Unclassified: Dist A. Approved for Public Release

2014 NDIA GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM
SYSTEMS ENGINEERING (SE) MINI-SYMPOSIUM
AUGUST 12-14, 2014 – NOVI, MICHIGAN

THE RDECOM INTEGRATED SYSTEMS ENGINEERING FRAMEWORK (ISEF)

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Abstract

The Integrated Systems Engineering Framework (ISEF) is an Army Research, Development, and Engineering Command (RDECOM) solution to address stovepiped systems engineering(SE) information and processes, disparate tools united by custom, one-off integrations, and a lack of accepted, common standards that exists in today's Department of Defense (DoD) operating environment. Ever increasing technical complexity of fielded solutions combined with budgetary constraints push DoD engineers to "do more with less," requiring a technical management solution that allows them collaborate virtually yet effectively with distributed engineers and other stakeholders. Easy access to systems engineering tools and information through a single "cloud" based application allows connections between federated databases, and facilitates knowledge preservation over time to avoid "reinventing the wheel" when new programs replace retired ones. ISEF is an ever-expanding collection of systems engineering tools united around a common information architecture to address these issues in today's Army and other DoD agencies, with a vision of continuous improvement to consistently expand and adapt the framework's capability to enable efficient problem solving for systems engineers in the DoD today and beyond.

This paper will provide insight into the current development status, near term planned development activities, and long term vision for ISEF, while identifying real-world programmatic successes enabled by the framework.

1. Introduction/Value Proposition

The Army Research Development and Engineering Command (RDECOM) Integrated Systems Engineering Framework (ISEF), formerly the Advanced Systems Engineering Capability (ASEC), is a collection of government off the shelf (GOTS) systems engineering tools with capability to link to commercial off the shelf tools, providing improved systems engineering capability throughout the entire product lifecycle and can be applied to all levels of systems, subsystems, and systems-of-systems. ISEF provides DoD engineers with common tools and processes, while minimizing knowledge loss that is inherent in document-artifact based systems engineering processes. The mission of ISEF is to provide a collaborative, integrated environment for the practice and management of systems engineering knowledge.

There are numerous pieces of literature that identify the needs for much better integration of processes in today's Army. The Decker-Wagner Report (Army, 2010) states "*A deliberate, rigorous, yet tailorable process, involving collaboration among the requirements/operational, cost/benefits analysis, technology, systems engineering, testing, project management, sustainment and contracting communities does not exist and too often, this has been attempted in an uncoordinated, serial approach."* The National Defense Industrial Association (NDIA) included in their list of top systems engineering issues (NDIA, 2010) in today's defense industry (among others), *"Decision makers lack the right info at the right time,"* as well as *"Insufficient SE application early in the lifecycle,"* issues that ISEF aims to help address.

1.1 Why Build a Systems Engineering Web Application?

A thin-client (i.e., web browser based) application provides significant benefits over thick-client (i.e., locally installed) application. Brown et. al (Browne, 2013) discuss this tradeoff in the context of their decision to create a thin-client SysML authoring tool stating "*A user must first receive approval to install the software, acquire a license (if required), install the software, and maintain the software up-to-date. Experience by the authors has shown some of these steps can be tedious and time/resource consuming especially for users on government-owned systems. By deploying in a web environment, a near-zero client footprint greatly broadens accessibility and removes the need for software approval and installation.*" A browser based application maintains a "security sandbox" on the client computer, preventing the user from introducing any security risks through installation of software, while allowing easier configuration management of code on a centralized server.

1.2 What IT Architecture is ISEF Built Upon?

ISEF is built on a SQL database to store SE data and associated metadata. The ISEF database uses a class-based information schema which ensures that SE data is organized in a manner that provides commonality across systems engineering

processes, while still allowing the information schema to be extended based on individual customer needs. Providing a centralized store of SE data (as opposed to a creating a string of document-artifacts that are stored locally on stakeholder hard drives or document repositories), provides several benefits: 1) Traceability is produced as classes of information progress throughout the product development lifecycle (explicitly tracing stakeholder needs to system requirements, for example); and 2) Data accessed by users is ensured to be live. ISEF can also read/write/trace to requirements data stored in an IBM DOORS ® database.

The ISEF application is built upon the ExtJS Javascript Framework, an Apache Web Server, and a PHP code backend. The ISEF IT infrastructure is show in Figure 1.

