Systems Engineering Leading Indicators for Human Systems Integration

Insights from the Practitioner Community

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Introduction

Research Objective: Improve predictability of HSI programmatic and technical performance through augmentation of leading indicators with HSI considerations.

Motivation: HSI - increasingly important in modern systems
Early consideration = fewer accidents, fewer errors, lower costs
Measuring HSI effectiveness on a program is essential

Research Scope: SE Leading Indicators. Widely used in industry. Currently contain weak characterizations in terms of HSI

Today's Presentation: Insights from industry interviews

Research Sponsorship: US Air Force
Office of Human Systems Integration (AFHSIO)

Rhodes, D.H., Ross, A.M., Gerst, K.J., and Valerdi, R., "Leading Indicators for Human Systems Integration Effectiveness," 7th Conference on Systems Engineering Research, UK, April 2009.

What are SE Leading Indicators?

Conventional systems engineering measures provide status and historical information

Leading indicators use an approach that draws on trend information to allow for more predictive insight

SE Leading Indicators Guide Version 1.0

- 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

SE Leading Indicators Guide Version 2.0 released Feb 2010

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

Roedler, G., Rhodes, D.H. (eds), *Systems Engineering leading Indicators Guide* (Version 2.0), Massachusetts Institute of Technology: INCOSE and PSM, 2010.

Research Overview

Mid-way Through Research Plan

MIT SEAri + Air Force HSI Office
Large research effort to more effectively address HSI considerations through the extension of the current leading indicator set

Extensive literature review (complete)

Gap analysis in current literature and leading indicators (preliminary)

Targeted industry interviews phase 1 (complete)

Targeted industry survey phase 2 (underway)

Enhance version 2.0 of Systems Engineering Leading Indicators Guide (complete; Appendix B)

Development of prescriptive information

Ongoing Survey of Practitioners

1. Confirm industry need exists and characterize it

2. Identify additional HSI-specific indicators (if needed)

Current Leading Indicator Set → 1 or 2 Identified HSI-specific Leading Indicators

3. Evaluate utility of HSI-specific LI subset

Current Leading Indicator Set → HSI-specific Leading Indicator **Subset**

Participants: Program management, executive leadership, systems engineers, and HSI subject matter experts

Interviews: 1hr – 1.5hr in-depth, structured interviews. 8 questions

Interview Development Methodology

Survey design and execution based on prominent methods derived from literature

In accordance with research survey design practice (Fowler & Mangione 1990), an initial set of questions was developed and refined through exploratory interviews in order to ensure that the final survey instrument was comprehensive and appropriate

Efforts to Minimize Sampling Error:

- Participants chosen from broad variety of fields, industries, experience levels
- Participants baselined with same set of knowledge—a standard definition list and description of HSI's nine domains—prior to each interview
- Standard, nondirective and neutral interviewing techniques were used
- Standard clarification responses developed to minimize execution variance

Houtkoop-Steenstra, H., "Interaction and the Standardized Survey Interview: The living questionnaire," Cambridge, UK, Cambridge University Press, 2001.

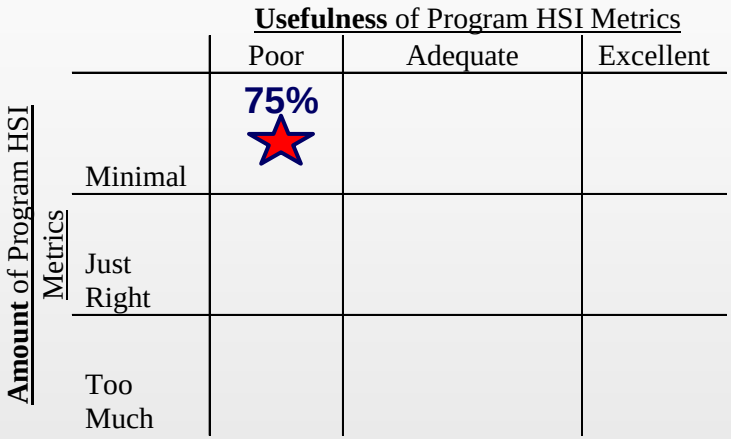
Dijkstra, W., "Interviewing Style and Respondent Behavior: An Experimental Study of the Survey-Interview", *Sociological Methods Research.1987; 16: 309-334.*

Fowler, F.J., Mangione, T.W., "Standardied Survey Interviewing: Minimizing Interviewer-Related Error," Applied Social Research Methods Series v.18, Newbury Park, CA, Sage Publications, Inc. 1990.

