

LEVERAGING INCOSE RESOURCES TO IDENTIFY SYSTEMS ENGINEERING BEST PRACTICES

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ABSTRACT

The ability to leverage best practices from industry, academia, and government programs can save a great deal of time and effort in the development and management of complex systems. Leveraging such knowledge requires easy access to information so technical teams can readily tailor and use these best practices to avoid pitfalls and rework, thereby improving the system development process and its output—the system of interest. The International Council on Systems Engineering (INCOSE) provides a wealth of reviewed and refined Systems Engineering best practices, lessons learned, and methods that can be used for this very purpose. The objective of this article is to provide an overview of INCOSE’s resources and how one can leverage them to aid in complex system development to ultimately improve system performance.

INTRODUCTION

This paper provides an overview of how to leverage Systems Engineering (SE) best practices made available by the International Council on Systems Engineering (INCOSE).

Although there is no “silver bullet” or “one way solves all” SE process or “wave a magic wand” SE tool, SE lessons learned and published information can assist teams in managing the complexity of technical programs today. In fact, there is a wealth of SE information available from INCOSE through its numerous resources. These resources include but are not limited to iPub to search INCOSE’s International Symposium publications, articles published in INCOSE’s *Systems Engineering* journal, the *INSIGHT* publication, INCOSE Technical Products and Working Groups, and the *INCOSE Systems Engineering Handbook*. An overview of how one can access and use these resources to quickly zero in on best practices and related information that the Systems Engineer can tailor for his or her specific program needs will be presented. Furthermore, this paper outlines the advantages of starting with a high-quality knowledge baseline through the use of these resources. The ultimate goal of this paper will be to add these available resources to the Systems Engineer’s toolkit as an aid to improve overall technical performance of systems and programs. Readers will gain clear understanding of how to

take advantage of decades of lessons learned and related best practices from the SE community provided via INCOSE.

THE CAVEAT AND POWER OF BEST PRACTICES

The term “best practice” is often used quite loosely. It’s an abstract term that could be applied to policies, standards, processes, procedures, tools, or design, build, or test methods. It might relate to when one activity is performed in relation to another, or the level of detail required, or the quality methods employed, and so forth. Wikipedia.com provided the two following definitions:¹

A best practice is a technique, method, process, activity, incentive, or reward that is believed to be more effective at delivering a particular outcome than any other technique, method, process, etc. when applied to a particular condition or circumstance.

Best practices can also be defined as the most efficient (least amount of effort) and effective (best results) way of accomplishing a task, based on repeatable procedures that have proven themselves over time for large numbers of people.

There really is no end to what a “best practice” could encompass, which is especially true within the discipline of

Systems Engineering, which has a very comprehensive scope. Further complicating the application of best practices is the increasing dynamics of systems' use context which is making development activities more complicated and complex and often not very repeatable at a detailed level. Systems Engineers and Systems Engineering teams now often need to rely more on generalizations, heuristics, and principles from which to tailor program specific plans to remain adaptive and flexible to move with the necessary precision and speed on an individual program given its unique requirements.

Nonetheless, one assertion many relate to is that engineers and development teams desire to eliminate rework, reduce risk and optimize systems and the work required to successfully deliver them. Within this paper the use of the term "best practice" is focused on any technique, method, practice, process, activity, or piece of information that can be used to the benefit of an organization involved in systems development (from concept to disposal). This benefit can be realized via either increased effectiveness or efficiency in the process of system development and/or an improvement in system performance.

For SE within the Department of Defense (DoD) there has been a recent convergence of SE terminology through reference to a common industry standard. More specifically the most recent Defense Acquisition Guidebook Systems Engineering process terminology is now aligned with ISO/IEC 15288:2008 which outlines standard system lifecycle processes. This is the same standard which the INCOSE handbook is aligned to, and it allows for common semantics between INCOSE products and DoD training offered through the Defense Acquisition University (DAU). This commonality allows for and enables an easier categorization and translation of best practices. However, while this aids the translation and sharing of best practices across programs and sectors, a practice that works in one context (program, sector or industry) may or may not work in another.

