security standards, interface standards, etc.) These data help in recreating or reevaluating the assessments during later project phases.
User of Information	1. Program/Project Manager 2. Chief Systems Engineer 3. Chief Architect 4. Process Lead 5. Architecture Review Board
Data Collection Procedure	See Appendix F
Data Analysis Procedure	See Appendix F

Each of the eighteen leading indicators has a specification, developed through empirical investigation, for the purpose of providing guidance for implementation and interpretation.

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Investigating How Digital Engineering Impacts SE Leading Indicators (LI)

Approach uses three categories to analyze how leading indicators will need to be adapted or newly created

Category 1	Digital engineering has minimal impact on the leading indicator	Additional Information section of measurement specification augmented with descriptive information
Category 2	Digital engineering results in significant changes and additions to leading indicators measurement specification	Modify and add information to all relevant areas of the measurement specification
Category 3	Digital engineering provides opportunities for novel leading indicators	Generate new measurement specification and illustrative graphics of displayed information

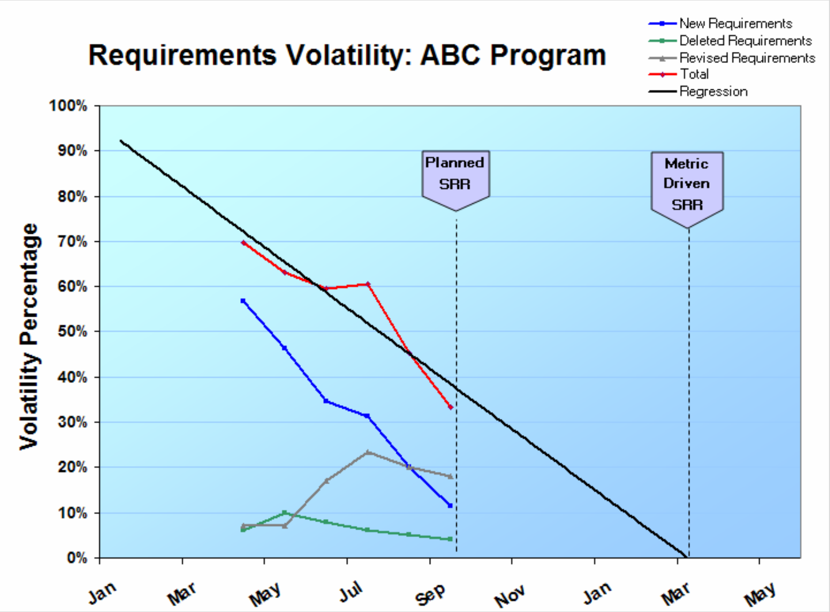
Traditional engineering: Example of how leading indicators have contributed to effective systems engineering

By monitoring requirements validation trend, team was able to more effectively predict SRR readiness

Initially the program had selected a calendar date, but in subsequent planning made the decision to have SRR be event driven, resulting in a new date for review

Revised date was set based on an acceptable level of requirements validation in accordance with the leading indicator

Had original date been used, it is likely SRR would not have been successful



How can adapted/extended leading indicators be used for proactive assessment on model-centric programs?

Composability

Composability concerns the selection of elements that can logically and reasonably be assembled.

- Requirements Trend indicators, for instance, are used to evaluate trends in the growth, change, completeness and correctness of the definition of system requirements
- Traditional engineering: requirements are central objects used for assessing maturity of system definition
- MBSE - there are requirements diagrams, use case diagrams, activity diagrams, state machine diagrams, parametric diagrams, and others.

With model-based measurement data, the question arises as to which measureable data elements can be composed into leading indicators for engineering effectiveness in model-based acquisition programs.

Emerging …

- Model-based toolsets…potential to generate new and more extensive data and analytics
- Digital environments enable real-time access, data on demand, more context information
- Interactive dashboards more easily created and populated in real-time
- Our societal expectations for delivery of information have evolved

91% of consumers now prefer interactive and visual content over traditional, text-based or static media. **Forbes Magazine, 2018**

Current/Planned Research

sponsored by Naval Postgraduate School Acquisition Research Program

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Current

Research Tasks:

- Adapt/extend LIs for Digital (Model-Based) Engineering and Digital Artifacts
- Expert Assessment on Usefulness
- Illustrative Application Case
- Select publically available model-based case studies
- Show value of LIs in providing insight into program decisions

Future

Research Questions:

- *How can digital engineering* ***measurement data be composed into leading indicators and displayed*** *to best enable assessment of engineering effectiveness?*
- *How can* ***leading- edge techniques*** *(automated data collection, visual analytics, etc.) be used to* ***collect and synthesize measurement data from digital artifacts*** *and environments?*

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