# Part V

## Planning, management, and implementation issues

This final section of the book primarily deals with the topic of how managers – both line managers and project managers – plan, implement, develop, and sustain verification, validation, and uncertainty quantification (VV&UQ) capabilities in their organizations. Some readers may feel this topic is inappropriate in a book on scientific computing; however, our experience and the experience of others has convinced us that while technical issues and computing resources are important, they are not the limiting factor in improving the credibility and usefulness of scientific computing used in a decision-making environment. We point out that although computing speed has continued to increase by a factor of ten every four years for multiple decades, we do not believe there has been a comparable impact of the information produced in modeling and simulation (M&S). We believe that nontechnical issues have significantly constrained improvements in the credibility of the information produced in M&S. Examples of these issues are (a) poor allocation of resources relative to the simulation needs of a project, (b) inadequate and ambiguous characterization and understanding of uncertainties in simulations, and (c) the difficulty of management and staff to assess how the time and resources invested in VV&UQ produce a net benefit for the credibility of the simulation results produced.

Chapter 14, Planning and prioritization in modeling and simulation, deals with a process for allocating resources, given a wide range of M&S activities, to best achieve the goals of a project. We take the perspective of the management responsibilities for a large-scale, project-oriented activity as opposed to a research effort or general capability development of a commercial software package. Our discussion applies to both projects within industry and government. We emphasize engineering system projects, but the discussion also applies to the analysis of natural systems. The system of interest could be a new or proposed system in the design phase, an existing system that is being considered for modification or upgrade, or analysis of a system as it presently exists.

Chapter 15, Maturity assessment of modeling and simulation, reviews several approaches for assessing the maturity and, in some sense, the quality of a M&S effort. Given our perspective of scientific computing, we discuss the strengths and weaknesses of several well-developed approaches. We then present a detailed discussion of a recently developed technique that has been used at Sandia National Laboratories. The procedure gives a description of four levels of maturity for the following technical contributors to M&S: representation and geometric fidelity, physics and material model fidelity, code verification, solution verification, model validation, and uncertainty quantification and sensitivity

analysis. The procedure has proven very beneficial in assessing progress in M&S activities, as well as helping identify activities where improvements are needed.

The concluding chapter of the book is Chapter 16, Development and responsibilities for verification, validation, and uncertainty quantification. We present a summary of some of the key research topics that we feel are needed to advance VV&UQ in scientific computing. This list is not meant to be comprehensive, but only suggestive. We then discuss our view of staff and management responsibilities in VV&UQ activities. Ours is primarily a business perspective of M&S, i.e., how M&S can produce credible information on which to make decisions. We then give a brief discussion of our ideas on how V&V databases might be developed in various technical communities. We close with a few final remarks on the role of engineering societies and the International Organization for Standardization (ISO) in the development of engineering standards in V&V.