

## A SYSTEMS ENGINEERING FRAMEWORK

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**Abstract.** This paper proposes a suitable framework for consideration of the elements of Systems Engineering. A framework is necessary due to the breadth, complexity and interrelationships that exist within the Systems Engineering discipline. Current frameworks such as those contained in engineering standards necessarily contain complexity, terminology and detail to guide Systems Engineers. However these attributes make them less than ideal for the delivery of education and training. The Systems Engineering Body of Knowledge (SEBOK) framework proposed in this paper divides Systems Engineering into Processes, Management, Tools and Related Disciplines. The SEBOK framework has been tested through the development and delivery of two courses of study; an introductory course and a practitioner's course. Initial feedback from both courses indicates that the SEBOK is an effective framework for the consideration of Systems Engineering.

### INTRODUCTION

Systems Engineering, as we know it today, emerged from the United States Department of Defense acquisition programs of the 1950s. These programs often involved: emerging technology and the subsequent high technical risk; complex and challenging user requirements; and large numbers of different technical disciplines. Systems Engineering methodologies and practices have continued to develop since the 1950s, and are widely applied to many of today's challenging system acquisition projects.

The focus of Systems Engineering is on the "system" as a whole, requiring it to maintain a strong interdisciplinary approach. Project Management, Quality Assurance, Integrated Logistics Support, and the traditional design disciplines such as Hardware and Software Engineering are but a few of the many disciplines that must become part of a coordinated Systems Engineering effort. Discussions on Systems Engineering become complicated by the broad mandate of the System, the complexity and interrelationship of the many Systems Engineering constituents, and the relationships with other disciplines throughout the entire System lifecycle.

The ability to understand a complex subject such as Systems Engineering is greatly enhanced by a solid framework within which concepts can be considered greatly enhances. An excellent example is the Project Management Body of Knowledge (PMBOK) [1] that provides a clear framework upon which many Project Management courses are based. Without an equivalent framework, the broad scope of Systems Engineering soon becomes confusing given the complexity of its components and their many interrelationships. There are a number of excellent Systems Engineering standards available today which seem to provide such a framework, but each standard contains complexity, terminology and detail that requires substantial interpretation. The entry level of many students, young engineers and project managers does not allow the use of such standards as effective Systems Engineering frameworks.

This paper proposes a framework within which the Systems Engineering discipline can be understood and implemented.

### SYSTEMS ENGINEERING BODY OF KNOWLEDGE

A Systems Engineering Body of Knowledge (SEBOK) [2] has been synthesised through a thorough survey of existing Systems Engineering publications and standards. The main

aim of the SEBOK is to develop a framework that is able to withstand the sometimes rapid changes in Systems Engineering processes and practices.

### System Lifecycle

The SEBOK framework is based on the lifecycle approach to engineering a system and draws on the popular and familiar system lifecycle contained in Blanchard [3] and MIL-STD-499B [4]. The lifecycle model used in the SEBOK is shown in Figure 1.

This model was selected as it shows sufficient detail in the early stages of the acquisition phase where Systems Engineering arguably has the potential to make the most significant contributions. In addition, there is a clear delineation between acquisition and utilisation phases allowing the application of Systems Engineering during utilisation to be investigated and documented. The focus of the SEBOK and its framework emphasises that a system begins with a perceived need and finishes upon disposal; the so called "cradle-to-the-grave" approach.

### SEBOK Framework

The proposed framework developed within the SEBOK is shown in Figure 2. By referring to this framework throughout the SEBOK, readers are able to maintain a clear focus on where they currently are within the Systems Engineering course.

### Systems Engineering Processes

Systems Engineering processes and tasks are divided into the lifecycle stages within which they typically occur. The SEBOK uses the classic "Analysis-Synthesis-Evaluation" loop as the basic Systems Engineering process, and shows how this loop is iteratively applied throughout the system lifecycle. The SEBOK does not attempt to investigate exhaustively detailed Systems Engineering processes. Instead, it concentrates on the intent and main aim of each phase, and explains some of the likely techniques that may be used to arrive at that aim. For example, the tasks completed during Conceptual Design are shown to focus on achieving a clear and complete definition of the system-level requirements. The concepts of design reviews and audit, test and evaluation, specifications and standards (to name a few) are introduced during this part of the SEBOK, as an effective lead-in to the section on Systems Engineering Management.