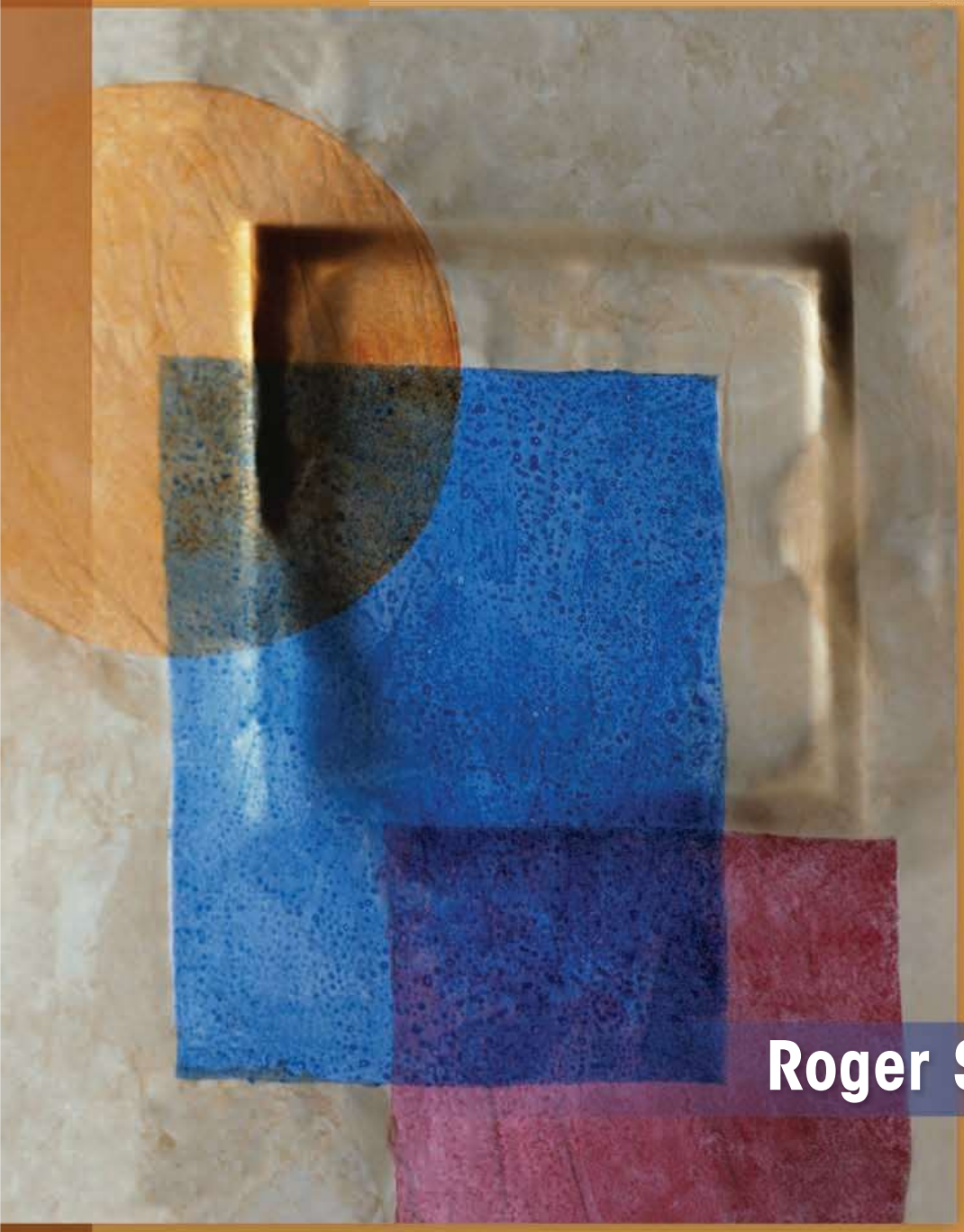
Software Engineering

A Practitioner's Approach



Seventh Edition

Roger S. Pressman

Software Engineering

A PRACTITIONER'S APPROACH

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SEVENTH EDITION

Roger S. Pressman, Ph.D.

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In loving memory of my father who lived 94 years and taught me, above all, that honesty and integrity were the best guides for my journey through life.

About the Author

Roger S. Pressman is an internationally recognized authority in software process improvement and software engineering technologies. For almost four decades, he has worked as a software engineer, a manager, a professor, an author, and a consultant, focusing on software engineering issues.

As an industry practitioner and manager, Dr. Pressman worked on the development of CAD/CAM systems for advanced engineering and manufacturing applications. He has also held positions with responsibility for scientific and systems programming.

After receiving a Ph.D. in engineering from the University of Connecticut, Dr. Pressman moved to academia where he became Bullard Associate Professor of Computer Engineering at the University of Bridgeport and director of the university's Computer-Aided Design and Manufacturing Center.

Dr. Pressman is currently president of R.S. Pressman & Associates, Inc., a consulting firm specializing in software engineering methods and training. He serves as principal consultant and has designed and developed *Essential Software Engineering,* a complete video curriculum in software engineering, and *Process Advisor,* a self-directed system for software process improvement. Both products are used by thousands of companies worldwide. More recently, he has worked in collaboration with *EdistaLearning* in India to develop comprehensive Internet-based training in software engineering.

Dr. Pressman has written many technical papers, is a regular contributor to industry periodicals, and is author of seven technical books. In addition to *Software Engineering: A Practitioner's Approach,* he has co-authored *Web Engineering* (McGraw-Hill), one of the first books to apply a tailored set of software engineering principles and practices to the development of Web-based systems and applications. He has also written the award-winning *A Manager's Guide to Software Engineering* (McGraw-Hill); *Making Software Engineering Happen* (Prentice Hall), the first book to address the critical management problems associated with software process improvement; and *Software Shock* (Dorset House), a treatment that focuses on software and its impact on business and society. Dr. Pressman has been on the editorial boards of a number of industry journals, and for many years, was editor of the "Manager" column in *IEEE Software.*

Dr. Pressman is a well-known speaker, keynoting a number of major industry conferences. He is a member of the IEEE, and Tau Beta Pi, Phi Kappa Phi, Eta Kappa Nu, and Pi Tau Sigma.

On the personal side, Dr. Pressman lives in South Florida with his wife, Barbara. An athlete for most of his life, he remains a serious tennis player (NTRP 4.5) and a single-digit handicap golfer. In his spare time, he has written two novels, The *Aymara Bridge* and *The Puppeteer,* and plans to begin work on another.

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Preface

When computer software succeeds—when it meets the needs of the people who use it, when it performs flawlessly over a long period of time, when it is easy to modify and even easier to use—it can and does change things for the better. But when software fails—when its users are dissatisfied, when it is error prone, when it is difficult to change and even harder to use—bad things can and do happen. We all want to build software that makes things better, avoiding the bad things that lurk in the shadow of failed efforts. To succeed, we need discipline when software is designed and built. We need an engineering approach.

It has been almost three decades since the first edition of this book was written. During that time, software engineering has evolved from an obscure idea practiced by a relatively small number of zealots to a legitimate engineering discipline. Today, it is recognized as a subject worthy of serious research, conscientious study, and tumultuous debate. Throughout the industry, software engineer has replaced programmer as the job title of preference. Software process models, software engineering methods, and software tools have been adopted successfully across a broad spectrum of industry segments.