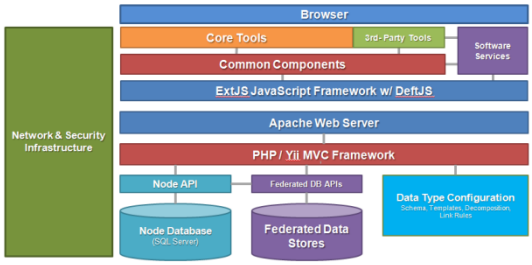

Figure 1: ISEF IT Architecture

1.3 How does the ISEF software architecture support lean, agile tool development?

Systems Engineers inherently perform the same basic functions in order to make sense of a complicated world – they decompose data, trace data, lay information out over time, develop workflow to manage process implementation, and more. During early development of the ASEC tool, the ASEC development team realized that there was a large amount of commonality across early applications and architected the software in a manner to provide maximum reuse of common components. The software architects also built the tool around the idea of a registry. A base registry creates a common base information schema for all ISEF tools (for example – a common method of conducting a functional decomposition) however a custom registry can be applied to any data within ISEF (to modify the decomposition structure without necessitating a change to the underlying application code. The result of this built-in modularity and flexibility allows ISEF to create brand new tools for decomposing data of any type without coding changes, as well as rapidly prototype "custom" applications to provide unique visualizations and functionality as requested by ISEF customers.

1.4 How Does ISEF Integrate With Other Applications?

ISEF has an Application Programming Interface (API) defined to facilitate integrations with any open (i.e., also containing an API) COTS and GOTS tools, as well as federated databases. This is consistent with the ISEF methodology to avoid duplication of COTS and GOTS tool functionality and data, but instead leverage the best-of-breed systems engineering tools in a manner that provides the maximum capability to DoD engineers at the lowest cost to the government. The ISEF API is currently a "developer's" API – it defines the protocols for another application to speak to ISEF and the necessary documentation to extend the current applications to meet a new purpose. A future task would be to expose a set of "user" APIs, that can be executed with minimal coding. An example of this would be a generic API to import high level results of modeling and simulation directly into the ISEF tool to facilitate improved decision making.

1.5 How Does ISEF Support Pattern Learning and Information Reuse?

The ISEF team maintains a set of patterns within ISEF that can be used to seed ISEF modules and provide a "jump start" to any new program that utilizes ISEF. An example is a common ground vehicle functional decomposition, which provides a starting point for the generation of performance requirements for a new vehicle. ISEF can maintain patterns for any type of data that it houses (criteria, requirements, decisions, etc). Furthermore, ISEF has built in functionality called a "pattern copy/paste" to promote continuous improvement of patterns over time. Whenever an instance of a pattern is created in a new module for a program, a breadcrumb trail is built back to the original. Thus, a system administrator can look out over all ISEF data and see how users have built upon the patterns, then use that information to grow the pattern over time.

1.6 Why Build a GOTS Tool/Framework Instead of Purchasing a COTS Alternative?

In 2013, RDECOM sponsored an analysis of alternatives with representatives of each Research, Development, and Engineering Center (RDEC) under RDECOM to determine what the right framework of tools to unite systems engineers throughout the Army consisted of. The conclusion of the study was that the best approach was a blend of COTS and GOTS tools, expanding the previously developed ASEC tool into a framework that met the needs of each RDEC while promoting commonality in systems engineering methods, tools, and processes. No COTS solution could provide this level of tailoring and service to meet the everchanging needs of today's Army.

In addition, the framework better supports the Army's business model by enabling early problem framing through decisions, as well as aligning missions to needs, requirements, and risks. This provides the government the capability to do better upfront systems engineering resulting in a higher quality requirements set communicated to contractors to support innovation, while still ensuring that the end product meets the needs of a soldier. ISEF focuses on the "top ends" of the SE "Vee" Model (early up front framing of the problem and implementation of a chosen contractor solution) and supports model-based systems engineering, modeling and simulation, and lifecycle models to develop a rich tradespace that enables data driven decision-making with confidence.

1.7 How Can ISEF Support Collaboration Beyond Intra-Government Communication?

ISEF has received TACOM legal approval that the tool can be used by any government or contract employee with a legitimate purpose of benefit to the government:

"It is permissible to say that Government contactors can use ISEF in the following way. The Government will have ISEF on a Government server and keep all the source code on its server. Contractors can access the server, supply data to the server and get results from the server based on ISEF software operation. Such use by contractors must only be for Government purposes and must have approval from the appropriate Government program being supported by the contractors' activities."

ISEF can be a facilitator of information between an OEM and the government, and has sufficient, proven access rights control to ensure that data is only shared to those who are given rights. As a stretch goal, ISEF would like to build the capability to leverage crowd-sourcing to solve critical problems

and drive innovation where information can be exposed to the general public to do so.

