Establishing profiles for Systems Engineering (SE) Standards: a Great help for companies to manage their processes

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Authors

- Université de Toulouse: ~120,000 students, 14 higher education member institutions (4 Universities, 10 Institutes)
- International Research and Industrial center: aerospace, agronomic, health, economics… research platforms

- Research, Innovation and Transfer in Information Sciences and Technologies.
- Complex Systems: integrated, embedded, distributed, mobile, autonomous
- Application: aeronautics, space, telecommunications, transports, production, services, security and defense, energy, healthcare, environment…

- Hefei University
Purpose

- System design becomes complex to manage: necessity to rely on SE standards for companies


⇒ To improve companies 'competitiveness, the choice of the ‘good’ (well adapted) standard is key to achieve performance and success.

- This paper aims at helping companies to chose the right standard
  - Presents analysis + comparison of current releases of SE standards
  - Illustrates how to choose a SE standard on the basis of specific criteria of the project.
Contents

1. Current situation and Motivations
3. Analysis and Comparison of SE standards
4. Extension of the study: a tailor-made standard?
5. Conclusion and Perspectives
1. Current situation & Motivations

- With the growing complexity of systems, it is necessary to rely on Systems Engineering standards.

- Since 1969, many systems engineering standards have been drawn up in different fields of application: military, aeronautics, automatic, management... [Weigel, 2000; Sahraoui, 2006]

- Difficult to identify features of standards:
  - Different profiles: domain of activity, goal, scope, size of company, features of systems...
  - Standards undergo many changes at each release.

Need for a company to be able to characterize SE standards to choose the most-adapted one to rely on.
Evolution of SE standards

- At the same time, some of the editorship of ANSI/EIA-632 was present in the ISO/IEC-15288 construction.

- Now ANSI/EIA-632, ISO/IEC-15288 and IEEE-1220 play the most important roles [Doran, 2000, Roedler, 2002].
This paper provides an help to company establishing its own SE policies: choice of a reference SE standard, example of how to ‘customized’ a standard if needed.
2. Introduction to SE standards

- **ANSI/EIA 632:1998**
  - Results from a joint project of EIA and INCOSE (1994)
  - Extensively used by the industry and the Air Force
  - Provides a set of fundamental processes to guide developers in engineering or re-engineering a system.
  - Focuses on enterprise-based systems
  - *One of the most useful features: the close connection between processes.*
  - *Description of activities & tasks at a high level of abstraction => flexibility to the developer (constraints are less detailed), wide range of applications*
2. Introduction to SE standards

- ANSI/EIA 632:1998 structure
  - 13 processes, 5 groups
  - Describes relationships between processes, purpose & related requirements of each process
2. Introduction to SE standards

  - Developed in 2002, derives from EIA-632
  - First international standard to provide a comprehensive set of life cycle processes for most man-made systems.
  - *Purpose*: provide a defined set of processes to facilitate communication among the acquirers, suppliers and other stakeholders.
  - *Covers* the system’s entire lifecycle (6 stages), from conception through to retirement of the system.
## 2. Introduction to SE standards

- **ISO/IEC 15288:2008 structure**

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<tr>
<th>Agreement Processes</th>
<th>Acquisition</th>
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<th>Stakeholder Requirements Definition</th>
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<th>Special Process</th>
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- **25 processes, 4 groups**
- **Describes processes, purpose and outcomes**
2. Introduction to SE standards

- **IEEE 1220:2005**
  - First published in 1995
  - Purpose: manage a system from initial concept through development, operations, and disposal.
  - *Scope covers the entire system life cycle, while focusing on product development.*
  - *More detailed than the EIA-632 and IEC-15288: less flexibility…*
  - *Can be used in complement to the ISO/IEC-15288 standard*
2. **Introduction to SE standards**