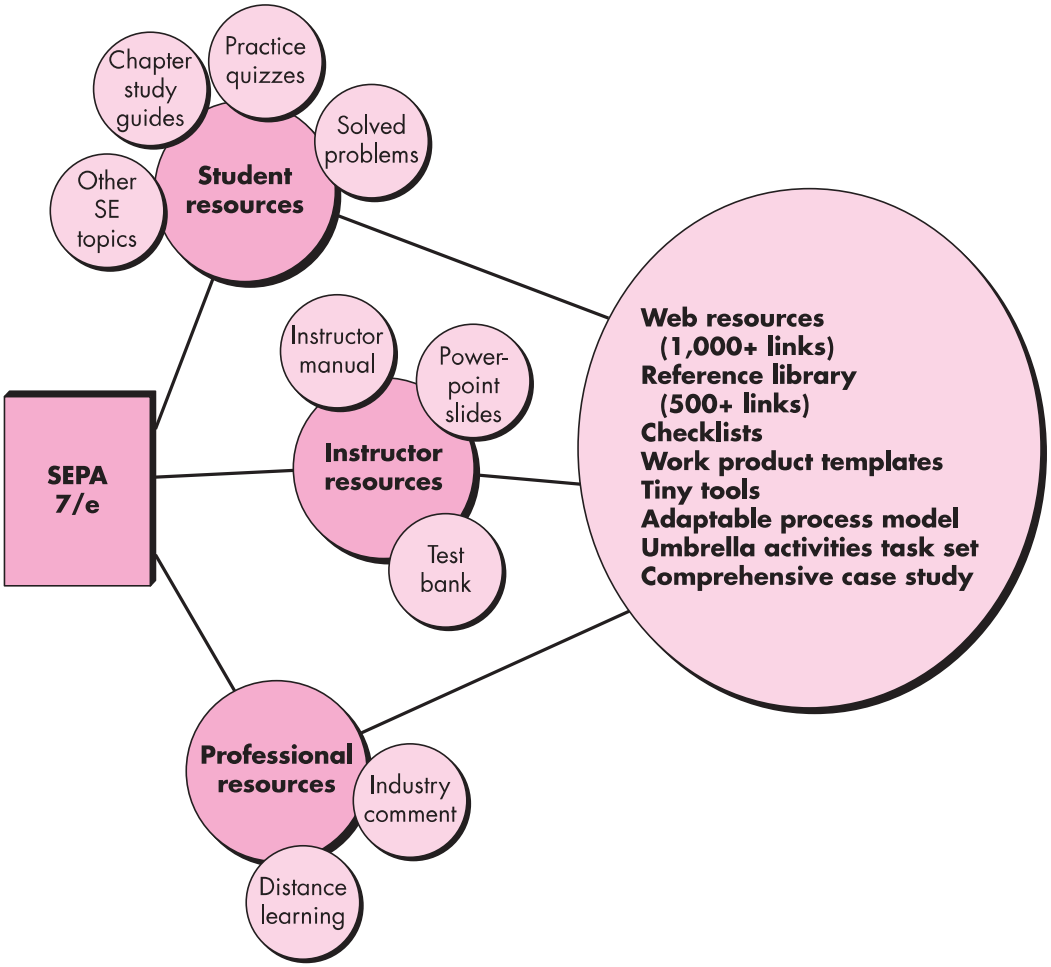
Although managers and practitioners alike recognize the need for a more disciplined approach to software, they continue to debate the manner in which discipline is to be applied. Many individuals and companies still develop software haphazardly, even as they build systems to service today's most advanced technologies. Many professionals and students are unaware of modern methods. And as a result, the quality of the software that we produce suffers, and bad things happen. In addition, debate and controversy about the true nature of the software engineering approach continue. The status of software engineering is a study in contrasts. Attitudes have changed, progress has been made, but much remains to be done before the discipline reaches full maturity.

The seventh edition of *Software Engineering: A Practitioner's Approach* is intended to serve as a guide to a maturing engineering discipline. Like the six editions that preceded it, the seventh edition is intended for both students and practitioners, retaining its appeal as a guide to the industry professional and a comprehensive introduction to the student at the upper-level undergraduate or first-year graduate level.

The seventh edition is considerably more than a simple update. The book has been revised and restructured to improve pedagogical flow and emphasize new and important software engineering processes and practices. In addition, a revised and updated "support system," illustrated in the figure, provides a comprehensive set of student, instructor, and professional resources to complement the content of the book. These resources are presented as part of a website (www.mhhe.com/ pressman) specifically designed for *Software Engineering: A Practitioner's Approach.*

The Seventh Edition. The 32 chapters of the seventh edition have been reorganized into five parts. This organization, which differs considerably from the sixth edition, has been done to better compartmentalize topics and assist instructors who may not have the time to complete the entire book in one term.

Support System for SEPA, 7/e



Part 1, *The Process,* presents a variety of different views of software process, considering all important process models and addressing the debate between prescriptive and agile process philosophies. Part 2, *Modeling,* presents analysis and design methods with an emphasis on object-oriented techniques and UML modeling. Pattern-based design and design for Web applications are also considered. Part 3, *Quality Management,* presents the concepts, procedures, techniques, and methods that enable a software team to assess software quality, review software engineering work products, conduct SQA procedures, and apply an effective testing strategy and tactics. In addition, formal modeling and verification methods are also considered. Part 4, *Managing Software Projects,* presents topics that are relevant to those who plan, manage, and control a software development project. Part 5, *Advanced Topics,* considers software process improvement and software engineering trends. Continuing in the tradition of past editions, a series of sidebars is used throughout the book to present the trials and tribulations of a (fictional) software team and to provide supplementary materials about methods and tools that are relevant to chapter topics. Two new appendices provide brief tutorials on UML and object-oriented thinking for those who may be unfamiliar with these important topics.

The five-part organization of the seventh edition enables an instructor to "cluster" topics based on available time and student need. An entire one-term course can be built around one or more of the five parts. A software engineering survey course would select chapters from all five parts. A software engineering course that emphasizes analysis and design would select topics from Parts 1 and 2. A testing-oriented software engineering course would select topics from Parts 1 and 3, with a brief foray into Part 2. A "management course" would stress Parts 1 and 4. By organizing the seventh edition in this way, I have attempted to provide an instructor with a number of teaching options. In every case, the content of the seventh edition is complemented by the following elements of the *SEPA, 7/e Support System*.

Student Resources. A wide variety of student resources includes an extensive online learning center encompassing chapter-by-chapter study guides, practice quizzes, problem solutions, and a variety of Web-based resources including software engineering checklists, an evolving collection of "tiny tools," a comprehensive case study, work product templates, and many other resources. In addition, over 1000 categorized *Web References* allow a student to explore software engineering in greater detail and a *Reference Library* with links to over 500 downloadable papers provides an in-depth source of advanced software engineering information.

Instructor Resources. A broad array of instructor resources has been developed to supplement the seventh edition. These include a complete online *Instructor's Guide* (also downloadable) and supplementary teaching materials including a complete set of over 700 *PowerPoint Slides* that may be used for lectures, and a test bank. Of course, all resources available for students (e.g., tiny tools, the Web References, the downloadable Reference Library) and professionals are also available.

The *Instructor's Guide for Software Engineering: A Practitioner's Approach* presents suggestions for conducting various types of software engineering courses, recommendations for a variety of software projects to be conducted in conjunction with a course, solutions to selected problems, and a number of useful teaching aids.

Professional Resources. A collection of resources available to industry practitioners (as well as students and faculty) includes outlines and samples of software engineering documents and other work products, a useful set of software engineering checklists, a catalog of software engineering (CASE) tools, a comprehensive collection of Web-based resources, and an "adaptable process model" that provides a detailed task breakdown of the software engineering process.

When coupled with its online support system, the seventh edition of *Software Engineering: A Practitioner's Approach,* provides flexibility and depth of content that cannot be achieved by a textbook alone.

Acknowledgments. My work on the seven editions of *Software Engineering: A Practitioner's Approach* has been the longest continuing technical project of my life. Even when the writing stops, information extracted from the technical literature continues to be assimilated and organized, and criticism and suggestions from readers worldwide is evaluated and cataloged. For this reason, my thanks to the many authors of books, papers, and articles (in both hardcopy and electronic media) who have provided me with additional insight, ideas, and commentary over nearly 30 years.