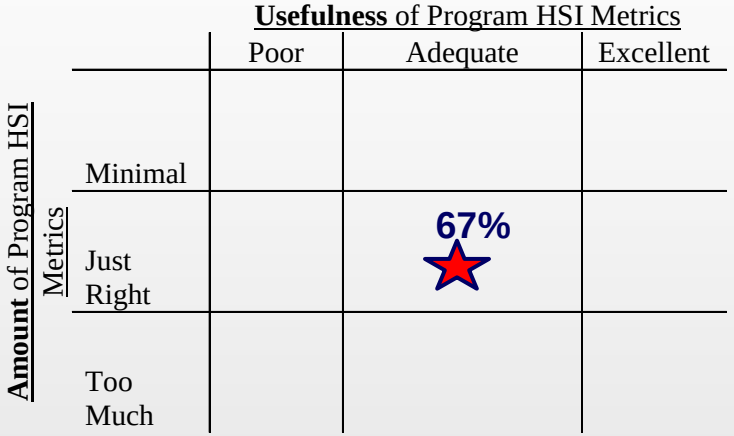
Holstien, J., Gubrium, J.F., "Handbook of Interview Research: Context and Method", London, UK, Sage Publications, Inc., 2001.

Preliminary Insights

Defense Response



Commercial Products Response



DoD respondents strongly indicated a need for HSI measures displaying: higher visibility, increased standardization, full coverage of all domains, leading vs lagging

Insights from Commercial Domain

Commercial Example

Management's focus on HSI, described as "constant and relentless" and "critical to product success"

Close and tangible tie between the user/customer experience and ***profits***

Case of the attacking autonomous lawn mower…

Defense Example

Pilots Killed Ejecting From F104A Thunderchief

Cause: Bad seat design. Inadequate clearance
Solution: Fleet grounded, Seat was replaced.
Result: Orders continued – 835 built in total.

Goddard, D., "Avoiding Injury Through Human-Capable Design", US Army Center for Health Promotion & Prevention, Ergonomics Program, Arlington VA

F105D Cockpit

Strong Participant Request:
High-Level / High-Visibility

Strong Recommendation by Participants for HSI KPPs:

- Participants strongly recommended that one or more Key Performance Parameters (KPPs) be required to relate to HSI
- Participants discussed large difference in staffing, funding, and visibility given to HSI domains when an HSI measure had elevated KPP status

HSI design concerns given low priority, “placed on the back burner”, and “the first to receive funding cuts”

Real World Example

Manager of large military systems design and development project:

"An HSI requirement existed that all visual displays be a minimum of nineteen inches in width.

As system development progressed and the customer requested additional functionality - space became an issue, functionality was prioritized by the customer over ergonomics of the design, and the displays were cut in size."

Real World Example

Manager at large aircraft manufacturer on conducting tradespace analysis:

"S*ystem performance* was requested by the customer to be weighted five times greater than human systems integration aspects of the design.

This prioritization lead to design decisions which were not equally optimized for HSI related concerns and customer preferences."