- **IEEE 1220:2005 structure**

<table>
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<tr>
<th>General Requirements</th>
<th>System engineering process</th>
<th>Policies and procedures for system engineering</th>
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<td>Planning the technical effort</td>
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<td>Integrated data package</td>
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<td>Drawing tree</td>
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<td>Technical reviews</td>
<td>Integration of the system engineering effort</td>
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<td>Quality management</td>
<td>Product and process improvement</td>
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<tr>
<th>Application of system engineering throughout the system life cycle</th>
<th>System definition stage</th>
<th>The system engineering process</th>
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<td>Preliminary design stage</td>
<td>Requirements analysis</td>
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<td>Detailed design stage</td>
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<td>Production and support stage</td>
<td>Functional analysis</td>
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<td>Fabrication, assembly, integration, and test stage</td>
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<td>Simultaneous engineering of life cycle processes</td>
<td>Synthesis</td>
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- Defines 14 general requirements, 6 stages and 8 processes
3. Analysis & Comparison of SE standards

What do standards share

- Describe best SE practices.
- Approved through a defined industry-approval process.
- Say what should be done, but not how to do it:
  - focus on processes and related activities & tasks rather than on methods & tools.
- May implicitly evoke a life cycle to provide a context.
3. Analysis & Comparison of SE standards

What differs

- **Scope** (number of processes and structure): induces or not complexity.
- **Systems life cycle** coverage: dimension of the standard application through life cycle
- **Level of detail** (or abstraction level): provides flexibility, allows expandability.
- **Focus**: type of system, company, specific development stage…
## Comparison & Conclusions

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<td>Defines 5 process groups, a total of 33 requirements for 13 processes, gives tasks and outcomes for each requirement, gives some application context and key concepts</td>
<td>Defines 3 concept groups and 4 process groups, 25 system life cycle processes, gives the purpose, tasks and outcomes for each process</td>
<td>Defines 14 general requirements for developing a total system, gives 8 sub processes for one systems engineering process, gives the tasks and activities for each sub process</td>
</tr>
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<td><strong>System life cycle</strong></td>
<td>Assessment of opportunities, Investment decision, System concept development, Subsystem design and pre-deployment, Development, operations, support and disposal</td>
<td>Conception, Development, Production, Utilization, Support, Retirement</td>
<td>System definition, Preliminary design, Detailed design, FAIT, Production, Support</td>
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<td><strong>Level of detail of the processes</strong></td>
<td>Higher level than ISO/IEC-15288, lower than IEEE-1220</td>
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<td>Product-oriented systems</td>
<td>The engineering activities necessary to guide product development</td>
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- EIA-632 is more suitable for engineering enterprise-based systems; it focuses on technical management, validation and verification aspects.
- IEC-15288 is more suitable for engineering complex systems, especially projects that cover an entire system life cycle.
- IEEE-1220 focuses on the development stage rather than the whole system life cycle or the technical management aspects.

This analysis provides help to companies to chose a reference SE standard.
4. **Extension: a tailor-made standard?**

And if no standard fully satisfies all the company selection criteria?

⇒ We consider the option of extending a standard with another one, to obtain a multi-standard reference

- **Example** on a research project, DECWAYS
  - We needed a standard that
    - Covered the entire system life cycle, from conception to retirement
    - Provided a detailed view of the V&V processes.
    - Detailed relationships between processes.
    - Offered a medium level of details to provide flexibility.
4. Extension: a tailor-made standard?

- Evaluation of standards with respect to project needs:
  - Covers all the systems life cycle: ISO-15288
  - Provides a detailed view of the V&V processes: ANSI/EIA 632
  - Gives relationships between processes: ANSI/EIA 632
  - The level of detail is medium: ANSI/EIA 632