Special thanks go to Tim Lethbridge of the University of Ottawa, who assisted me in the development of UML and OCL examples and developed the case study that accompanies this book, and Dale Skrien of Colby College, who developed the UML tutorial in

Appendix 1. Their assistance and comments were invaluable. Special thanks also go to Bruce Maxim of the University of Michigan–Dearborn, who assisted me in developing much of the pedagogical website content that accompanies this book. Finally, I wish to thank the reviewers of the seventh edition: Their in-depth comments and thoughtful criticism have been invaluable.

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The content of the seventh edition of *Software Engineering: A Practitioner's Approach* has been shaped by industry professionals, university professors, and students who have used earlier editions of the book and have taken the time to communicate their suggestions, criticisms, and ideas. My thanks to each of you. In addition, my personal thanks go to our many industry clients worldwide, who certainly have taught me as much or more than I could ever teach them.

As the editions of this book have evolved, my sons, Mathew and Michael, have grown from boys to men. Their maturity, character, and success in the real world have been an inspiration to me. Nothing has filled me with more pride. And finally, to Barbara, my love and thanks for tolerating the many, many hours in the office and encouraging still another edition of "the book."

Roger S. Pressman

CHAPTER

1

SOFTWARE AND SOFTWARE ENGINEERING

KEY CONCEPTS

He had the classic look of a senior executive for a major software company—mid-40s, slightly graying at the temples, trim and athletic, with eyes that penetrated the listener as he spoke. But what he said shocked me.

"Software is *dead*."

I blinked with surprise and then smiled. "You're joking, right? The world is driven by software and your company has profited handsomely because of it. It isn't dead! It's alive and growing."

He shook his head emphatically. "No, it's dead . . . at least as we once knew it."

I leaned forward. "Go on."

He spoke while tapping the table for emphasis. "The old-school view of software—you buy it, you own it, and it's your job to manage it—that's coming to an end. Today, with Web 2.0 and pervasive computing coming on strong, we're going to be seeing a completely different generation of software. It'll be delivered via the Internet and will look exactly like it's residing on each user's computing device . . . but it'll reside on a far-away server."

QUICK LOOK

What is it? Computer software is the product that software professionals build and then support over the long term. It encompasses programs that execute within a computer of any size and architecture, content that is presented as the computer programs execute, and descriptive information in both hard copy and virtual forms that encompass virtually any electronic media. Software engineering encompasses a process, a collection of methods (practice) and an array of tools that allow professionals to build high-quality computer software.

Who does it? Software engineers build and support software, and virtually everyone in the industrialized world uses it either directly or indirectly.

Why is it important? Software is important because it affects nearly every aspect of our lives and has become pervasive in our commerce, our culture, and our everyday activities. Software engineering is important because it enables us to build complex systems in a timely manner and with high quality.

What are the steps? You build computer software like you build any successful product, by applying an agile, adaptable process that leads to a high-quality result that meets the needs of the people who will use the product. You apply a software engineering approach.

What is the work product? From the point of view of a software engineer, the work product is the set of programs, content (data), and other work products that are computer software. But from the user's viewpoint, the work product is the resultant information that somehow makes the user's world better.

How do I ensure that I've done it right? Read the remainder of this book, select those ideas that are applicable to the software that you build, and apply them to your work.

I had to agree. "So, your life will be much simpler. You guys won't have to worry about five different versions of the same App in use across tens of thousands of users."

He smiled. "Absolutely. Only the most current version residing on our servers. When we make a change or a correction, we supply updated functionality and content to every user. Everyone has it instantly!"

I grimaced. "But if you make a mistake, everyone has that instantly as well."

He chuckled. "True, that's why we're redoubling our efforts to do even better software engineering. Problem is, we have to do it 'fast' because the market has accelerated in every application area."

I leaned back and put my hands behind my head. "You know what they say, . . . you can have it fast, you can have it right, or you can have it cheap. Pick two!"

"I'll take it fast and right," he said as he began to get up.

I stood as well. "Then you really do need software engineering."

"I know that," he said as he began to move away. "The problem is, we've got to convince still another generation of techies that it's true!"

Is software *really* dead? If it was, you wouldn't be reading this book!

Quote:

"Ideas and technological discoveries are the driving engines of economic growth."

Wall Street Journal

Computer software continues to be the single most important technology on the world stage. And it's also a prime example of the law of unintended consequences. Fifty years ago no one could have predicted that software would become an indispensable technology for business, science, and engineering; that software would enable the creation of new technologies (e.g., genetic engineering and nanotechnology), the extension of existing technologies (e.g., telecommunications), and the radical change in older technologies (e.g., the printing industry); that software would be the driving force behind the personal computer revolution; that shrink-wrapped software products would be purchased by consumers in neighborhood malls; that software would slowly evolve from a product to a service as "on-demand" software companies deliver just-in-time functionality via a Web browser; that a software company would become larger and more influential than almost all industrial-era companies; that a vast software-driven network called the Internet would evolve and change everything from library research to consumer shopping to political discourse to the dating habits of young (and not so young) adults.

No one could foresee that software would become embedded in systems of all kinds: transportation, medical, telecommunications, military, industrial, entertainment, office machines, . . . the list is almost endless. And if you believe the law of unintended consequences, there are many effects that we cannot yet predict.

No one could predict that millions of computer programs would have to be corrected, adapted, and enhanced as time passed. The burden of performing these "maintenance" activities would absorb more people and more resources than all work applied to the creation of new software.

As software's importance has grown, the software community has continually attempted to develop technologies that will make it easier, faster, and less expensive

to build and maintain high-quality computer programs. Some of these technologies are targeted at a specific application domain (e.g., website design and implementation); others focus on a technology domain (e.g., object-oriented systems or aspect-oriented programming); and still others are broad-based (e.g., operating systems such as Linux). However, we have yet to develop a software technology that does it all, and the likelihood of one arising in the future is small. And yet, people bet their jobs, their comforts, their safety, their entertainment, their decisions, and their very lives on computer software. It better be right.

This book presents a framework that can be used by those who build computer software—people who must get it right. The framework encompasses a process, a set of methods, and an array of tools that we call *software engineering.*

1.1 The Nature of Software

Software is both a product and a vehicle that delivers a product.

Today, software takes on a dual role. It is a product, and at the same time, the vehicle for delivering a product. As a product, it delivers the computing potential embodied by computer hardware or more broadly, by a network of computers that are accessible by local hardware. Whether it resides within a mobile phone or operates inside a mainframe computer, software is an information transformer—producing, managing, acquiring, modifying, displaying, or transmitting information that can be as simple as a single bit or as complex as a multimedia presentation derived from data acquired from dozens of independent sources. As the vehicle used to deliver the product, software acts as the basis for the control of the computer (operating systems), the communication of information (networks), and the creation and control of other programs (software tools and environments).

Software delivers the most important product of our time—*information.* It transforms personal data (e.g., an individual's financial transactions) so that the data can be more useful in a local context; it manages business information to enhance competitiveness; it provides a gateway to worldwide information networks (e.g., the Internet), and provides the means for acquiring information in all of its forms.

"Software is a place where dreams are planted and nightmares harvested, an abstract, mystical swamp where terrible demons compete with magical panaceas, a world of werewolves and silver bullets."

Brad J. Cox

The role of computer software has undergone significant change over the last half-century. Dramatic improvements in hardware performance, profound changes in computing architectures, vast increases in memory and storage capacity, and a wide variety of exotic input and output options, have all precipitated more sophisticated and complex computer-based systems. Sophistication and complexity can produce dazzling results when a system succeeds, but they can also pose huge problems for those who must build complex systems.