Therein lies the danger in the term "best practice." Depending on the level of detail within the best practice it may only be a "best" practice within the context it was developed and applied. As such, a best practice used within a different context could actually do more damage than good. This goes to the axiom expressed by Albert Einstein: "Everything should be made as simple as possible, but not simpler." To simplify and improve the system development process, we desire to leverage best practices, but often the application of best practices is not as simple as a "copy and paste" of a detailed process or adherence to an abstract international standard. The integration and application of SE best practices requires a knowledgeable and experienced Systems Engineer to properly tailor the "practice" for useful application to improve organizational, program or system

performance. With this caveat in mind, we need both quality lessons learned and the experience and knowledge to apply them wisely. It has also been shown that the application of best practices can have a significant impact on the success of a project—but only if the practices are tailored to the needs and culture of the organization that will use them.²

However, with these caveats in mind, if one can wisely apply a known best practice and tailor it to the culture of the organization and needs of a particular program, great power can be achieved through improved effectiveness, efficiency, and improvements in overall system performance. In fact, it has been shown that speeding the system development time has numerous positive effects including improved innovation, quality and cost. These are all advantages possible when appropriately leveraging and tailoring a high-quality SE knowledge baseline as provided by INCOSE through its numerous SE resources. Furthermore, such an impact can be continually refined and appropriately tailored to become fully integrated and effective through a robust continuous process improvement effort.

INCOSE RESOURCES AND SE BEST PRACTICES

INCOSE's depth and breadth of SE resources and best practices stems from its genesis in 1990 when it began to address fundamental issues within the discipline. As a not-for-profit membership organization founded to develop and disseminate the interdisciplinary principles and practices that enable the realization of successful systems INCOSE has more than 7,000 members and 58 chapters worldwide. Collectively the membership works toward providing Systems Engineers the resources and best practices necessary to fulfill INCOSE's Mission, Vision, and Goals:

Mission

Share, promote and advance the best of systems engineering from across the globe for the benefit of humanity and the planet.

Vision

The world's authority on Systems Engineering.









Goals

- To provide a focal point for dissemination of systems engineering knowledge.
- To promote international collaboration in systems engineering practice, education, and research.
- To ensure the establishment of competitive, scaleable professional standards in the practice of systems engineering.
- To improve the professional status of all persons engaged in the practice of systems engineering.
- To encourage governmental and industrial support for research and educational programs that will improve the systems engineering process and its practice

As one can see, the Mission, Vision, and Goals of INCOSE are directly related to providing SE best practices, which in turn has led to INCOSE's development of numerous SE resources (products, publications, handbooks, primers and databases).

Many of the products are free to nonmembers and members alike while others are only available to INCOSE members and employees of Corporate Advisory Board (CAB) members. Table 1 provides a list and summary of some of the INCOSE resources outlined within this paper. For each of the elements listed in Table 1 the resource descriptions were adopted and/or copied from INCOSE's website at www.incose.org.

Table 1: Select INCOSE Resources
(Media Type: P = Print, E = Electronic)

Symbol	Description
	SE Handbook
	Journal of Systems Engineering
	INSIGHT
	i-Pub Publications Database
	Community Resources
	Webinars
	Working Groups (REGAL example)
	Discussion Forum

INCOSE Technical Products are technical information developed within INCOSE, processed in accordance with the Technical Product Review and Approval Process. To be distinguished as an official INCOSE Technical Product, the product must have been reviewed and approved by the INCOSE Technical Board. This process provides technical integrity to the products provided by INCOSE thereby establishing a high-quality knowledge baseline from which to obtain SE best practices and knowledge of how to tailor and apply them. Some INCOSE Technical Products are offered for sale to the general public, and to members at a discounted price, such as the *INCOSE Systems Engineering Handbook*, *International Symposium Proceedings*, and so forth.

INCOSE Technical Products are formally approved information, including:

- Technical Publications such as Handbooks and Guidebooks, providing formal INCOSE technical

information relative to topics within SE, and providing task guidance, advanced methods, guidance, lessons learned, cookbook techniques, criteria, and so forth.

- Primers providing formal INCOSE introductory technical information that explain the basic language and approaches of an SE topic
- Database Products providing formal INCOSE-derived technical information, usually capturing data on a variety of topics that can be best presented in database form.