2 Current ISEF Capabilities

2.1 *Soldier Feedback / Lessons Learned Tool*

The ISEF Lessons Learned supports capture, processing, and analysis of soldier feedback in the form of Observation Reports (ORs). The tool was developed for the Stryker TRADOC Capability Manager (TCM) to facilitate soldier feedback forums, in which feedback from soldier in-theater experience was captured and attributed to various DOTMLPF (Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities) and Warfighter (Fires, Intelligence, etc.) functions. The tool supports multiple summary views of the data, which break down soldier feedback into matrices and charts based on the different functions they apply to. Soldier feedback is instantly summarized, allowing immediate response during the sessions on where the soldier's highest areas of concern are. The ISEF Lessons Learned tool has reduced the time and effort to capture and analyze ORs by at least 5x.

2.2 Stakeholder Needs Analysis

The ISEF PM 1-N Needs Tool supports the capture, prioritization, analysis, and decomposition of needs for the Army ground vehicle domain. The tool facilitates a collaborative environment between TARDEC's PEO/PM customers and the TARDEC Ground Domain Planning and Integration (GDP&I) organization to help align the TARDEC Science and Technology (S&T) portfolio with capability gaps that PEOs and PMs need addressed.

Previously, TARDEC had initiated an annual data call via excel from its PM customers to list current needs and capability gaps. This process led to a "fire and forget" cycle, where nearly identical needs were identified each year from scratch. With the PM 1-N Needs tool, needs are preserved over time and PM customers can simply validate, delete, and add needs each year in the most efficient manner possible. In addition, the tool serves as a facilitator to the S&T project community throughout TARDEC to understand current operational needs of the PMs. S&T project leads who are producing technologies to fill a capability gap can search PM customers in need of the technology and create a trace between PM Needs and their system requirements, to validate that the need is being addressed by TARDEC.

To help the PM and TARDEC better understand how an individual need traces to Army level needs, the PM 1-N Needs tool supports a trace from PM Need to an ARCIC Capability Needs Analysis (CNA) Gap or a Warfighter Outcome (WFO). The tool also supports an initial decomposition of a need statement into functions, performance requirements, and constraints to clarify stakeholder intent.

In addition to the PM 1-N Needs Tool, ISEF has stood up a Generic Stakeholder Needs Tool. The PM 1-N Needs tool has a unique UI, some custom workflow, and specialized reporting that make it specifically designed for ground vehicle PEOs and PMs. Generic Stakeholder Needs, however, still achieves 80+% of the utility of the PM 1-N Needs variant (still supports the capture, prioritization, analysis, and decomposition of needs in a centralized, collaborative environment) and is available for use by any customer throughout the DoD. Further comparison can be provided on request.

2.3 Capability Analysis / Requirements Management

The ISEF Capability Analysis (CA) tool supports analysis, decomposition, and management of operational capabilities and system requirements. The tool is built on an embedded recursive decomposition strategy that can be applied to any system. A common functional decomposition thread when defining performance requirements for a new vehicle would define capabilities (mobility, for example). Each capability would be decomposed into functions that define how the vehicle must achieve each capability (generate torque). Each function would then be decomposed into performance requirements that define how well the vehicle must achieve each function ("the vehicle shall produce x foot-pounds of torque"). The CA tool in total supports 8 classes of data (unless extended) – Capability, Use Case, Action, Function, Performance Requirement, Constraint, Interface Requirement, and Lifecycle Requirement.

ISEF discussion threads provide a collaborative way to discuss and validate any changes to requirements and gather feedback on suggested requirement trades during a system's requirements generation. The ISEF CA tool improves over 3rd party requirements tools by: 1) increasing accessibility and avoiding the need for tools like a virtual private network (VPN) to access a requirements database; and 2) Providing a simpler user interface that users can be completely trained on in a couple hours; and 3) Providing a (currently) free requirements tool to any smaller S&T or acquisition program, which may not have available funding to purchase a COTS solution and would otherwise manage requirements in Excel.

2.4 Compliance Evaluation

The ISEF Compliance Evaluation (CE) Tool is designed to capture and summarize the level of compliance provided by contractor solutions against Army requirements for a system. Compliance data is tracked against the requirements presented to the contractor (a P-Spec or Purchase Description document), but is rolled up to show the impact that a potential compliance failure could have to government requirements documents (such as a Capability Development Document) and highlight potential requirements trades that need to be made. The CE tool is designed to simplify the task of collecting, organizing, visualizing and analyzing compliance data and trends in compliance data across multiple dimensions (such as time and competing contract firms). Current developmental upgrades will extend the CE tool's capability to include graphical representations of compliance data as well as expand the tool's capability to manage test procedures and test reports.

