Systems Engineering and Quality Attributes

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Every system has a set of properties that are largely a function of the system as a whole rather than just its constituent parts. There are dozens of these properties such as security, reliability, safety, resistance to electromagnetic interference, usability, and resilience. This Knowledge Area (KA) describes many of the most important such properties and how they are realized. The vocabulary to talk about these properties is not standard. Alternatively, they are called *quality attributes, non-functional requirements, -ilities,* and *specialties.* In this KA, the term specialty engineering refers to the collective engineering of all quality attributes of a system.

Quality attributes are often interdependent rather than orthogonal; e.g. making a system more secure may make it harder to use but also safer. Increasing system reliability often requires using more expensive parts and adding redundant components. Hence, higher reliability often means higher cost to deliver a system – another system property. However, higher reliability might mean lower maintenance cost – another system property. A systems engineer typically makes many decisions and takes many actions with regard to system properties; e.g. specifying which properties are important for a particular system, stating how those properties will be measured, trading off conflicting properties, and verifying that a system has the specified properties. Barry Boehm (2016), as the lead for a project of the Systems Engineering Research Center, introduced an ontology to describe system quality attributes as a way

of enabling smarter tradeoffs between them and understanding the impact of those trades on cost. Also, see the article on Quality Management for more information on how these decisions and actions are managed. de Weck, et al. (2012) has a lengthy and insightful chapter on quality attributes (which they call *-ilities).*

Many consider specialty engineering to be a sub-discipline of SE itself; e.g. they consider security engineering, safety engineering, resilience engineering, etc. to be part of SE. Others consider them to be stand-alone disciplines in their own right with close ties to SE. Either way, their mastery is important to a system engineer. This KA includes topical articles on several specialty engineering disciplines. Some articles will treat the topic of the article as a sub-discipline of SE itself; others will treat it as a closely related but separate discipline. This disparity reflects both the diversity of opinions on this matter and the fact that SEBoK articles are written by a wide array of authors.

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Contents

Topics

Each part of the SEBoK is divided into knowledge areas (KAs), which are groupings of information with a related theme. The KAs, in turn, are divided into topics. This KA contains articles on the following topics, shown in alphabetical order:

- A Framework for Viewing Quality Attributes from the Lens of Loss
- Human Systems Integration
- Manufacturability and Producibility
- System Adaptability

- System Affordability
- System Hardware Assurance
- System Reliability, Availability, and Maintainability
- System Resilience
- System Resistance to Electromagnetic Interference
- System Safety
- System Security

Over time, this KA will expand to add topical articles about other quality attributes.

Specialty Requirements

The systems engineering team must ensure that requirements about quality attributes (also called specialty requirements) are properly reviewed with regard to their impact on life cycle costs, development schedule, technical performance, and operational utility. For example, security requirements can impact operator workstations, electromagnetic interference requirements can impact the signal in the interfaces between subsystems, and mass-volume requirements may preclude the use of certain materials to reduce subsystem weight.

Engineering specialists audit the evolving design and resulting configuration items to ensure that the overall system performance also satisfies the specialty requirements. Including appropriate specialty engineers within each systems engineering team ensures that all specialty requirements are identified and balanced throughout the development cycle.

Integration of Specialty Engineering

Integration of specialty engineering into a project or program is, or should be, a major objective of systems engineering management. (Endler 2016, Kossiakoff et al. 2020) With properly implemented procedures, the rigor of the systems engineering process ensures participation of the specialty disciplines at key points in the technical decision-making process. Special emphasis on integration is mandatory because a given design could in fact be accomplished without consideration of these specialty disciplines, leading to the possibility of system ineffectiveness or failure when an unexamined situation occurs in the operational environment.

For example, human factors considerations can contribute to reduced workloads and therefore lower error rates by operators in aircraft cockpits, at air-traffic consoles, or in nuclear reactor stations. Similarly, mean-time-to-repair features can significantly increase overall system availability in challenging physical environments, such as mid-ocean or outer space or in safety critical environments such as hospital intensive care units or in traffic control systems in city centers. Specialty engineering requirements are often manifest as constraints on the overall system design space. The role of systems engineering is to balance these constraints with other functionality in order to harmonize total system performance. The end goal is to produce a system that provides utility and effectiveness to the customer at an affordable price.

As depicted in Figure 1, systems engineering plays a leadership role in integrating traditional disciplines, specialty disciplines, and unique system product demands to define the system design. Relationships for this integration process are represented as interactions among three filters.

The first filter is a conceptual analysis that leverages traditional design consideration (structural, electronics, aerodynamics, mechanical, thermodynamics, etc.). The second filter evaluates the conceptual approach using specialty disciplines, such as safety, affordability, quality assurance, human factors, reliability and maintainability, producibility, packaging, test, logistics, and others, to further requirements development. Design alternatives that pass through these two processes go through a third filter that incorporates facility design, equipment design, procedural data, computer programs, and personnel to develop the final requirements for design selection and further detailed development.
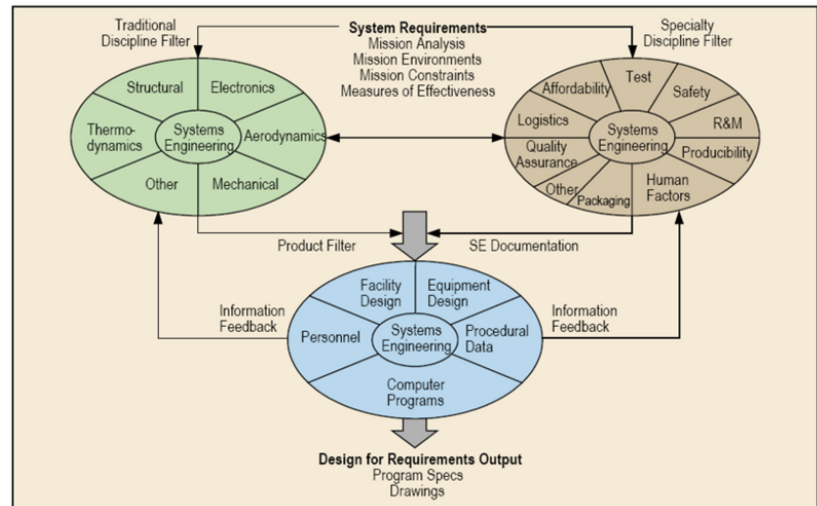
Figure 1. Integration Process for Specialty Engineering (USAF 2000). Released by the U.S. Air Force.

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Additional References

None.

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