INCOSE Systems Engineering Handbook

Version 3.2 of the *INCOSE Systems Engineering Handbook* represents a shift in paradigm toward global industry application consistent with the Systems Engineering Vision. This resource was developed for the new Systems Engineer, the engineer in another discipline who needs to perform systems engineering, or the experienced Systems Engineer who needs a convenient reference. The handbook provides an updated description of the key process activities performed by Systems Engineers. It also provides context diagrams for each process area and an N² analysis of the processes showing where dependencies exist in the form of shared inputs or outputs.

The descriptions in the handbook show what each SE process activity entails, in the context of designing for affordability and performance. On some projects, a given activity may be performed very informally (e.g., on the back of an envelope, or in an engineer's notebook); on other projects, very formally, with interim products under formal configuration control. This document is not intended to advocate any particular level of formality but to provide a guideline to be used as necessary or appropriate in a particular situation.

Members may download both version 3.2 and earlier versions of the *Systems Engineering Handbook* from the product area of INCOSE Connect. There is no charge to members for an electronic soft copy, which is extremely useful in identification of best practices by topic through use of search functions. Members and the general public may purchase a hard-copy version from the INCOSE Office.



Systems Engineering – The Journal of The International Council on Systems Engineering

Systems Engineering, INCOSE's journal, is a primary source of multidisciplinary information for the systems engineering and management of products and services, and processes of all types. SE activities involve the technologies, processes, and systems management approaches needed for: definition of systems, including identification of user requirements and technological specifications; development of systems, including conceptual architectures, tradeoff of

design concepts, configuration management during system development, integration of new systems with legacy systems, and integrated product and process development; and deployment of systems, including operational test and evaluation, maintenance over an extended lifecycle, and reengineering.

Modern systems, including both products and services, are often very knowledge intensive and are found in both the public and private sectors. The journal emphasizes strategic and program management of these, and the information and knowledge base for knowledge principles, knowledge practices, and knowledge perspectives for the engineering of systems. Definitive case studies involving systems engineering practice are often provided.

The *Systems Engineering* Journal is included in both the INSPEC and COMPENDEX indices.

The *Journal of Systems Engineering* is produced four times a year: January, April, July, and October. INCOSE Members may access the journal online at the Wiley InterScience® website. Prior registration is required. Registration instructions can be found in INCOSE Connect. Hard-copy subscriptions to The *Systems Engineering* Journal are available for purchase by INCOSE members.

In regards to “best practices,” INCOSE recognizes an outstanding paper from The *Systems Engineering* Journal each year (see Table 2). Any one of these articles, or others published in the journal, could yield several best practices for its particular area of focus within the discipline of SE

To further aid the identification of best practices, topical searches across the full database of SE Journal publications is made possible via the Wiley InterScience site. The search capability provides simple and advanced applications allowing Systems Engineers and engineering teams the opportunity to rapidly identify applicable research and current methods around any SE topic.



INSIGHT

INSIGHT is the newsletter of International Council on Systems Engineering. It is published four times per year: January, April, July, and October. *INSIGHT* features status and information about INCOSE’s technical work, local chapters, and committees and boards. Additionally, related events, editorials, book reviews, trends, and how-to-do articles that are pertinent to the many aspects of a Systems Engineer’s job are also included, as space permits.

Table 2: Outstanding Papers Recognized by INCOSE

Award Year	Title and SE Journal Volume and Number
Awarded 2010	"Universal Architecture Description Framework," <i>Systems Engineering</i> , Vol. 12, no. 2, 2009
Awarded 2010	"Systems Engineering Leading Indicators for Assessing Program and Technical Effectiveness," <i>Systems Engineering</i> , Vol. 12, no. 1, 2009
Awarded 2009	"Defining Changeability: Reconciling Flexibility, Adaptability, Scalability, Modifiability, and Robustness for Maintaining Life Cycle Value," <i>Systems Engineering</i> , Vol. 11, No. 3, 2008
Awarded 2008	"Assessing Risks and Opportunities of Technology Infusion in System Design," <i>Systems Engineering</i> , Vol. 10, no. 1, 2007
Awarded 2007	"A Theory of Enterprise Transformation," <i>Systems Engineering</i> , Vol. 8, no. 4, 2005
Awarded 2006	"Some Future Trends and Implementations for Systems and Software Engineering Processes," <i>Systems Engineering</i> , Vol. 9, no. 1, 2006
Awarded 2005	"Toward a Systematic Approach for Selection of NASA Technology Portfolios," <i>Systems Engineering</i> , Vol. 7, no. 4, 2004
Awarded 2004	"Development and Integration of Winning Technologies as Key to Competitive Advantage," <i>Systems Engineering</i> , Vol. 3, no. 4, 2000
Awarded 2004	"Synthesizing Executable Models of Object Oriented Architectures," <i>Systems Engineering</i> , Vol. 6, no. 4, 2003

