



Leading Indicators of Program and Technical Performance for Systems of Systems

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Systems of Systems

Research Questions MIT ESD is Addressing

- How can we address the unique programmatic and technical issues involved in SoS programs?
- What concepts and methods can be used to assess the SoS “ilities”?
- What are the costs and benefits related to integration/coupling of legacy systems into SoS?



Systems Engineering Research

Lean Aerospace Initiative (LAI) Research Group at MIT

LAI has performed research related to systems engineering for many years.... In 2004 **4 specific requests** were made by (then) Assistant Secretary of AF for Acquisition, Dr Marvin Sambur

1. Value (ROI) of SE
 - LAI published Technical Report on Value of SE, Oct 2004

2. Leading Indicators for Goodness of SE
 - LAI formed industry/government working group and published Beta Guide, Dec 2005

3. System-of-Systems Engineering Methodology
 - LAI served on the AF Scientific Advisory Board study on SoSE; report published Dec 2005

4. Practices and Methods for System “Robustness”
 - Past and ongoing LAI research (Value-based Methods Cluster)



What are Leading Indicators?

A leading indicator is a measure for evaluating the effectiveness of a how a specific activity is applied on a program in a manner that provides information about impacts that are likely to affect the system performance objectives.

A leading indicator may be an individual measure, or collection of measures, that are predictive of future system performance before the performance is realized.



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, SSCI, and PSM

- **Co-Leads: Garry Roedler, Lockheed Martin & Donna Rhodes, MIT ESD/LAI Research Group; Pilot Program Lead: Chris Miller, SSCI**
- **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



How do Leading Indicators Differ from Conventional SE Measures?

- Conventional measures provide status and historical information, while leading indicators use an approach that draws on trend information to allow for predictive analysis (forward looking).
- By analyzing trends, predictions can be forecast on the outcomes of certain activities. Trends are analyzed for insight into both the entity being measured and potential impacts to other entities.
- This provides leaders with the data they need to *make informed decisions* and where necessary, take preventative or corrective action during the program in a proactive manner.
- While the 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.*



Systems Engineering Leading Indicators

Thirteen leading indicators defined by SE measurement experts - many from LAI consortium member organizations

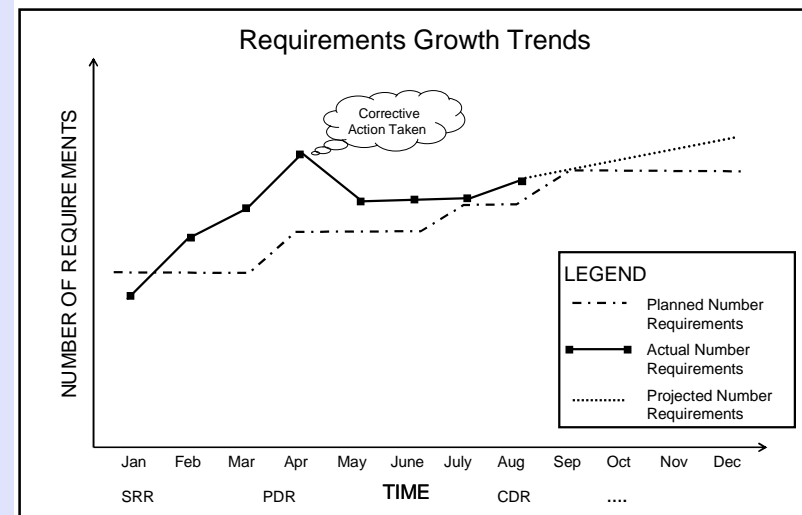
Developed by a working group sponsored by Lean Aerospace Initiative (LAI) collaboratively with INCOSE, PSM, and SSCI

Beta guide released December 2005; pilot programs underway

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



Beta release can be downloaded from lean.mit.edu



SE Leading Indicators (beta release)

