Part I

Fundamental concepts

Chapter 2, *Fundamental Concepts and Terminology* and Chapter 3, *Modeling and Computational Simulation* form the foundation of the book. These chapters are recommended reading for individuals interested in any aspect of verification and validation (V&V) of mathematical models and scientific computing simulations. In Chapter 2, all of the key terms are defined and discussed. The chapter is much more than a glossary because it describes the development of the terminology and the underlying philosophical principles of each concept. The reader may be surprised that this chapter is devoted to fundamental concepts and terminology; however, understanding the underlying concepts is critical because many of the terms (e.g., verification, validation, predictive capability, calibration, uncertainty, and error) have a common language meaning that is imprecise and some terms are even contradictory from one technical field to another. One of the exciting aspects of the new field of V&V is that all of the principles developed must be applicable to *any* field of scientific computing, and even beyond. This is also challenging, and at times frustrating, because the terminology from various technical fields can be at odds with the terminology that is developing in the field of V&V. The discussion presents clear arguments why the concepts and terminology are logical and useable in real applications of scientific computing. Chapter 2 closes with an in-depth discussion of a framework of how all of the aspects of V&V and predictive capability are related and sequentially accomplished.

Chapter 3 discusses the basic concepts in modeling and simulation (M&S) with the emphasis on the physical sciences and engineering. We formally define the terms *system*, *surroundings*, *environments*, and *scenarios*. Although the latter two terms are not used in many areas of the physical sciences, the two terms are very useful for the analysis of engineered systems. We discuss the concept of nondeterministic simulations and why the concept is important in the analysis of most systems. Some fields have conducted nondeterministic simulations for decades, while some have only conducted deterministic simulations. The key goal of nondeterministic simulations is to carefully and unambiguously characterize the various sources of uncertainties, as they are understood at a given point in the analysis, and determine how they impact the predicted response of the system of interest. It is pointed out that there are two fundamentally different types of uncertainty. First, uncertainty due to inherent randomness in the system, surrounding, environments, and scenarios, which is referred to as *aleatory uncertainty*. Second, uncertainty due to our lack of knowledge of the system, surroundings, environments, and scenarios, which is referred to as *epistemic uncertainty*. The second half of Chapter 3 combines these concepts with a conceptual framework for the six formal phases in computational simulation.