SE Leading Indicators Guide

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A Collaborative Industry Effort

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

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

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 has 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

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

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 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

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

Problem Addressed By Leading Indicators

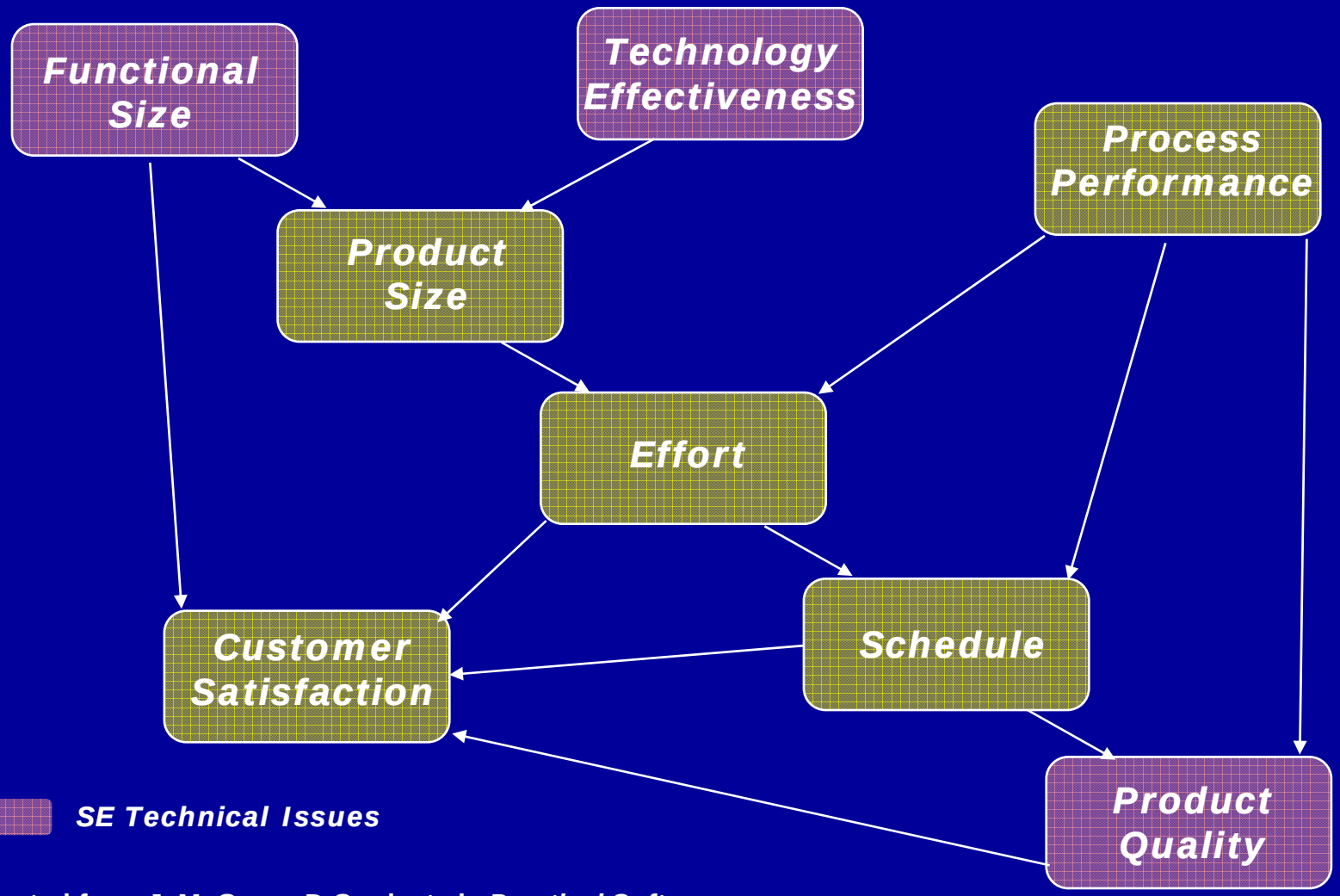
- Leading indicators provide insight into potential future states to allow management to take action before problems are realized