Each *INSIGHT* publication has a theme that provides a rich review of a particular topic or industry area and its relevant application of SE. Table 3 provides a listing of past and future publication themes by volume and date for the last year. Each volume is available via www.incose.org and fully searchable to help identify best practices by topic or key word search.

Table 3: Previous and Future *INSIGHT* Themes

Vol - Issue - Date		INSIGHT THEME
To Be Published	Vol 14 Issue 1: April 2011	Knowledge Management for Systems Engineering
	Vol 13 Issue 4: December 2010	Systems Development from Deep Sea to Deep Space: Lessons from the Johns Hopkins Applied Physics Lab
	Vol 13 Issue 3: October 2010	2010 International Symposium Coverage: Chicago, Illinois, USA
Published	Vol 13 Issue 2: July 2010	The Best of Loughborough: Highlights from the Conference on Systems Engineering Research and SEANET
	Vol 13 Issue 1: April 2010	Reflections on the Technical Engine of INCOSE
	Vol 12 Issue 4: December 2009	Model-Based Systems Engineering: The New Paradigm
	Vol 12 Issue 3: October 2009	East Meets West: The Human Dimension to Systems Engineering
	Vol 12 Issue 2: July 2009	The Interplay of Architecture, Security, and Systems Engineering
	Vol 12 Issue 1: April 2009	Cognition: Pursuing the Next Level in System Performance
	Vol 11 Issue 5: December 2008	Space Systems: Navigating Complexity to Explore the Unknown



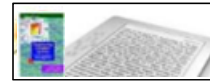
i-PUB Publications Database

i-Pub is a search engine for publications presented at INCOSE symposia and conferences. The proceedings of the many INCOSE symposia and conferences hold a wealth of knowledge and comprise a key resource for the systems community. i-Pub, INCOSE’s online publications database, provides online access to this resource. INCOSE members can search for a paper using the author’s name, a keyword in the title or abstract, or the year.

INCOSE Members can log onto i-Pub using their INCOSE Connect account—the personalized passport to INCOSE’s many online benefits.

INCOSE will add additional papers as intellectual property releases are received. In particular, INCOSE plans to release papers from INCOSE symposia prior to 2001 (currently, only abstracts are available); regional INCOSE conferences, such as EuSEC, MARC, HRA, and UK; and other chapter events.

i-Pub currently contains all symposia abstracts since 1991. INCOSE has released all papers from INCOSE/NCOSE symposia from 1991–2007 in this database. Papers from European Systems Engineering Conferences (EuSEC) are also available in the database, with permission from AFIS. Furthermore, contact information for authors who are presently members of INCOSE can be found in the searchable member directory.



Community Resources

In conjunction with the authors and publishers, INCOSE has made the following books available free to all those interested in systems and the systems approach.

Engineering Complex Systems with Models and Objects
by David W. Oliver, Timothy P. Kelliher, and James G. Keegan, Jr.

This book explains how to apply SE modeling approaches not only to products, processes, and business enterprises but also to the description of the process of SE. The result is an easily understood description of the SE process which can be tailored to the many methodologies, notations, and tools that compete for adoption. The book provides an engineering basis for: specification of near-optimal products and processes; tailoring the SE process to commercial or aerospace projects; selection of a specific methodology and notation; selection and development of tools for automation; and training students in a systems development disciplines.

The Systems Approach: Fresh Solutions to Complex Problems Through Combining Science and Practical Common Sense

by Simon Ramo and Robin K. St. Clair.

From the first chapter: The systems approach has beginnings far back in history. But as modern systems analysis has broadened, it has already begun to be controversial and misunderstood. The systems approach has quickly attracted overly zealous proponents and, as often, misinformed detractors. Substantial disagreement exists among the professionals as to how useful the approach is for the bigger problems of society, or for smaller ones when they are more “social” than “technological.”



