Fundamentals for Future Systems Engineering

Lead Author: *Rick Adcock*, ***Contributing Author:*** *Duane Hybertson*

This article forms part of the Systems Fundamentals knowledge area (KA). It considers future trends in SE and how these might influence the evolution of future fundamentals.

The SEBoK contains a guide to generalized knowledge about the practice of SE. It does not pass judgement on that knowledge. However, it can be useful in some cases to indicate which parts of the knowledge are rooted in existing practice and which point towards the future evolution of SE.

This article provides a sketch of how SE is changing and suggests how these changes may affect the future of systems engineering, the SEBoK, and the foundations in Part 2.

☐

Contents

Additional References

INCOSE Vision

The INCOSE Vision 2025 statement (INCOSE 2014) depicts some future directions in:

Broadening SE Application Domains

- SE relevance and influence will go beyond traditional aerospace and defense systems and extend into the broader realm of engineered, natural and social systems
- SE will be applied more widely to assessments of socio-physical systems in support of policy decisions and other forms of remediation

More Intelligent and Autonomous Systems

- Systems of the future need to become smarter, self-organized, sustainable, resource-efficient, robust and safer
- The number of autonomous vehicles and transportation systems needs to increase
- Systems become more “intelligent” and dominate human-safety critical applications

Theoretical Foundations

- SE will be supported by a more encompassing foundation of theory and sophisticated model-based methods and tools allowing a better understanding of increasingly complex systems and decisions in the face of uncertainty
- Challenge: A core body of systems engineering foundations is defined and taught consistently across academia and forms the basis for systems engineering practice

In this article we will consider how the fundamentals of SE might need to evolve to support this vision.

How will SE Change?

In Types of Systems, we describe three general contexts in which a SE life cycle can be applied. In a product system context, the outputs of SE focus on the delivery of technological systems. While such systems are designed to be used by people and fit into a wider problem-solving context, this context has been seen as largely fixed and external to SE. The service system context allows SE to consider all aspects of the solution system as part of its responsibility. This is currently seen as a special case of SE application largely focused on software intensive solutions. The enterprise system context offers the potential for a direct application of SE to tackle complex socio-technical problems, by supporting the planning, development and use of combinations of service systems. While this is done, it can be difficult to connect to the product focused life cycles of many SE projects.

The role of the systems engineer has already begun to change somewhat due to the first two of the future trends above. Changes to the scope of SE application and the increased use of software intensive reconfigurable and autonomous solutions will make the service system context the primary focus of most SE life cycles. To enable this, most product systems will need to become more general and configurable, allowing them to be used in a range of service systems as needed. These life cycles are increasingly initiated and managed as part of an enterprise portfolio of related life cycles.

In this evolution of SE, the systems engineer cannot consider as many aspects of the context to be fixed, making the problem and possible solution options more complex and harder to anticipate. This also means the systems engineer has greater freedom to consider solutions which combine existing and new technologies and in which the role of people and autonomous software can be changed to help deliver desired outcomes. For such systems to be successful, they will need to include the ability to change, adapt and grow both in operation and over several iterations of their life cycle. This change moves SE to be directly involved in enterprise strategy and planning, as part of an ongoing and iterative approach to tackling the kinds of societal problems identified in the INCOSE vision.

This evolution of both the role and scope of SE will also see the system of systems aspects of all system contexts increase. We can expect System of Systems Engineering to become part of the systems engineering of many, if not most, SE life cycles.

Evolution of Fundamentals

These ongoing changes to SE place more emphasis on the role of autonomous agents in systems engineering, and agency will be an area of increased emphasis in the systems engineering and SEBoK of the future. Hybertson (2019) spells out in more detail the increased role of agents and agency in future SE. Moving from a total control model to a shared responsibility model changes the nature of engineering to something more like collective actualization, as proposed by Hybertson (2009 and 2019). Systems will represent a combination and interplay of technology and social factors, and they can range from technical product to service provider to social entity. In many cases they will be a socio-technical combination or hybrid.

The above trends have an impact on SE foundations, including technical aspects, social aspects, and ethical aspects. Inclusion of people in systems implies significant expansion of foundation sciences, to provide principles, theories, models, and patterns of the human, biological, social, and agent realm as well as the technical and physical realm. Emphasis on agents implies a revised conceptualization of system change, from the traditional model of mechanistic and controlled fixes and upgrades to a more organic change model that involves growth, self-learning, self-organizing, and self-adapting. Ethical considerations will include how to allocate responsibility for a system in a shared responsibility model. Further discussion of the expanded foundation and a list of foundation disciplines for future SE are presented in (Hybertson 2009 and 2019).

References

Works Cited

Hybertson, D. (2009). *Model-Oriented Systems Engineering Science: A Unifying Framework for Traditional and Complex Systems*, Boca Raton, FL, USA: Auerbach/CRC Press.

Hybertson, D. (2020 forthcoming). *Systems Engineering Science*. Chapter in G. S. Metcalf, H. Deguchi, and K. Kijima (editors in chief). Handbook of Systems Science. Tokyo: Springer.

INCOSE (2014). “A world in motion: Systems engineering vision 2025.” International Council on Systems Engineering.

Primary References

None.

Additional References

None.

< Previous Article | Parent Article | Next Article >
SEBoK v. 2.10, released 06 May 2024