Preliminary Survey Insights
Proposed HSI Specific Additions

Identified by over two-thirds of elicitation participants

A measure indicating frequency and quality with which end user is involved in design review process

User Involvement in Design Trends	
Information Need Description	
Information Need	• Evaluate the adequacy of user involvement in the system design process and early consideration of Human System Integration needs. • Understand the growth, change, completeness and correctness of the definition of the system requirements.
Measurable Concept and Leading Insight	
Measurable Concept	Evaluate the frequency and quality with which the end user is involved in the design review process.
Leading Insight Provided	• Indicates the extent to which user needs are considered in initial system design. • Indicates the level of programmatic focus on HSI concerns. • Indicates risks of change due to poor HSI execution in architecture, design, and implementation.
Proposed Measurements	1. % Design Reviews involving the user = (# design reviews involving the user / total # of design reviews)*100 as a function of time 2. % Design Reviews specifically focused on the user experience = (# design reviews conducted with the primary focus being evaluation of the user experience and HSI considerations / total # of design reviews)*100 as a function of time 3. % Quality of users involved in the design review process = (actual # of users with the specified experience level involved in the design review process / planned # of users with the specified experience level involved in the design review process)*100 as a function of time

Robey, D., Farrow, D., "User Involvement in Information Systems Development: A conflict model and empirical test," *Management Science, 20, 73-85, 1982.*

Preliminary Survey Insights
HSI Leading Indicator Subset

Informal validation of the utility of HSI LI subset

Current LI Set → **HSI instantiated LI's** ***(Tailored for HSI Specific Use)***

	Current Leading Indicator Measure	Leading Indicators - Modified with HSI Characteristics
Staffing and Skills Trends	% of Effort (actual effort / total planned effort) - Planning vs. Actual	% of HSI Effort (actual HSI effort / total planned effort) - Planning vs. Actual
	% of Staffing per plan (actual staffing / total planned staffing) - Planned vs. Actual	% of HSI Staffing per plan (actual HSI staffing / total planned staffing) - Planned vs. Actual

Evaluated for Utility on a scale of 1 (low) to 5 (high)

Preliminary Findings:

Mean expert rating for all proposed indicators fell within 3 – 4 range (medium or better utility)

However, level of disagreement among experts surrounding utility of two indicators (Requirements Trends and Process Compliance Trends) was relatively higher than rest of the indicator set. *Based on the coefficient of variation.*

Preliminary Survey Insights

Each participant's functional history oriented their response:

Program managers looked at measure from perspective of, "*what decision can I make with this?*"

HSI and Systems Engineering experts evaluated measures from perspective of, "*how useful is this measure in elevating HSI system issues and how difficult is it to gather the data to track this measure?*"

Research Conclusions

1. Confirmed need within practicing community for high-level, leading, HSI measures and guidance

2. Gathered strong recommendation for additional HSI-specific leading indicator:
   - User involvement in design trends

John Heysham Gibbon – physician, USER designer of the heart-lung machine

Von Hippel, E., "Lead User Innovation", MIT Sloan User-Centered Innovation, Feb 12, 2010

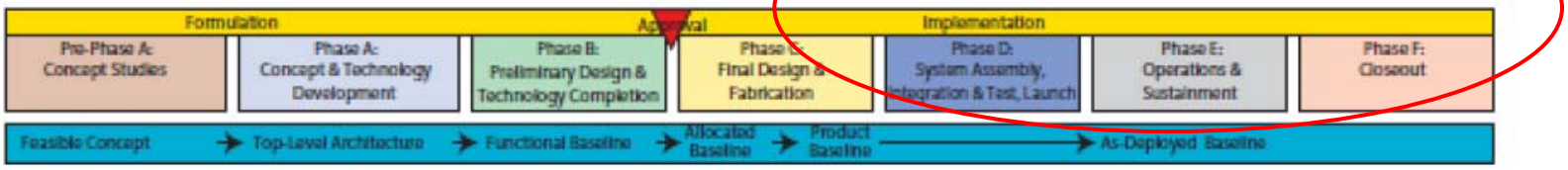
3. Demonstrated perceived utility of HSI leading indicator subset

Future Work

Next Steps...

Phase 2 of targeted industry interviews:

- Expansion of participation pool
- Further exploration of Commercial domain, what are they doing right and what can be applied to defense projects?
- Investigation into how program management can measure/monitor quality of user-centered design practices.
- Development of heuristics uncovered through interview process



NASA Handbook 2007