- 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

Additional leading indicators to be developed



Plans for the Future

Pilot programs are ongoing in 2006

In support of continuing validation and refinement, MIT graduate research is planned to analyze effectiveness and adequacy of indicators in support of improved enterprise performance

As lessons are learned in validation process, action team will be providing briefings to and seeking input from selected government forums and SE societies/associations

Longer term plan includes transition of this activity and guidance document from LAI to INCOSE Measurement Working Group



Considerations for Applicability to Systems of Systems Engineering

Use of standard leading indicators across organizations and projects is desirable

Some leading indicators are directly usable by an LSI and for SoS level activities

Additional thinking needed around how leading indicators applied at systems level, by multiple systems in an SoS, could be used effectively as a collected set

Lack of historical/baseline trend data for SoS level will be a challenge for implementing leading indicators



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ilities are desired systems properties including flexibility, expandability, scalability, robustness, etc.



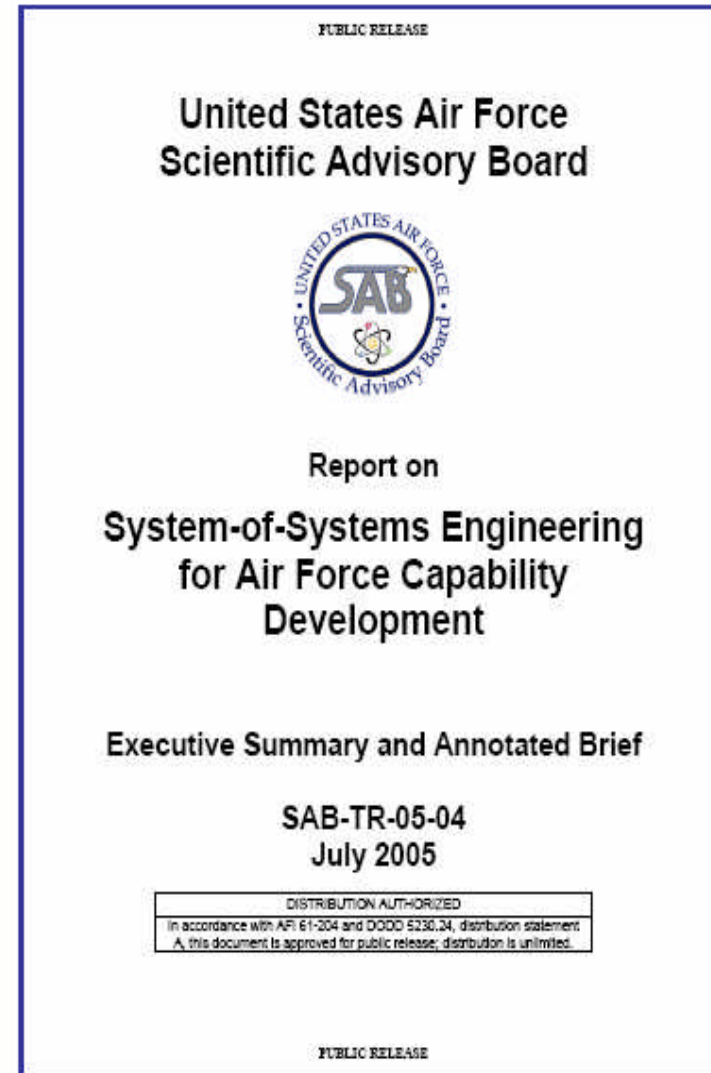
IMPORTANT AREAS for RESEARCH

Quantifying and understanding relationship of “ilities”

Role of experimentation

Importance of human element

Development of framework and tools for helping identify convergence protocols



<http://stinet.dtic.mil>



Ongoing MIT ESD Research

Leading Indicator for Changeability of an Architecture

- Ross, 2006 doctoral dissertation
- *A quantification of changeability is shown to be the Filtered Outdegree of a design within a networked tradespace formed through explicit consideration of transition paths between design instantiations.*