Today, a huge software industry has become a dominant factor in the economies of the industrialized world. Teams of software specialists, each focusing on one part of the technology required to deliver a complex application, have replaced the lone programmer of an earlier era. And yet, the questions that were asked of the lone

programmer are the same questions that are asked when modern computer-based systems are built:[1]

- Why does it take so long to get software finished?
- Why are development costs so high?
- Why can't we find all errors before we give the software to our customers?
- Why do we spend so much time and effort maintaining existing programs?
- Why do we continue to have difficulty in measuring progress as software is being developed and maintained?

These, and many other questions, are a manifestation of the concern about software and the manner in which it is developed—a concern that has lead to the adoption of software engineering practice.

1.1.1 Defining Software

Today, most professionals and many members of the public at large feel that they understand software. But do they?

A textbook description of software might take the following form:

? How should we define *software?*

> Software is: (1) instructions (computer programs) that when executed provide desired features, function, and performance; (2) data structures that enable the programs to adequately manipulate information, and (3) descriptive information in both hard copy and virtual forms that describes the operation and use of the programs.

There is no question that other more complete definitions could be offered.

But a more formal definition probably won't measurably improve your understanding. To accomplish that, it's important to examine the characteristics of software that make it different from other things that human beings build. Software is a logical rather than a physical system element. Therefore, software has characteristics that are considerably different than those of hardware:

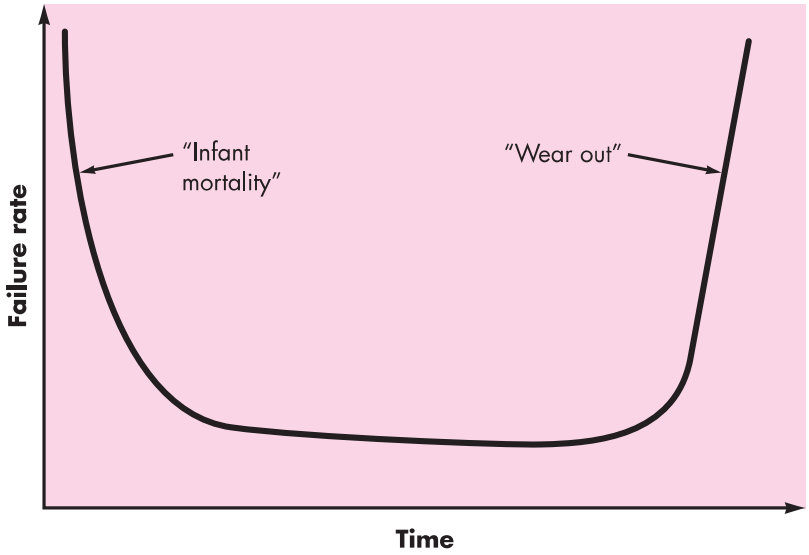
KEY POINT Software is engineered, not manufactured.

1. *Software is developed or engineered; it is not manufactured in the classical sense.*

   Although some similarities exist between software development and hardware manufacturing, the two activities are fundamentally different. In both activities, high quality is achieved through good design, but the manufacturing phase for hardware can introduce quality problems that are nonexistent

1 In an excellent book of essays on the software business, Tom DeMarco [DeM95] argues the counterpoint. He states: "Instead of asking why software costs so much, we need to begin asking 'What have we done to make it possible for today's software to cost so little?' The answer to that question will help us continue the extraordinary level of achievement that has always distinguished the software industry."

FIGURE 1.1
Failure curve for hardware



(or easily corrected) for software. Both activities are dependent on people, but the relationship between people applied and work accomplished is entirely different (see Chapter 24). Both activities require the construction of a "product," but the approaches are different. Software costs are concentrated in engineering. This means that software projects cannot be managed as if they were manufacturing projects.

2. *Software doesn't "wear out."*

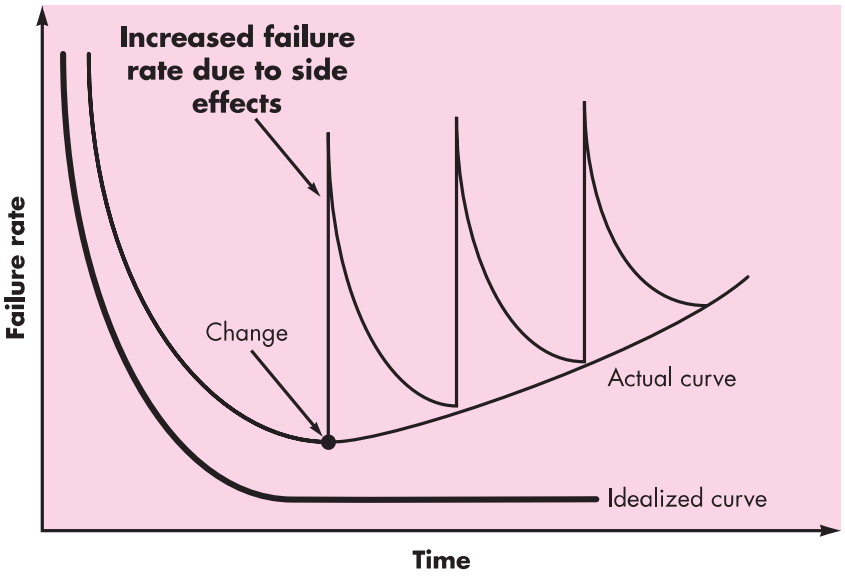
KEY POINT
Software doesn't wear out, but it does deteriorate.

Figure 1.1 depicts failure rate as a function of time for hardware. The relationship, often called the "bathtub curve," indicates that hardware exhibits relatively high failure rates early in its life (these failures are often attributable to design or manufacturing defects); defects are corrected and the failure rate drops to a steady-state level (hopefully, quite low) for some period of time. As time passes, however, the failure rate rises again as hardware components suffer from the cumulative effects of dust, vibration, abuse, temperature extremes, and many other environmental maladies. Stated simply, the hardware begins to *wear out.*

Software is not susceptible to the environmental maladies that cause hardware to wear out. In theory, therefore, the failure rate curve for software should take the form of the "idealized curve" shown in Figure 1.2. Undiscovered defects will cause high failure rates early in the life of a program. However, these are corrected and the curve flattens as shown. The idealized curve is a gross oversimplification of actual failure models for software. However, the implication is clear—software doesn't wear out. But it does *deteriorate!*

ADVICE
If you want to reduce software deterioration, you'll have to do better software design (Chapters 8 to 13).

FIGURE 1.2
Failure curves for software



KEY POINT
Software engineering methods strive to reduce the magnitude of the spikes and the slope of the actual curve in Figure 1.2.

This seeming contradiction can best be explained by considering the actual curve in Figure 1.2. During its life,[2] software will undergo change. As changes are made, it is likely that errors will be introduced, causing the failure rate curve to spike as shown in the "actual curve" (Figure 1.2). Before the curve can return to the original steady-state failure rate, another change is requested, causing the curve to spike again. Slowly, the minimum failure rate level begins to rise—the software is deteriorating due to change.

Another aspect of wear illustrates the difference between hardware and software. When a hardware component wears out, it is replaced by a spare part. There are no software spare parts. Every software failure indicates an error in design or in the process through which design was translated into machine executable code. Therefore, the software maintenance tasks that accommodate requests for change involve considerably more complexity than hardware maintenance.

Quote:
"Ideas are the building blocks of ideas."
Jason Zebehazy

3. *Although the industry is moving toward component-based construction, most software continues to be custom built.*

As an engineering discipline evolves, a collection of standard design components is created. Standard screws and off-the-shelf integrated circuits are only two of thousands of standard components that are used by mechanical and electrical engineers as they design new systems. The reusable components have been created so that the engineer can concentrate on the truly innovative elements of a design, that is, the parts of the design that represent

2 In fact, from the moment that development begins and long before the first version is delivered, changes may be requested by a variety of different stakeholders.

something new. In the hardware world, component reuse is a natural part of the engineering process. In the software world, it is something that has only begun to be achieved on a broad scale.