INCOSE WEBINARS

INCOSE also offers free monthly web-based service to the greater SE community in the form of webinars. These webinars are yet another valuable INCOSE resource one can use to obtain

best practices and help to remain current on leading practices within SE.

Once a month, recognized experts in the field present the state of the art in SE (see Table 4). These presentations are conducted live, via the Internet. Each will last for one hour, including an opportunity for discussion and questions.

Table 4: Recent INCOSE Webinars

Date	Webinar Title
21 July 10	ISO/IEC 15288 and 12207 Modeling to Assess Harmonization
29 June 10	Complex Systems Engineering Working Group Webinar: Relevance of Natural Systems Science to Systems Engineering
19 May 10	An Update on INCOSE Professional Certification and the New Expert
21 Apr 10	Leading Indicators for Systems Engineering Effectiveness
17 Mar 10	Lean Enablers for Systems Engineering
17 Feb 10	Introducing Systems Engineering Principles to the Commercial Product Development Cycle
20 Jan 10	The Importance of Early Systems Engineering Activities and Associated Technical Products in Support of U.S. Department of Defense Weapon Systems Development
16 Dec 09	Architecting Resilient Systems
18 Nov 09	K-12 Science, Technology, Engineering, and Mathematics Education
21 Oct 09	INCOSE President-Elect Candidates Present Their Position Statements
16 Sep 09	Divergent Thinking in Systems Engineering Practice: Is There a Shortfall?
19 Aug 09	Delivering NextGen—A System Engineering Perspective

INCOSE WORKING GROUPS

The heart of INCOSE’s Technical Operations effort is its more than 30 Working Groups (see Table 5), comprised of INCOSE members who—

- Are interested in building their expertise and contacts in a particular area of SE by working and networking with others with an interest and expertise in the same area, and/or;
- Have expertise to some level and are interested in sharing that with others as well as, on a voluntary basis,

participating in the creation of Working Group products that will bring value to INCOSE stakeholders.

Working Group members participate in such things as:

- Creating products unique to the Working Group for INCOSE stakeholder use (e.g., Measurement Guide, Tools Database)
- Reviewing papers in their area that have been submitted for an INCOSE International Symposium or an INCOSE co-sponsored event
- Forming and/or participating in a panel or tutorial sponsored by the Working Group
- Helping to develop or review international standards
- Developing supporting material for standards (e.g., application guides, training checklists, references to sources of information) for use by INCOSE stakeholders and possible publication for wider use
- Collaborating with other Working Groups on similar projects that require expertise from different areas
- Supporting a technical initiative aimed at furthering the realization of the INCOSE Vision 2020, a view of the future of systems engineering
- Participating with INCOSE Chapters to set up and hold regional technical events
- Researching practices to support INCOSE Corporate Advisory Board (CAB) needs



One example of a product developed by a Working Group is the Requirements Engineering Guide for All (REGAL) developed by the Requirements Working Group (RWG).

REGAL is a web-based interactive solution to find helpful best practices for Systems Engineers performing requirements development and management. It is structured to align with the outline of Version 3 of the *INCOSE Systems Engineering Handbook* and the IPAL as a requirements engineering Book of Knowledge.

The REGAL webpage uses Windows Explorer folders software and is formatted with the *INCOSE Systems Engineering Handbook* outlines on the top left of the page and a list of best practices on the bottom left. The right side of the webpage shows the text of the best practice that the user selects by clicking on the left folder or topic. The user can click the folder to open or close subfolders until the desired text of the best practice is reached. The user can also use the keyword search function to locate a specific best practice or all the best practices under a specific process in the handbook.