- 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

Difference from Conventional SE Measures

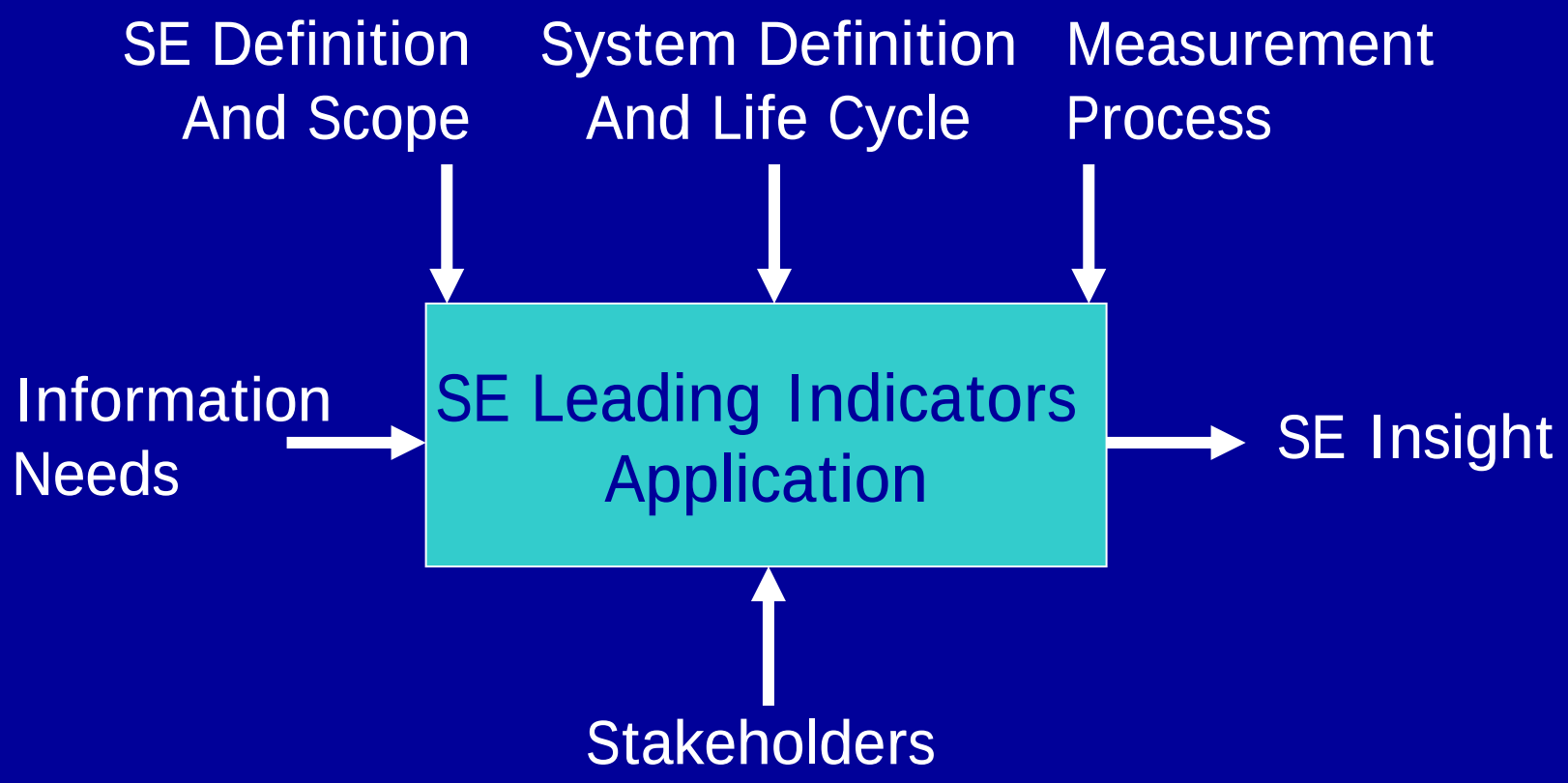
- Conventional measures provide status and historical information
  - Provide a snapshot of “where the activity has been”
- Leading indicators draw on trend information to allow for predictive analysis (forward looking)
  - Trend analysis allows predictions of the outcomes of certain “downstream” activities
  - 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***