A software component should be designed and implemented so that it can be reused in many different programs. Modern reusable components encapsulate both data and the processing that is applied to the data, enabling the software engineer to create new applications from reusable parts.[3] For example, today's interactive user interfaces are built with reusable components that enable the creation of graphics windows, pull-down menus, and a wide variety of interaction mechanisms. The data structures and processing detail required to build the interface are contained within a library of reusable components for interface construction.

1.1.2 Software Application Domains

Today, seven broad categories of computer software present continuing challenges for software engineers:

System software—a collection of programs written to service other programs. Some system software (e.g., compilers, editors, and file management utilities) processes complex, but determinate,[4] information structures. Other systems applications (e.g., operating system components, drivers, networking software, telecommunications processors) process largely indeterminate data. In either case, the systems software area is characterized by heavy interaction with computer hardware; heavy usage by multiple users; concurrent operation that requires scheduling, resource sharing, and sophisticated process management; complex data structures; and multiple external interfaces.

WebRef

One of the most comprehensive libraries of shareware/ freeware can be found at **shareware.cnet.com**

Application software—stand-alone programs that solve a specific business need. Applications in this area process business or technical data in a way that facilitates business operations or management/technical decision making. In addition to conventional data processing applications, application software is used to control business functions in real time (e.g., point-of-sale transaction processing, real-time manufacturing process control).

Engineering/scientific software—has been characterized by "number crunching" algorithms. Applications range from astronomy to volcanology, from automotive stress analysis to space shuttle orbital dynamics, and from molecular biology to automated manufacturing. However, modern applications within the engineering/scientific area are moving away from

3 Component-based development is discussed in Chapter 10.

4 Software is *determinate* if the order and timing of inputs, processing, and outputs is predictable. Software is *indeterminate* if the order and timing of inputs, processing, and outputs cannot be predicted in advance.

conventional numerical algorithms. Computer-aided design, system simulation, and other interactive applications have begun to take on real-time and even system software characteristics.

Embedded software—resides within a product or system and is used to implement and control features and functions for the end user and for the system itself. Embedded software can perform limited and esoteric functions (e.g., key pad control for a microwave oven) or provide significant function and control capability (e.g., digital functions in an automobile such as fuel control, dashboard displays, and braking systems).

Product-line software—designed to provide a specific capability for use by many different customers. Product-line software can focus on a limited and esoteric marketplace (e.g., inventory control products) or address mass consumer markets (e.g., word processing, spreadsheets, computer graphics, multimedia, entertainment, database management, and personal and business financial applications).

Web applications—called "WebApps," this network-centric software category spans a wide array of applications. In their simplest form, WebApps can be little more than a set of linked hypertext files that present information using text and limited graphics. However, as Web 2.0 emerges, WebApps are evolving into sophisticated computing environments that not only provide stand-alone features, computing functions, and content to the end user, but also are integrated with corporate databases and business applications.

Artificial intelligence software—makes use of nonnumerical algorithms to solve complex problems that are not amenable to computation or straightforward analysis. Applications within this area include robotics, expert systems, pattern recognition (image and voice), artificial neural networks, theorem proving, and game playing.

Quote:

"There is no computer that has common sense."

Marvin Minsky

Millions of software engineers worldwide are hard at work on software projects in one or more of these categories. In some cases, new systems are being built, but in many others, existing applications are being corrected, adapted, and enhanced. It is not uncommon for a young software engineer to work a program that is older than she is! Past generations of software people have left a legacy in each of the categories I have discussed. Hopefully, the legacy to be left behind by this generation will ease the burden of future software engineers. And yet, new challenges (Chapter 31) have appeared on the horizon:

Open-world computing—the rapid growth of wireless networking may soon lead to true pervasive, distributed computing. The challenge for software engineers will be to develop systems and application software that will allow mobile devices, personal computers, and enterprise systems to communicate across vast networks.

Netsourcing—the World Wide Web is rapidly becoming a computing engine as well as a content provider. The challenge for software engineers is to architect simple (e.g., personal financial planning) and sophisticated applications that provide a benefit to targeted end-user markets worldwide.

Open source—a growing trend that results in distribution of source code for systems applications (e.g., operating systems, database, and development environments) so that many people can contribute to its development. The challenge for software engineers is to build source code that is self-descriptive, but more importantly, to develop techniques that will enable both customers and developers to know what changes have been made and how those changes manifest themselves within the software.

Quote:

"You can't always predict, but you can always prepare."

Anonymous

Each of these new challenges will undoubtedly obey the law of unintended consequences and have effects (for businesspeople, software engineers, and end users) that cannot be predicted today. However, software engineers can prepare by instantiating a process that is agile and adaptable enough to accommodate dramatic changes in technology and to business rules that are sure to come over the next decade.

1.1.3 Legacy Software

Hundreds of thousands of computer programs fall into one of the seven broad application domains discussed in the preceding subsection. Some of these are state-of-the-art software—just released to individuals, industry, and government. But other programs are older, in some cases *much* older.

These older programs—often referred to as *legacy software*—have been the focus of continuous attention and concern since the 1960s. Dayani-Fard and his colleagues [Day99] describe legacy software in the following way:

> Legacy software systems . . . were developed decades ago and have been continually modified to meet changes in business requirements and computing platforms. The proliferation of such systems is causing headaches for large organizations who find them costly to maintain and risky to evolve.

Liu and his colleagues [Liu98] extend this description by noting that "many legacy systems remain supportive to core business functions and are 'indispensable' to the business." Hence, legacy software is characterized by longevity and business criticality.

? What do I do if I encounter a legacy system that exhibits poor quality?

Unfortunately, there is sometimes one additional characteristic that is present in legacy software—*poor quality*.[5] Legacy systems sometimes have inextensible designs, convoluted code, poor or nonexistent documentation, test cases and results

5 In this case, quality is judged based on modern software engineering thinking—a somewhat unfair criterion since some modern software engineering concepts and principles may not have been well understood at the time that the legacy software was developed.

that were never archived, a poorly managed change history—the list can be quite long. And yet, these systems support "core business functions and are indispensable to the business." What to do?

The only reasonable answer may be: *Do nothing,* at least until the legacy system must undergo some significant change. If the legacy software meets the needs of its users and runs reliably, it isn't broken and does not need to be fixed. However, as time passes, legacy systems often evolve for one or more of the following reasons:

? What types of changes are made to legacy systems?

- The software must be adapted to meet the needs of new computing environments or technology.
- The software must be enhanced to implement new business requirements.
- The software must be extended to make it interoperable with other more modern systems or databases.
- The software must be re-architected to make it viable within a network environment.

ADVICE

Every software engineer must recognize that change is natural. Don't try to fight it.

When these modes of evolution occur, a legacy system must be reengineered (Chapter 29) so that it remains viable into the future. The goal of modern software engineering is to "devise methodologies that are founded on the notion of evolution"; that is, the notion that software systems continually change, new software systems are built from the old ones, and . . . all must interoperate and cooperate with each other" [Day99].

1.2 The Unique Nature of WebApps

Quote:

"By the time we see any sort of stabilization, the Web will have turned into something completely different."

Louis Monier

In the early days of the World Wide Web (circa 1990 to 1995), *websites* consisted of little more than a set of linked hypertext files that presented information using text and limited graphics. As time passed, the augmentation of HTML by development tools (e.g., XML, Java) enabled Web engineers to provide computing capability along with informational content. *Web-based systems and applications*[6] (I refer to these collectively as *WebApps*) were born. Today, WebApps have evolved into sophisticated computing tools that not only provide stand-alone function to the end user, but also have been integrated with corporate databases and business applications.

