PREFACE

Current trends indicate that, in general, the complexity of systems is increasing, with constantly changing requirements and the introduction of new technologies on a continuing and evolutionary basis. The life cycles of many systems are being extended, and many of the systems (or products) in use today are not meeting the needs of the customer/user in terms of performance, quality, and overall cost-effectiveness. At the same time, there is a greater degree of "outsourcing" and the utilization of suppliers throughout the world, there is a need for greater cooperation and exchange, and competition is increasing in a global environment. This is happening at a time when available resources are dwindling worldwide.

Given today's environment, there is an ever-increasing need to develop and produce systems that are robust, reliable and of high quality, supportable, cost-effective, and that will respond to the needs of the customer in a satisfactory manner. From past experience, the majority of the problems noted have been the direct result of not applying a *systems* approach in meeting the desired objectives. That is, the overall requirements for the system in question were not well defined from the beginning; a bottom-up (versus top-down) approach was followed in the system development process; the perspective relative to meeting a customer need was relatively "short-term"; and, in many instances, the philosophy has been to "design it now and fix it later"! In essence, the system design and development process has suffered somewhat from the lack of good early planning and the subsequent definition of *requirements* in a complete and methodical manner. This approach has turned out to be quite costly in the long term, particularly in assessing the risks associated with the decision-making process during the early stages of system development.

The combination of these and related factors has created a critical need—that is, the requirement for developing and producing (or constructing) well-integrated, high-quality, cost-effective systems with complete customer (user) satisfaction in mind. In this highly competitive resource-constrained environment, it is now more important than ever to ensure that the principles and concepts of *system engineering* are properly implemented in both the design and the development of new systems and/or the reengineering of existing systems. System requirements must be defined well from the beginning. The system must be viewed in terms of *all* of its components on a totally integrated basis: prime equipment, software, operating personnel, facilities, data and information, the production and distribution process, and the elements of main-

tenance and support. A top-down, integrated approach must be assumed, with the appropriate allocation of requirements from the system level and down to its various elements. Further, the system must be viewed in terms of its entire life cycle, that is, from conceptual design through preliminary and detailed design, production and/or construction, system utilization, maintenance and support, and system retirement and the recycling/disposal of residual material.

These concepts are not necessarily novel. System engineering has been a subject of interest since the late 1950s and early 1960s (and perhaps even earlier). The principles have been successfully applied in a few programs. However, in most instances, although we may believe that we utilize these methods successfully, we really do not implement them very well (if at all). The successful implementation of system engineering requires not only a *technical* thrust, but a *management* thrust as well. It is essential that one select the appropriate technologies, utilize the proper analytical tools, and apply the necessary resources to enhance the system engineering process. In addition, the proper organizational environment must be established to allow for the successful implementation of this process. Thus, it is necessary, first, to understand and believe in the process and, second, to establish the proper management and organizational structure that will allow it to happen. This approach, in turn, provides a *cultural* challenge for the future.

This text has been developed with the preceding objectives in mind. The basic principles and concepts, the need for system engineering and its applications, and an introduction to some key terms and definitions are covered in Chapter 1. This leads to a comprehensive presentation of the *system engineering process* in Chapter 2. This process commences with the identification of a consumer need and extends through the definition of system operational requirements and the maintenance concept, the identification and prioritization of technical performance measures (TPMs), a description of the system in *functional* terms, and the allocation of requirements to the various elements of the system, synthesis, analysis and design optimization, concurrent engineering and design integration, test and evaluation, production and/or construction, distribution and system utilization, maintenance and support, and system retirement and material recycling and/or disposal. Key areas of emphasis for system engineering are noted. A thorough understanding of this process is fundamental in dealing with the overall subject area. The material in Chapter 2 serves as a baseline for discussion in subsequent chapters.

Given the preceding overview, it is appropriate to delve further into some of the objectives of system engineering. One goal includes the integration of a wide variety of key design disciplines into the total mainstream system design effort. Chapter 3 provides an introduction to some of these disciplines: software engineering, reliability, maintainability, human factors, safety, security, manufacturing and production, logistics and supportability, disposability, quality, environmental and value/cost engineering. Chapter 4 follows with a discussion pertaining to the application of design methods and tools, utilized in such a manner as to enhance the fulfillment of system engineering objectives. The appropriate application of electronic commerce (EC), information technology (IT), electronic data interchange (EDI), and computer-aided methods allows for more front-end analysis, leading to a better design definition at an

earlier stage in the life cycle. Chapter 5 discusses the "checks and balances" in the design process, provided through the accomplishment of design review, evaluation, feedback and control, and the initiation of changes for corrective action as necessary. An objective of system engineering is to provide a strong engineering leadership role relative to the initial definition of system requirements, the necessary *integration* of design activities to ensure effective and efficient results, and the follow-on measurement and evaluation functions to ensure that the initially specified requirements have been met.

The next step addresses the *management* issues pertaining to the application of system engineering requirements to different projects. Chapter 6 leads off with an in-depth discussion of planning and the development of the System Engineering Management Plan (SEMP). System engineering tasks, the development of a work breakdown structure (WBS), program task schedules, and the preparation of cost projections are included. Customer, producer (prime contractor), and supplier activities are covered. Of particular note is the identification, selection, and contracting with key suppliers. Chapter 7 addresses system engineering in a typical project organizational structure, highlighting the differences between functional, product-line, project, and matrix structures. The many interfaces between the customer (consumer), the producer (contractor), and suppliers are addressed, as well as the human resources requirements pertaining to the staffing and management of a system engineering department/group. Having covered the planning, organization, and implementation of a system engineering program, it is essential that one consider a formal *evaluation* to properly measure and assess the degree to which the organization is performing. Chapter 8 introduces organizational "benchmarking" and the application of several different models for the purposes of evaluation and feedback (e.g., the *SECM* and the *CMMI* models). Dealing with the issues of planning and organization only, without the benefit of evaluation and feedback, constitutes only part of the process and tends to inhibit future growth.

Finally, the appendixes include an updated bibliography (Appendix *A*), some supporting "case studies" (Appendix *B*), a detailed description of the life-cycle cost analysis process (Appendix *C*), an in-depth design review checklist (Appendix *D*), a supplier evaluation checklist (Appendix *E*) and a list of abbreviations (Appendix *F*). All of the material included within serves as an excellent supplement to the subjects covered in the eight chapters.

In summary, the intent of this text is to describe system engineering in terms of its objectives and applications and the steps in the system engineering process, and to provide a management perspective for the implementation of programs with a system engineering thrust. It is believed that this text can be effectively utilized in the academic classroom, in support of a continuing education seminar or workshop, and as an "on-the-job" reference guide. Questions and problem exercises are included at the end of each chapter to provide the necessary emphasis where required.

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