Table 5: INCOSE Working Groups

Working Group
Accreditation
Affordability
Anti-Terrorism International
Architecture
Autonomous System Test & Evaluation
Biomedical
Complex Systems
Cost Engineering
Defense Systems
Education
Global Earth Observation System of Systems (GEOSS)
Human Systems Integration
Information Systems
Infrastructure
In-Service Systems
Intelligent Enterprises
Lean Systems Engineering
Life Cycle Management
Measurement
Model-Driven System Design
Motor Sports
Net-centric Operations
Power & Energy Systems
Process Improvement
Requirements
Research
Resilient Systems
Risk Management
Space Systems
Standards
System Safety Integration
Systems Engineering in the Commercial World
Systems Security Engineering
Systems Science
Tools Database
Tools Integration and Interoperability
Transportation
Verification and Validation (V&V)
Very Small and Medium Enterprise

<http://www.incose.org/practice/techops/>

The following features are provided by REGAL:

- Allow practitioners to comment and submit new best practice
- Allow practitioners to rate practices interactively and view other people's ratings of practices

- Allow practitioner to define a context in which the good practices are available
- User comments and newly submitted best practices will be monitored and implemented, if deemed valuable. REGAL is intended to be a dynamic, growing Body of Knowledge for Requirements Engineers.

Table 6 below provides a summary of some of the identified best practices by the RWG within REGAL.

Table 6: REGAL TOP 20 Best Practices

Best practice
Create links to establish traceability
Consider verification activities during the development of requirements
Avoid premature solution details
Avoid multiple instances of the same requirements
Avoid ambiguous terms and grammar in expressing requirements
Document the system goals as part of scope
Detail each test by method, stage and success criteria
Define the system context
Ensure that every requirement is quantified
Define new products in terms of deltas on existing products
Define a standard document structure for collecting requirements
Ensure that interface requirements are complete.
Ensure that the requirements can be verified
Establish a glossary for the requirements
Evaluate feasibility before accepting requirements.
Get management sponsorship of requirements engineering deployment
Identify and clearly distinguish traceability relationships
Identify key requirements
Obtain approval on requirements
Organize formal requirements reviews

<http://www.incose.org/REGAL/Regal.aspx>



INCOSE'S DISCUSSION FORUM

INCOSE's threaded discussion forum allows members to discuss systems topics of interest, share lessons learned and prior experience, and interact with other members from around the world. The discussion forum organizes posts in a way that makes it easy for Systems Engineers to quickly find the information they are interested in without having to sift through unrelated information. INCOSE's discussion forum facilitates broader dialog, capturing valuable exchanges for future use and fostering communities of interest. The overall objective is to help more members find technical fulfillment in INCOSE. This resource allows for a rich dialog among SE professionals and can be an outstanding source for best practices and collaboration.

Discussion forum features allow users to "subscribe" to forums or individual topics. Subscribed users will be e-mailed when new messages are posted to each area for which they are subscribed.

Users who are subscribed to one or more forums will receive a single digest e-mail of all new posts every 15

minutes. E-mails will not be sent if there are no new posts during that time period.

Users who are subscribed to a topic will receive an e-mail every time a new message is posted to the topic.

OTHER INCOSE RESOURCES

Other resources from INCOSE that could provide and assist in finding SE best practices not covered within this paper include: INCOSE's monthly eNOTE, involvement in INCOSE annual International Workshop, and Tutorials and Panel Discussions conducted at the International Symposium. INCOSE Technical Data includes any technical information developed within INCOSE or under INCOSE auspices, which meets INCOSE standards but are not produced as Technical Products. Lastly, several INCOSE products were not covered within this paper. These products include INCOSE's Measurement Primer, Metrics Guidebook, Technical Measurement Guide, Tools Database, SE Primer, Conops of SE Education Community, SECAM, SE Leading Indicators Guide, SE Competencies Framework, and Technical Resource Center.

CONCLUSION

INCOSE provides a broad range of resources for the System Engineer to engage, which, when wisely and properly applied, can wield significant power toward improving program and system performance. The resources provided by INCOSE range from publications to interactive forums. INCOSE also provides several channels to build

collaborative relationships within the Systems Engineering professional community through the International Symposium, International Workshop and local chapter events. These events often afford the greatest opportunity to tap the incredible wealth of information available within INCOSE - the knowledge and experience of its membership and the products they produce. INCOSE's membership and resources come from industry, academia, and the government. The resources outlined within this paper are easily accessible and searchable for review and application on simple to highly complex technical programs. Although there is no Silver Bullet, one-way-solves-all, or magic wand solution to managing the complexity inherent in today's programs and technical systems, INCOSE's suite of resources and professional network provides a rich toolkit and collaborative environment for the new Systems Engineer and the veteran Systems Engineer alike.

REFERENCES

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