As noted in Section 1.1.2, WebApps are one of a number of distinct software categories. And yet, it can be argued that WebApps are different. Powell [Pow98] suggests that Web-based systems and applications "involve a mixture between print publishing and software development, between marketing and computing, between

6 In the context of this book, the term *Web application* (WebApp) encompasses everything from a simple Web page that might help a consumer compute an automobile lease payment to a comprehensive website that provides complete travel services for businesspeople and vacationers. Included within this category are complete websites, specialized functionality within websites, and information processing applications that reside on the Internet or on an Intranet or Extranet.

internal communications and external relations, and between art and technology." The following attributes are encountered in the vast majority of WebApps.

? What characteristic differentiates WebApps from other software?

Network intensiveness. A WebApp resides on a network and must serve the needs of a diverse community of clients. The network may enable worldwide access and communication (i.e., the Internet) or more limited access and communication (e.g., a corporate Intranet).

Concurrency. A large number of users may access the WebApp at one time. In many cases, the patterns of usage among end users will vary greatly.

Unpredictable load. The number of users of the WebApp may vary by orders of magnitude from day to day. One hundred users may show up on Monday; 10,000 may use the system on Thursday.

Performance. If a WebApp user must wait too long (for access, for server-side processing, for client-side formatting and display), he or she may decide to go elsewhere.

Availability. Although expectation of 100 percent availability is unreasonable, users of popular WebApps often demand access on a 24/7/365 basis. Users in Australia or Asia might demand access during times when traditional domestic software applications in North America might be taken off-line for maintenance.

Data driven. The primary function of many WebApps is to use hypermedia to present text, graphics, audio, and video content to the end user. In addition, WebApps are commonly used to access information that exists on databases that are not an integral part of the Web-based environment (e.g., e-commerce or financial applications).

Content sensitive. The quality and aesthetic nature of content remains an important determinant of the quality of a WebApp.

Continuous evolution. Unlike conventional application software that evolves over a series of planned, chronologically spaced releases, Web applications evolve continuously. It is not unusual for some WebApps (specifically, their content) to be updated on a minute-by-minute schedule or for content to be independently computed for each request.

Immediacy. Although *immediacy*—the compelling need to get software to market quickly—is a characteristic of many application domains, WebApps often exhibit a time-to-market that can be a matter of a few days or weeks.[7]

Security. Because WebApps are available via network access, it is difficult, if not impossible, to limit the population of end users who may access the application. In order to protect sensitive content and provide secure modes

7 With modern tools, sophisticated Web pages can be produced in only a few hours.

of data transmission, strong security measures must be implemented throughout the infrastructure that supports a WebApp and within the application itself.

Aesthetics. An undeniable part of the appeal of a WebApp is its look and feel. When an application has been designed to market or sell products or ideas, aesthetics may have as much to do with success as technical design.

It can be argued that other application categories discussed in Section 1.1.2 can exhibit some of the attributes noted. However, WebApps almost always exhibit all of them.

1.3 Software Engineering

In order to build software that is ready to meet the challenges of the twenty-first century, you must recognize a few simple realities:

KEY POINT
Understand the problem before you build a solution.

- Software has become deeply embedded in virtually every aspect of our lives, and as a consequence, the number of people who have an interest in the features and functions provided by a specific application[8] has grown dramatically. When a new application or embedded system is to be built, many voices must be heard. And it sometimes seems that each of them has a slightly different idea of what software features and functions should be delivered. *It follows that a concerted effort should be made to understand the problem before a software solution is developed.*

KEY POINT
Design is a pivotal software engineering activity.

- The information technology requirements demanded by individuals, businesses, and governments grow increasing complex with each passing year. Large teams of people now create computer programs that were once built by a single individual. Sophisticated software that was once implemented in a predictable, self-contained, computing environment is now embedded inside everything from consumer electronics to medical devices to weapons systems. The complexity of these new computer-based systems and products demands careful attention to the interactions of all system elements. *It follows that design becomes a pivotal activity.*

KEY POINT
Both quality and maintainability are an outgrowth of good design.

- Individuals, businesses, and governments increasingly rely on software for strategic and tactical decision making as well as day-to-day operations and control. If the software fails, people and major enterprises can experience anything from minor inconvenience to catastrophic failures. *It follows that software should exhibit high quality.*
- As the perceived value of a specific application grows, the likelihood is that its user base and longevity will also grow. As its user base and time-in-use

8 I will call these people "stakeholders" later in this book.

increase, demands for adaptation and enhancement will also grow. *It follows that software should be maintainable.*

These simple realities lead to one conclusion: *software in all of its forms and across all of its application domains should be engineered.* And that leads us to the topic of this book—*software engineering.*

Quote:

"More than a discipline or a body of knowledge, engineering is a verb, an action word, a way of approaching a problem."

Scott Whitmir

Although hundreds of authors have developed personal definitions of software engineering, a definition proposed by Fritz Bauer [Nau69] at the seminal conference on the subject still serves as a basis for discussion:

> [Software engineering is] the establishment and use of sound engineering principles in order to obtain economically software that is reliable and works efficiently on real machines.

You will be tempted to add to this definition.[9] It says little about the technical aspects of software quality; it does not directly address the need for customer satisfaction or timely product delivery; it omits mention of the importance of measurement and metrics; it does not state the importance of an effective process. And yet, Bauer's definition provides us with a baseline. What are the "sound engineering principles" that can be applied to computer software development? How do we "economically" build software so that it is "reliable"? What is required to create computer programs that work "efficiently" on not one but many different "real machines"? These are the questions that continue to challenge software engineers.

The IEEE [IEE93a] has developed a more comprehensive definition when it states:

? How do we define software engineering?

> Software Engineering: (1) The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software. (2) The study of approaches as in (1).

And yet, a "systematic, disciplined, and quantifiable" approach applied by one software team may be burdensome to another. We need discipline, but we also need adaptability and agility.

KEY POINT

Software engineering encompasses a process, methods for managing and engineering software, and tools.

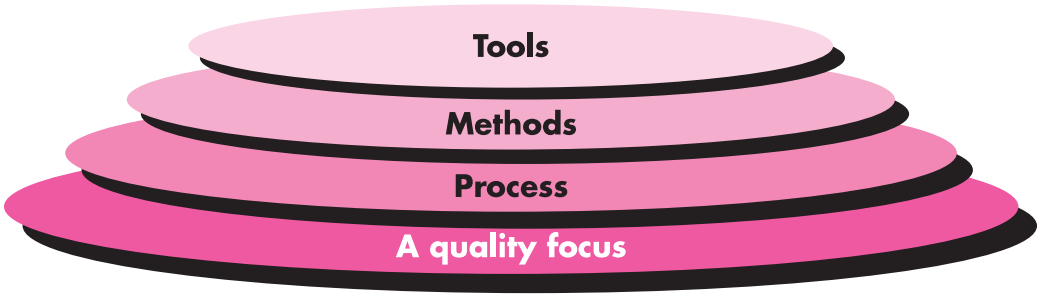
Software engineering is a layered technology. Referring to Figure 1.3, any engineering approach (including software engineering) must rest on an organizational commitment to quality. Total quality management, Six Sigma, and similar philosophies[10] foster a continuous process improvement culture, and it is this culture that ultimately leads to the development of increasingly more effective approaches to software engineering. The bedrock that supports software engineering is a quality focus.

The foundation for software engineering is the *process* layer. The software engineering process is the glue that holds the technology layers together and enables rational and timely development of computer software. Process defines a framework

9 For numerous additional definitions of *software engineering,* see www.answers.com/topic/software-engineering#wp-_note-13.

10 Quality management and related approaches are discussed in Chapter 14 and throughout Part 3 of this book.

FIGURE 1.3
Software engineering layers



WebRef
CrossTalk is a journal that provides pragmatic information on process, methods, and tools. It can be found at: **www.stsc.hill.af.mil**.

that must be established for effective delivery of software engineering technology. The software process forms the basis for management control of software projects and establishes the context in which technical methods are applied, work products (models, documents, data, reports, forms, etc.) are produced, milestones are established, quality is ensured, and change is properly managed.

