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

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Background


SYSTEMS ENGINEERING LEADING INDICATORS GUIDE

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

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

Guide developed under **assumptions of traditional** systems engineering

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

Research Questions

Phase 1

ACQUISITION RESEARCH PROGRAM
NAVAL POSTGRADUATE SCHOOL

Phase 2

Research Questions:

- *How can existing systems engineering leading indicators be **adapted and extended** for model-centric programs?*
- *To what extent can leading indicators be **implemented** with **direct or partial use** of model-based toolsets?*

Research Questions:

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

Research Issue

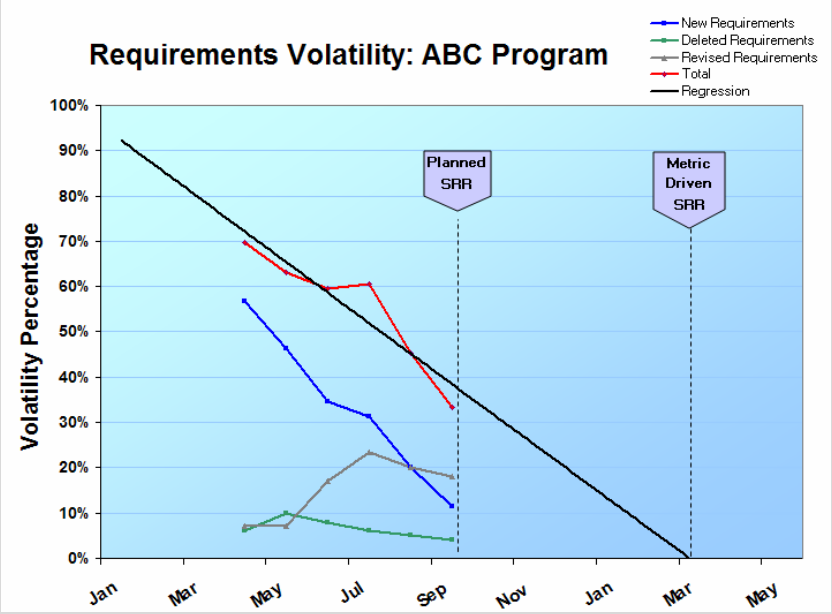
Traditional engineering: Example of how leading indicators have contributed to effective systems engineering

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 set based on an acceptable level of requirements validation in accordance with leading indicator

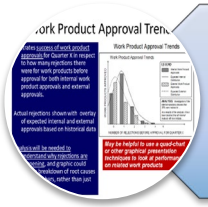
Had original date been used, it is likely SRR would not have been successful



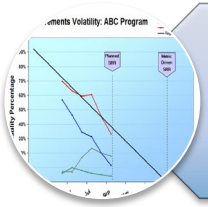
How can adapted/extended leading indicators be used for proactive assessment on model-centric programs?

Research Approach

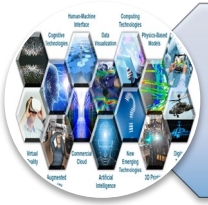
Draw on prior research and **engage systems community** through workshops and interviews



Re-examine current set of SE leading indicators and **identify model-based implications**



Use **illustrative case** to explore leading indicators with direct use of model-based toolset



Investigate literature and ongoing research to explore **opportunities to use newer technologies for composability and display** of indicators