Interactions Among Factors



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

Application of SE Leading Indicators

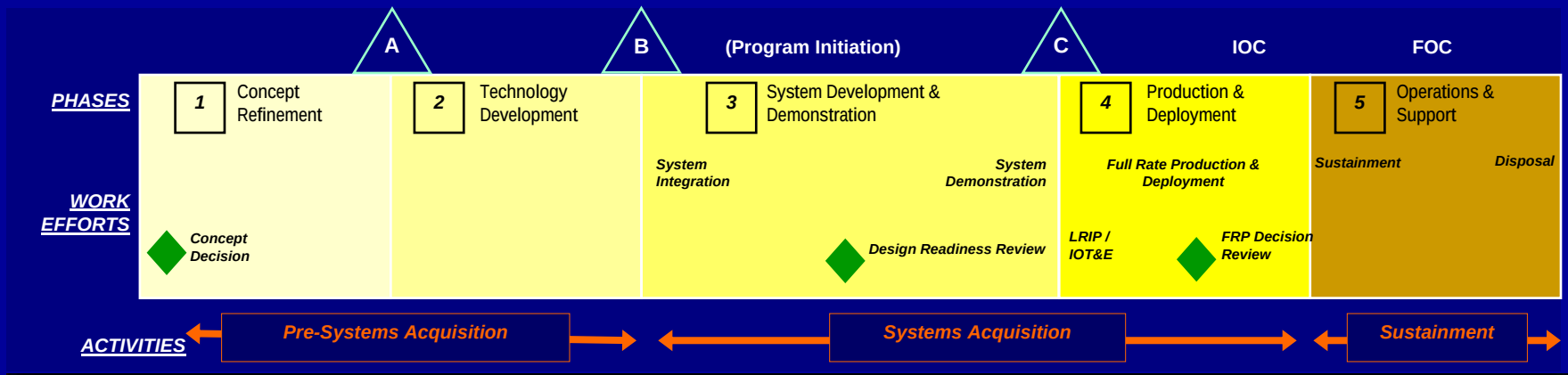


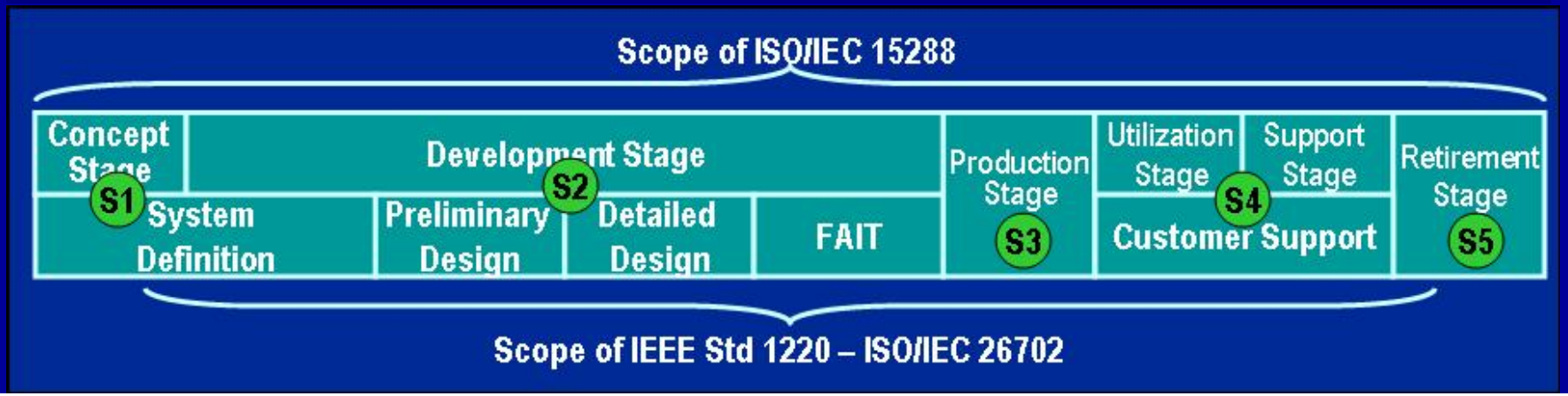
Applying SE Leading Indicators

- 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

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

Validation and Input for Release Version

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

Why Improve Beta Version?

- Improve maturity and confidence of use
- Incorporate feedback from usage and surveys
  - Make the guidance more usable
    - Consistency between 3.x and 4.x
    - Ensure clear link between the user and the interpretation
  - Better recommendations for indicator representation
    - Realism of the graphics – consider thresholds, as applicable
  - Make more capable of predicting (trends) and showing correlation to achieving program goals or other activities
    - Is the “leading insight provided” truly leading and insightful?

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

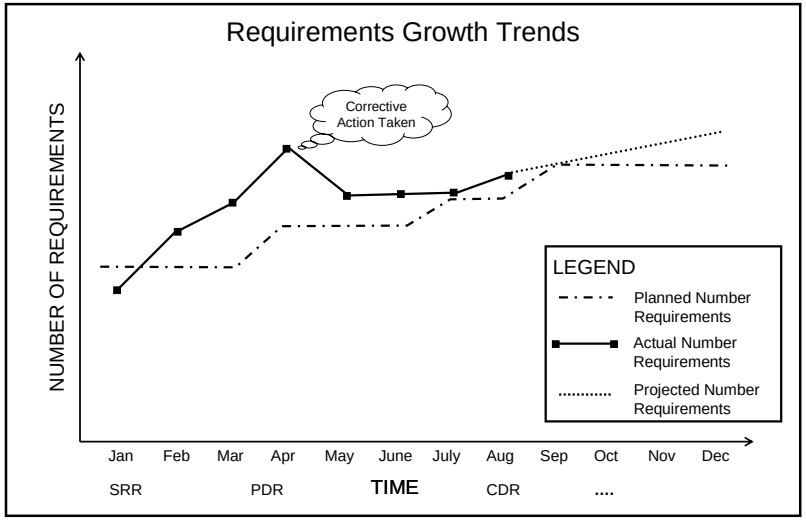
Beta guide released December 2005; pilot programs conducted in 2006; Version 1.0 released in June 2006

Additional leading indicators being defined

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

Requirements Trends



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

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

Potential Future Work

- Conduct workshop after v1.0 to further look at definitions, examples, etc.
- Consider additional indicators
  - SE Product Quality
  - SE Productivity
  - Team Cohesion
  - Stakeholder Participation
  - Complexity (e.g., system, organization, etc.)
  - Overarching SE Effectiveness Index (summarizing the SE LIs)
  - Review indicators that did not make the cut in the original set
- Consider Matrices for:
  - Indicators vs. SE Activities
  - Indicators vs. Program Profile
  - Cost Effective set of Base Measures that support greatest number of indicators
  - Insight from indicators per phase
- SoS Appendix explaining how to use the indicators for SoS (including an example)

Other Information Needs

- Information Needs
  - Questions Addressed

ISO/IEC 15288: 2007

Technical

- Stakeholder Reqmts Definition Process
- Requirements Analysis Process
- Architectural Design Process
- Implementation Process
- Integration Process
- Verification Process
- Transition Process
- Validation Process
- Operation Process
- Maintenance Process
- Disposal Process