Software engineering *methods* provide the technical how-to's for building software. Methods encompass a broad array of tasks that include communication, requirements analysis, design modeling, program construction, testing, and support. Software engineering methods rely on a set of basic principles that govern each area of the technology and include modeling activities and other descriptive techniques.

Software engineering *tools* provide automated or semiautomated support for the process and the methods. When tools are integrated so that information created by one tool can be used by another, a system for the support of software development, called *computer-aided software engineering*, is established.

1.4 THE SOFTWARE PROCESS

? What are the elements of a software process?

Quote:
"A process defines who is doing *what* *when* and *how* to reach a certain goal."
Ivar Jacobson, Grady Booch, and James Rumbaugh

A *process* is a collection of activities, actions, and tasks that are performed when some work product is to be created. An *activity* strives to achieve a broad objective (e.g., communication with stakeholders) and is applied regardless of the application domain, size of the project, complexity of the effort, or degree of rigor with which software engineering is to be applied. An *action* (e.g., architectural design) encompasses a set of tasks that produce a major work product (e.g., an architectural design model). A *task* focuses on a small, but well-defined objective (e.g., conducting a unit test) that produces a tangible outcome.

In the context of software engineering, a process is *not* a rigid prescription for how to build computer software. Rather, it is an adaptable approach that enables the people doing the work (the software team) to pick and choose the appropriate set of work actions and tasks. The intent is always to deliver software in a timely manner and with sufficient quality to satisfy those who have sponsored its creation and those who will use it.

A *process framework* establishes the foundation for a complete software engineering process by identifying a small number of *framework activities* that are applicable to all software projects, regardless of their size or complexity. In addition, the process framework encompasses a set of *umbrella activities* that are applicable across the entire software process. A generic process framework for software engineering encompasses five activities:

? What are the five generic process framework activities?

Communication. Before any technical work can commence, it is critically important to communicate and collaborate with the customer (and other stakeholders[11] The intent is to understand stakeholders' objectives for the project and to gather requirements that help define software features and functions.

Planning. Any complicated journey can be simplified if a map exists. A software project is a complicated journey, and the planning activity creates a "map" that helps guide the team as it makes the journey. The map—called a *software project plan*—defines the software engineering work by describing the technical tasks to be conducted, the risks that are likely, the resources that will be required, the work products to be produced, and a work schedule.

Quote:

"Einstein argued that there must be a simplified explanation of nature, because God is not capricious or arbitrary. No such faith comforts the software engineer. Much of the complexity that he must master is arbitrary complexity."

Fred Brooks

Modeling. Whether you're a landscaper, a bridge builder, an aeronautical engineer, a carpenter, or an architect, you work with models every day. You create a "sketch" of the thing so that you'll understand the big picture—what it will look like architecturally, how the constituent parts fit together, and many other characteristics. If required, you refine the sketch into greater and greater detail in an effort to better understand the problem and how you're going to solve it. A software engineer does the same thing by creating models to better understand software requirements and the design that will achieve those requirements.

Construction. This activity combines code generation (either manual or automated) and the testing that is required to uncover errors in the code.

Deployment. The software (as a complete entity or as a partially completed increment) is delivered to the customer who evaluates the delivered product and provides feedback based on the evaluation.

These five generic framework activities can be used during the development of small, simple programs, the creation of large Web applications, and for the engineering of large, complex computer-based systems. The details of the software process will be quite different in each case, but the framework activities remain the same.

11 A *stakeholder* is anyone who has a stake in the successful outcome of the project—business managers, end users, software engineers, support people, etc. Rob Thomsett jokes that, "a stakeholder is a person holding a large and sharp stake. . . . If you don't look after your stakeholders, you know where the stake will end up.").

For many software projects, framework activities are applied iteratively as a project progresses. That is, **communication, planning, modeling, construction,** and **deployment** are applied repeatedly through a number of project iterations. Each project iteration produces a *software increment* that provides stakeholders with a subset of overall software features and functionality. As each increment is produced, the software becomes more and more complete.

Software engineering process framework activities are complemented by a number of *umbrella activities.* In general, umbrella activities are applied throughout a software project and help a software team manage and control progress, quality, change, and risk. Typical umbrella activities include:

KEY POINT
Umbrella activities occur throughout the software process and focus primarily on project management, tracking, and control.

Software project tracking and control—allows the software team to assess progress against the project plan and take any necessary action to maintain the schedule.

Risk management—assesses risks that may affect the outcome of the project or the quality of the product.

Software quality assurance—defines and conducts the activities required to ensure software quality.

Technical reviews—assesses software engineering work products in an effort to uncover and remove errors before they are propagated to the next activity.

Measurement—defines and collects process, project, and product measures that assist the team in delivering software that meets stakeholders' needs; can be used in conjunction with all other framework and umbrella activities.

Software configuration management—manages the effects of change throughout the software process.

Reusability management—defines criteria for work product reuse (including software components) and establishes mechanisms to achieve reusable components.

Work product preparation and production—encompasses the activities required to create work products such as models, documents, logs, forms, and lists.

KEY POINT
Software process adaptation is essential for project success.

Each of these umbrella activities is discussed in detail later in this book.

Earlier in this section, I noted that the software engineering process is not a rigid prescription that must be followed dogmatically by a software team. Rather, it should be agile and adaptable (to the problem, to the project, to the team, and to the organizational culture). Therefore, a process adopted for one project might be significantly different than a process adopted for another project. Among the differences are

? How do process models differ from one another?

- Overall flow of activities, actions, and tasks and the interdependencies among them
- Degree to which actions and tasks are defined within each framework activity
- Degree to which work products are identified and required

Quote:

"I feel a recipe is only a theme which an intelligent cook can play each time with a variation."

Madame Benoit

- Manner in which quality assurance activities are applied
- Manner in which project tracking and control activities are applied
- Overall degree of detail and rigor with which the process is described
- Degree to which the customer and other stakeholders are involved with the project
- Level of autonomy given to the software team
- Degree to which team organization and roles are prescribed

In Part 1 of this book, I'll examine software process in considerable detail. *Prescriptive process models* (Chapter 2) stress detailed definition, identification, and application of process activities and tasks. Their intent is to improve system quality, make projects more manageable, make delivery dates and costs more predictable, and guide teams of software engineers as they perform the work required to build a system. Unfortunately, there have been times when these objectives were not achieved. If prescriptive models are applied dogmatically and without adaptation, they can increase the level of bureaucracy associated with building computer-based systems and inadvertently create difficulty for all stakeholders.

? What characterizes an "agile" process?

Agile process models (Chapter 3) emphasize project "agility" and follow a set of principles that lead to a more informal (but, proponents argue, no less effective) approach to software process. These process models are generally characterized as "agile" because they emphasize maneuverability and adaptability. They are appropriate for many types of projects and are particularly useful when Web applications are engineered.

1.5 Software Engineering Practice

WebRef

A variety of thought-provoking quotes on the practice of software engineering can be found at **www.literateprogramming.com**

In Section 1.4, I introduced a generic software process model composed of a set of activities that establish a framework for software engineering practice. Generic framework activities—**communication, planning, modeling, construction,** and **deployment**—and umbrella activities establish a skeleton architecture for software engineering work. But how does the practice of software engineering fit in? In the sections that follow, you'll gain a basic understanding of the generic concepts and principles that apply to framework activities.[12]

1.5.1 The Essence of Practice

ADVICE

You might argue that Polya's approach is simply common sense. True. But it's amazing how often common sense is uncommon in the software world.

In a classic book, *How to Solve It,* written before modern computers existed, George Polya [Pol45] outlined the essence of problem solving, and consequently, the essence of software engineering practice:

1. *Understand the problem* (communication and analysis).
2. *Plan a solution* (modeling and software design).