2.5 Risk Management

Project Recon is an integrated suite comprised of three tools: 1) Risk Recon: Supporting risk identification, prioritization and mitigation planning; 2) Opportunity Recon: Supporting opportunity identification, prioritization and growth planning; and 3) Issue Recon: Supporting risk-to-issue traceability, issue identification, prioritization and corrective action. All three tools share a common user interface design in line with the ISEF "learn-once, use everywhere" training mantra. Project Recon is widely used across the Army and USMC for risk management on ACAT programs and S&T projects.

ISEF supports automated linking between decisions in the ISEF Decision Management Tool and Risks in Project Recon. In addition, ISEF is in development to produce a tool for increased efficiency, consistency, and knowledge reuse when conducting

technical risk assessments. The tool will support an embedded methodology and process to score technologies for inclusion on programs of record on the dimensions of Technology Readiness Level (TRL), Manufacturing Readiness Level (MRL), and Integration Readiness Level (IRL).

2.6 Decision Management

The ISEF Decision Management (DM) tool is the "glue" that holds the framework together. Every Systems Engineering process is designed to support improved decision making throughout the product lifecycle. The ISEF DM tool has four components, each with a specific function.

2.6.1 Decision Breakdown Structure (DBS) Tool

The DBS Tool provides a logical way to breakdown technical/programmatic decisions (use cases to support, technology decisions, lifecycle decisions, etc.). A program cannot be captured in a single decision, nor would it be valuable use of time to capture thousands of minute decisions. Somewhere in between, is the breakdown of the critical decisions that will determine program/project success. The DBS is an area of ISEF that is significantly bolstered through the leveraging of patterns and pattern learning.

2.6.2 Roadmapping

The ISEF Roadmapping tool takes the decisions from the DBS and lays them out over time to search for capability gaps (points in time where a stakeholder need is not addressed by any alternative solution under consideration). This task is done to align portfolio decisions between S&T, PEO/PM and higher Army communities as well as inform Army leadership of a capability gap to be mitigated (possibly by moving project timelines or increasing investment in a technology to produce a capability sooner).

2.6.3 Decision Trace Tool (DTT)

The DTT takes a deep dive into a single decision as laid out in the DBS and frames the problem similarly to the Analytical Hierarchy Process. A user lays out decision criteria (the problem space) as well as potential alternatives (the solution space) on a single screen that connects the two. The user weights criteria into a scale of (1, 3, 5, 7, 10). The criteria scale is designed to be intentionally coarse enough to avoid decision makers debating precision on a decimal point level, but still provide enough detail to properly capture stakeholder importance of criteria. The user is also encouraged to produce a requirement to decision criteria link, as well as link from alternatives (if an alternative is chosen) to decision consequences (risks, derived requirements, etc).

2.6.4 Decision Analysis Tool (DAT)

The DAT prompts users to score alternatives against criteria, again using a (1, 3, 5, 7, 10) scale. Users can capture performance estimates (possibly from M&S tools) and scoring rationale. Upon completion of scoring, the user is given a weighted sum of how the alternatives perform on the dimensions of technical performance, risks, and opportunities, as well as spider and tornado chart representations of the decision and pairwise comparisons. The ISEF DAT is built on a methodology that easily handles a mix of qualitative and quantitative data without trying to transform from qualitative to quantitative.

It is important to point out that the DBS, Roadmapping, and Decision Trace tools are tools that are universally applicable to any program and its decisions. Every set of

decisions can be broken down, laid out over time, and fundamentally consists of a process where a decision maker is judging alternatives against criteria based on their performance. Decision Analysis, on the other hand, is more of an art (for evidence, see the wide of trade study and optimization tools across the DoD). The DAT is an *alternative* in the decision of which analysis tool to apply to a particular problem and excels under certain conditions, but the decision management framework is still applicable when combined with any mix of decision analysis tools.

2.7 COTS/GOTS Integrations

ISEF has completed, is engaged in, or is preparing requirements to integrate with the following COTS/GOTS tools in FY14/15: IBM DOORS ®, NoMagic MagicDraw ®, PEO-GCS Whole Systems Trades Analysis Tool (WSTAT), TARDEC Sustainment Engineering Risk Assessment (SERA), and Microsoft Project Server ®. Further details on the capabilities of these tools and how they will be leveraged into ISEF can be provided upon request.

2.8 ISEF Technology/Feedback Forums

Going beyond tool development, ISEF is in the process of setting up capability centric forums with representatives from PEOs, PMs, and all RDECs to guide the ISEF development roadmap, provide a forum for discussion of current ISEF capabilities and their application, and help prioritize how enhancements to current capabilities and user interfaces should be scheduled. Each major systems engineering capability area (risk, requirements, architecture, etc.) will have a separate forum and will not necessarily be chaired by a member of the PM ISEF team.

3 References

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