Model-based Implications

investigated through semi-structured interviews and technical exchange workshops

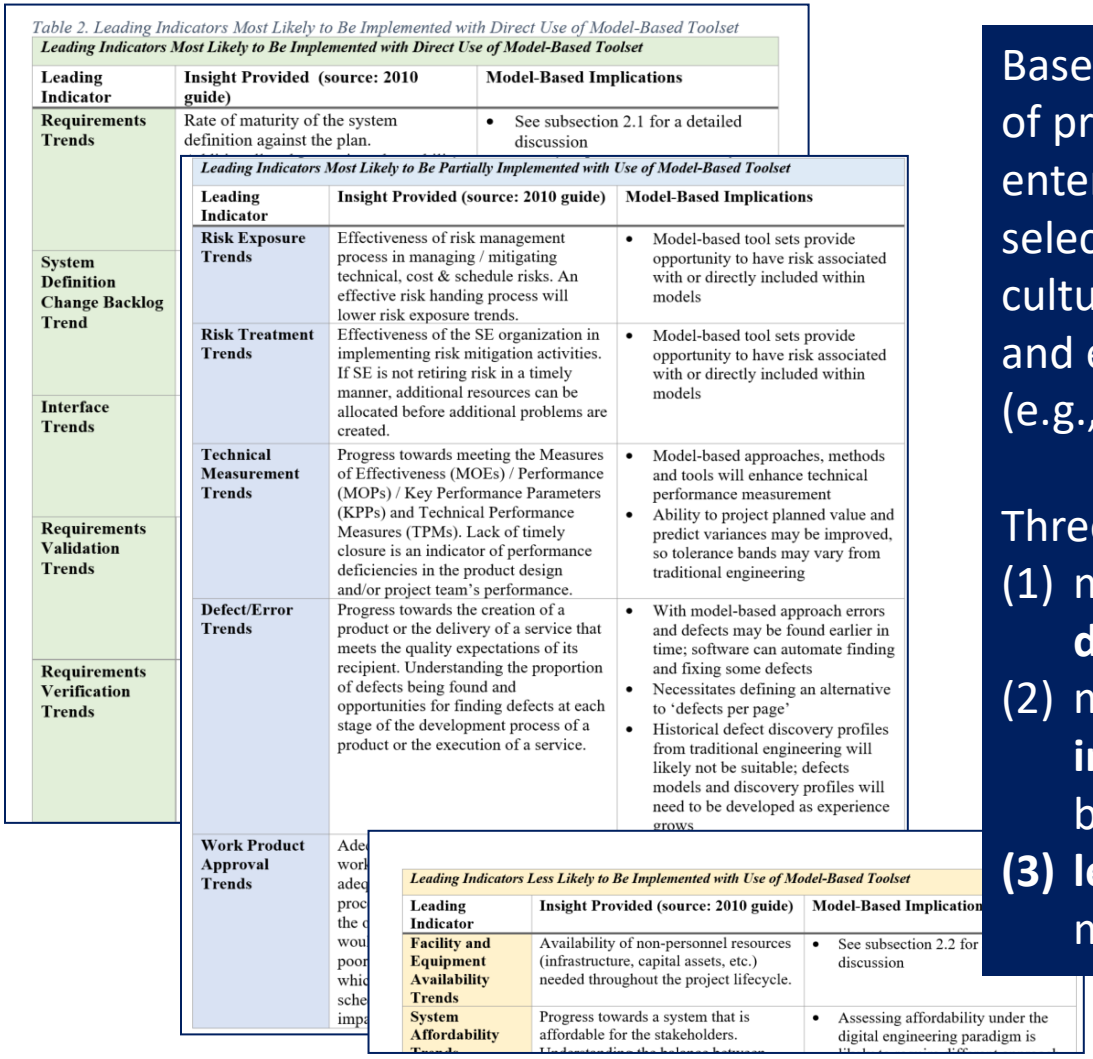


Table 2. Leading Indicators Most Likely to Be Implemented with Direct Use of Model-Based Toolset

Leading Indicators Most Likely to Be Implemented with Direct Use of Model-Based Toolset

Leading Indicator	Insight Provided (source: 2010 guide)	Model-Based Implications
Requirements Trends	Rate of maturity of the system definition against the plan.	• See subsection 2.1 for a detailed discussion
System Definition Change Backlog Trend		
Interface Trends		
Requirements Validation Trends		
Requirements Verification Trends		

Leading Indicators Most Likely to Be Partially Implemented with Use of Model-Based Toolset

Leading Indicator	Insight Provided (source: 2010 guide)	Model-Based Implications
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.	• Model-based tool sets provide opportunity to have risk associated with or directly included within models
Risk Treatment Trends	Effectiveness of the SE organization in implementing risk mitigation activities. If SE is not retiring risk in a timely manner, additional resources can be allocated before additional problems are created.	• Model-based tool sets provide opportunity to have risk associated with or directly included within models
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.	• Model-based approaches, methods and tools will enhance technical performance measurement • Ability to project planned value and predict variances may be improved, so tolerance bands may vary from traditional engineering
Defect/Error Trends	Progress towards the creation of a product or the delivery of a service that meets the quality expectations of its recipient. Understanding the proportion of defects being found and opportunities for finding defects at each stage of the development process of a product or the execution of a service.	• With model-based approach errors and defects may be found earlier in time; software can automate finding and fixing some defects • Necessitates defining an alternative to 'defects per page' • Historical defect discovery profiles from traditional engineering will likely not be suitable; defects models and discovery profiles will need to be developed as experience grows
Work Product Approval Trends	Ade work adeq proc the c wou poor whic sche impa	

Leading Indicators Less Likely to Be Implemented with Use of Model-Based Toolset

Leading Indicator	Insight Provided (source: 2010 guide)	Model-Based Implication
Facility and Equipment Availability Trends	Availability of non-personnel resources (infrastructure, capital assets, etc.) needed throughout the project lifecycle.	• See subsection 2.2 for discussion
System Affordability	Progress towards a system that is affordable for the stakeholders.	• Assessing affordability under the digital engineering paradigm is

Based on many factors, such as nature of program, processes used by the enterprise, model-based toolset selection/implementation, engineering culture, maturity of digital engineering, and external influences in enterprise (e.g., customer preference)

Three categories of leading indicators:

(1) most likely to be implemented with **direct use** of model-based toolset

(2) most likely to be **partially implemented with use** of model-based toolset

(3) less likely to be implemented using model-based toolset.

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
- Illustrative case on requirements trend leading indicators
  - selected MBSE toolset and ontology
  - Identified metrics data that can be extracted from toolset and composed as a leading indicators

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.

Exploring Leading Edge Technologies

Enhancing program decisions with leading indicators

- 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**

Next Steps and Future Directions

Next Steps

- Complete research tasks in process
- Continue collaboration in *Digital Engineering Metrics Initiative*
- Final reports with: (1) information useful to current programs and (2) insights for future investigations

Recommended Future Research

- Community effort to develop new version of guide
- Exploration of new leading indictors (e.g., model volatility)
- Experimentation with model-based toolsets and interactive dashboards to generate indicators

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