

## THE STATUS OF MODELS IN SYSTEMS ENGINEERING

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**Abstract:** Systems approaches inevitably rely heavily on models to develop understanding and aid communication and decisions. In systems engineering (SE) these system considerations and modelling lead directly to a design for a purposeful system or process that is implemented in the real world. In the past SE has been associated with hard, well bounded, precedented problems. This paper considers the changing nature of modern systems and their implications on the practice of SE, with particular focus on the role of models in the engineering of complex systems and capabilities. The paper also discusses the status of models at the various stages of the systems life cycle, their enduring nature, the fulfilment of stakeholder expectations and the relationship between soft and hard systems methodologies in SE. Finally, the paper highlights the applicability of systems methods that would not be seen as part of a traditional SE approach.

### INTRODUCTION

This paper considers the nature of systems engineering (SE) and the role that models play within the discipline. It discusses how SE relies heavily on models to develop understanding and aid communication and decisions throughout its application. In SE these system considerations and modelling lead directly to a design for a purposeful system or process that is implemented in the real world. In the past SE has been associated with hard, well-bounded, well-precedented and (it seemed) well-understood problems. Through a consideration of the changing nature of modern systems and the difficulty that is observed in the early stages of the system design process we identify how approaches from other systems research disciplines are enabling modern SE to deliver complex systems and capabilities in the defence world.

### WHAT IS SYSTEMS ENGINEERING?

SE is the application of systems thinking to real-world systems problems in the field of engineering in order to achieve successful solutions to such problems. Engineering is generally considered to mean a process of problem solving, in that some set of objectives are achieved. It is defined as "... the profession of applying scientific principles to the design, construction and maintenance of engines, cars, machines, buildings, roads, electrical machines, communication systems, chemical plant and machinery or aircraft" [1]. Engineering is thus a discipline that aims to solve real-world problems through the application of scientific and technical solutions. *Systems thinking* involves the realisation that many of the things that we deal with in day-to-day existence can be considered to be systems; that is sets of entities related in some way, often to achieve some purpose. These systems can contain (any combination of) people, processes, technology, hardware, software and organisations. Thus the remit of SE is much broader than in the traditional mature engineering disciplines. Further, these systems generally contain sub-systems and are themselves part of wider systems. Indeed these systems, sub-systems and wider systems can be conceived in different ways and from different perspectives. When dealing with systems we need to consider issues such as boundaries, viewpoints and emergence—behaviour manifest at the system level that is not apparent at the sub-system level. SE can thus be seen to

be the discipline that deals with designing systems composed of people, hardware, software, processes and procedures to meet user requirements, within a great variety of wider environmental influences.

SE is thus a systems discipline. As such, we need to consider a variety of systems consideration methodologies when looking at how to "do" SE. As stated above, we consider SE to be a discipline that applies the principles of systems to the practice of engineering. This is not a generally agreed definition. Many people see SE merely as a "systematic" process for the development of systems. Although, of course, process plays a large part in it, this view misses the "systemness" of the subject itself. Thus "traditional SE" is seen as being systematic, not systemic. It is often heard that "SE is a process not a discipline". This leads people to regard SE as dominated by process and the production of "hard" outputs, such as formal documents and hard engineered products. In turn, this leads to an emphasis on corresponding "hard" methods and tools, such as information management tools and formal system design methodologies. We believe that in good SE the notion of system pervades both the process and the product. It is through a systemic consideration of the problem in its domain together with a systematic approach to its solution that designed systems that meet user requirements can be developed with confidence.

What is in a name? A key achievement of Peter Checkland is that he was able to coin an enduring phrase for his approach to problem solving in managed systems—Soft Systems Methodology (SSM). In the name SE we have a term that has existed for 50 years. In that time both the subject and the object have changed substantially; in essence, the words are the same, but the meaning has changed. Thus two people can have a conversation about SE without realising that they are talking about what are, in effect, different things. This is one of the problems that currently beset the discipline—"systems engineering" can mean all things to all men. We believe that the time is right for a re-evaluation of what is meant by SE.

### THE NATURE OF MODERN SYSTEMS CHALLENGES

The process view of SE is reinforced when one is dealing with well-precedented systems problems and solutions, so that SE becomes dominated by the systematic application of these processes, methods and tools to situations that are (apparently) so well understood that we do not need to focus

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