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| **System life cycle** | - Assessment of opportunities  
- Investment decision  
- System concept development  
- Subsystem design and pre-deployment  
- Development, operations, support, retirement | - Concept identification  
- Concept selection  
- Concept evaluation  
- Concept utilization  
- Concept support  
- Concept retirement | - System definition  
- Preliminary design  
- Detailed design  
- FAIT  
- Production  
- Support |
| **Level of detail of the processes** | Higher level than ISO-15288 but lower than IEEE-1220 | Lowest level | Highest level |
| **Focal point** | Focus on systems | Product-oriented systems | The engineering activities necessary to guide product development |
| **Validation** | Gives more details about validation: requirement validation; solution representations, end product validation | Requirement validation | End product validation |
| **Verification** | Gives more details about verification: design solution and end product verification; enabling product readiness | Function verification | Design verification |
| **Internal consistency** | Highest, gives the relationship between the processes, activities | Higher than IEEE-1220 | Lowest |
Proposal: use a combination of standards.

⇒ Using ANSI/EIA-632 as the main body of the multi-standard because it satisfies most of the needs of the project

⇒ Using integration process, maintenance process and disposal process from ISO/IEC 15288 to complete the ANSI/EIA-632 in order to cover the whole system life cycle.
4. Extension: a tailor-made standard?

- Another example where it may be useful to rely on a multi-standard:
  - A company uses EIA-632 standard, well fitted to the design stage of its products
  - In order to respect some new quality criteria (environment, sustainable development) now it has to consider the retirement processes…
  
  ⇒ Expensive to change from EIA-632 to another standard for all the processes!...

⇒ The company can chose using the retirement processes defined by ISO/IEC-15288 standard and add this unique process to their industrial processes, based on EIA-632
4. Extension: a tailor-made standard?

- Obvious interests: economical, organizational, …

- What about the risks?
  - Inconsistency between processes?
    ⇒ Only need to switch tasks
  - Different abstraction levels...
    ⇒ Standards give definition, purpose, tasks, activities and outcomes of each process
  - Correspondence between standards structures?
    ⇒ Processes can be distributed in different groups
  - Definitions are the same?
    ⇒ Definitions are identical or similar
5. Conclusion

- This paper compared and analyzed the current releases of SE standard
- Objective: help companies to define a SE standard to rely on
  - Definition of comparison criteria
  - Evaluation of standards
    - Propose to chose the most suitable
    - or adapt it by extension: multi-standard reference (no risk to use a ‘customized’ reference)
Perspectives: on SE standards

- Today, the ISO/IEC 15288 norm seems to become a shared reference…
- However been able to adapt a norm to company practices is of high importance in industry
- To have a better adaptability of standards, need to:
  - Consider other good practices such a described in INCOSE Handbook or SEBoK
  - Refine the analysis including more criteria (revision frequency, difficulty of application…)
- Relying on a SE standard is necessary, even though the choice is not trivial, …
- … but is not enough to ensure the success of projects!
Perspectives: on SE management

- Managing SE processes in an coherent and optimized way is becoming a tricky issue to improve industrial performance in today competitive context

  ⇒ Cooperation between SE and Project Management (PM) is necessary for the success of projects

- Integrating SE and PM now lies at the very heart of current research and economic / industrial concerns.

  ⇒ A first means to make processes cooperate is to use associated standards from both domains.

    ⇒ standards need to be adapted to company practices

    ⇒ but need also to be compatible with each other
Perspectives:

- Compare PM with SE standards to determine the most suitable standard from each domain

But also

- Elaborate indicators based on both SE and PM domains to help managing engineering projects

- Develop a tool
  - to measure the progress of project based on the values of the indicators
  - to guide the project in a right way
  - that offers decision support means to managers & engineers
To read...


Rui XUE, Claude Baron, Philippe ESTEBAN, “Aligning systems engineering and project management standards to improve the management of processes”, 23rd international conference on systems engineering, 19-21, August, 2014 Las Vegas, USA.

Rui XUE, Claude Baron, Philippe ESTEBAN, “Towards the success of design projects by the alignment of processes in collaborative engineering”, a Joint conference on mechanical design engineering and advanced manufacturing, 6 pages, 18-20/06/2014, Toulouse, France.

Thank you!