Leading Indicators for Placement of Real Options in SoS

- Bartolomei (doctoral dissertation expected May 2007)
- Coupled-DSM methodology for end-to-end representation of a system (research underway to extend to SoS)
- Analysis techniques to identify/quantify change impacts to aid in identifying “hot spots” and “cold spots” for system



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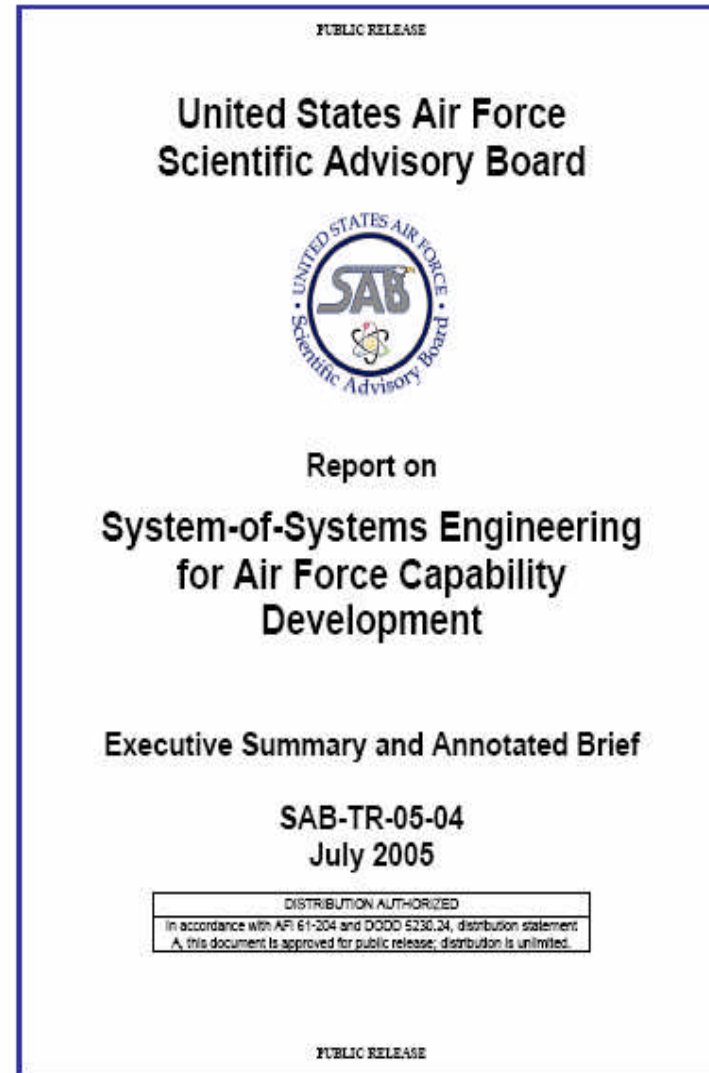
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Ongoing MIT Research SoS Loose Couplers

MIT Doctoral Student: Nirav Shah (nbshah@mit.edu)

RESEARCH HYPOTHESIS

The key issue in creating SoS is the interfaces

- Tight interfaces ensure synchronization and allow for reliable interaction, while loose interfaces are easily reconfigured
- Looseness/tightness of coupling is defined as the degree to which to existence of an interface allows for/inhibits independent action by the items being coupled

Loosely coupled SOS generate greater value than tightly coupled SOS in dynamic environments by adapting their local behaviors and objectives to best serve changing global needs

- The mechanism for discovering fruitful adaptations is cooperative and competitive experimentation by the constituent systems
- During such experimentation, loosely coupled SOS maintain operational and managerial independence thus fostering greater experimentation at a given cost



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MIT Research Questions

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What concepts and methods can be used to assess the SoS “ilities”?

What are the costs and benefits related to integration/coupling of legacy systems into SoS?