12 You should revisit relevant sections within this chapter as specific software engineering methods and umbrella activities are discussed later in this book.

3. *Carry out the plan* (code generation).
4. *Examine the result for accuracy* (testing and quality assurance).

In the context of software engineering, these commonsense steps lead to a series of essential questions [adapted from Pol45]:

Understand the problem. It's sometimes difficult to admit, but most of us suffer from hubris when we're presented with a problem. We listen for a few seconds and then think, *Oh yeah, I understand, let's get on with solving this thing.* Unfortunately, understanding isn't always that easy. It's worth spending a little time answering a few simple questions:

- *Who has a stake in the solution to the problem?* That is, who are the stakeholders?
- *What are the unknowns?* What data, functions, and features are required to properly solve the problem?
- *Can the problem be compartmentalized?* Is it possible to represent smaller problems that may be easier to understand?
- *Can the problem be represented graphically?* Can an analysis model be created?

Quote:

"There is a grain of discovery in the solution of any problem."

George Polya

Plan the solution. Now you understand the problem (or so you think) and you can't wait to begin coding. Before you do, slow down just a bit and do a little design:

- *Have you seen similar problems before?* Are there patterns that are recognizable in a potential solution? Is there existing software that implements the data, functions, and features that are required?
- *Has a similar problem been solved?* If so, are elements of the solution reusable?
- *Can subproblems be defined?* If so, are solutions readily apparent for the subproblems?
- *Can you represent a solution in a manner that leads to effective implementation?* Can a design model be created?

Carry out the plan. The design you've created serves as a road map for the system you want to build. There may be unexpected detours, and it's possible that you'll discover an even better route as you go, but the "plan" will allow you to proceed without getting lost.

- *Does the solution conform to the plan?* Is source code traceable to the design model?
- *Is each component part of the solution provably correct?* Have the design and code been reviewed, or better, have correctness proofs been applied to the algorithm?

Examine the result. You can't be sure that your solution is perfect, but you can be sure that you've designed a sufficient number of tests to uncover as many errors as possible.

- *Is it possible to test each component part of the solution?* Has a reasonable testing strategy been implemented?
- *Does the solution produce results that conform to the data, functions, and features that are required?* Has the software been validated against all stakeholder requirements?

It shouldn't surprise you that much of this approach is common sense. In fact, it's reasonable to state that a commonsense approach to software engineering will never lead you astray.

1.5.2 General Principles

The dictionary defines the word *principle* as "an important underlying law or assumption required in a system of thought." Throughout this book I'll discuss principles at many different levels of abstraction. Some focus on software engineering as a whole, others consider a specific generic framework activity (e.g., **communication**), and still others focus on software engineering actions (e.g., architectural design) or technical tasks (e.g., write a usage scenario). Regardless of their level of focus, principles help you establish a mind-set for solid software engineering practice. They are important for that reason.

David Hooker [Hoo96] has proposed seven principles that focus on software engineering practice as a whole. They are reproduced in the following paragraphs:[13]

Before beginning a software project, be sure the software has a business purpose and that users perceive value in it.

The First Principle: *The Reason It All Exists*

A software system exists for one reason: *to provide value to its users*. All decisions should be made with this in mind. Before specifying a system requirement, before noting a piece of system functionality, before determining the hardware platforms or development processes, ask yourself questions such as: "Does this add real value to the system?" If the answer is "no," don't do it. All other principles support this one.

The Second Principle: *KISS (Keep It Simple, Stupid!)*

Software design is not a haphazard process. There are many factors to consider in any design effort. *All design should be as simple as possible, but no simpler*. This facilitates having a more easily understood and easily maintained system. This is

13 Reproduced with permission of the author [Hoo96]. Hooker defines patterns for these principles at http://c2.com/cgi/wiki?SevenPrinciplesOfSoftwareDevelopment.

Quote:

"There is a certain majesty in simplicity which is far above all the quaintness of wit."

Alexander Pope (1688–1744)

not to say that features, even internal features, should be discarded in the name of simplicity. Indeed, the more elegant designs are usually the more simple ones. Simple also does not mean "quick and dirty." In fact, it often takes a lot of thought and work over multiple iterations to simplify. The payoff is software that is more maintainable and less error-prone.

The Third Principle: *Maintain the Vision*

A clear vision is essential to the success of a software project. Without one, a project almost unfailingly ends up being "of two [or more] minds" about itself. Without conceptual integrity, a system threatens to become a patchwork of incompatible designs, held together by the wrong kind of screws. . . . Compromising the architectural vision of a software system weakens and will eventually break even the well-designed systems. Having an empowered architect who can hold the vision and enforce compliance helps ensure a very successful software project.

The Fourth Principle: *What You Produce, Others Will Consume*

KEY POINT

If software has value, it will change over its useful life. For that reason, software must be built to be maintainable.

Seldom is an industrial-strength software system constructed and used in a vacuum. In some way or other, someone else will use, maintain, document, or otherwise depend on being able to understand your system. So, *always specify, design, and implement knowing someone else will have to understand what you are doing*. The audience for any product of software development is potentially large. Specify with an eye to the users. Design, keeping the implementers in mind. Code with concern for those that must maintain and extend the system. Someone may have to debug the code you write, and that makes them a user of your code. Making their job easier adds value to the system.

The Fifth Principle: *Be Open to the Future*

A system with a long lifetime has more value. In today's computing environments, where specifications change on a moment's notice and hardware platforms are obsolete just a few months old, software lifetimes are typically measured in months instead of years. However, true "industrial-strength" software systems must endure far longer. To do this successfully, these systems must be ready to adapt to these and other changes. Systems that do this successfully are those that have been designed this way from the start. *Never design yourself into a corner*. Always ask "what if," and prepare for all possible answers by creating systems that solve the general problem, not just the specific one.[14] This could very possibly lead to the reuse of an entire system.

14 This advice can be dangerous if it is taken to extremes. Designing for the "general problem" sometimes requires performance compromises and can make specific solutions inefficient.

The Sixth Principle: *Plan Ahead for Reuse*

Reuse saves time and effort.[15] Achieving a high level of reuse is arguably the hardest goal to accomplish in developing a software system. The reuse of code and designs has been proclaimed as a major benefit of using object-oriented technologies. However, the return on this investment is not automatic. To leverage the reuse possibilities that object-oriented [or conventional] programming provides requires forethought and planning. There are many techniques to realize reuse at every level of the system development process. . . . *Planning ahead for reuse reduces the cost and increases the value of both the reusable components and the systems into which they are incorporated*.

The Seventh principle: *Think!*

This last principle is probably the most overlooked. *Placing clear, complete thought before action almost always produces better results*. When you think about something, you are more likely to do it right. You also gain knowledge about how to do it right again. If you do think about something and still do it wrong, it becomes a valuable experience. A side effect of thinking is learning to recognize when you don't know something, at which point you can research the answer. When clear thought has gone into a system, value comes out. Applying the first six principles requires intense thought, for which the potential rewards are enormous.

If every software engineer and every software team simply followed Hooker's seven principles, many of the difficulties we experience in building complex computer-based systems would be eliminated.

1.6 Software Myths

Quote:

"In the absence of meaningful standards, a new industry like software comes to depend instead on folklore."

Tom DeMarco

Software myths—erroneous beliefs about software and the process that is used to build it—can be traced to the earliest days of computing. Myths have a number of attributes that make them insidious. For instance, they appear to be reasonable statements of fact (sometimes containing elements of truth), they have an intuitive feel, and they are often promulgated by experienced practitioners who "know the score."

Today, most knowledgeable software engineering professionals recognize myths for what they are—misleading attitudes that have caused serious problems for managers and practitioners alike. However, old attitudes and habits are difficult to modify, and remnants of software myths remain.

15 Although this is true for those who reuse the software on future projects, reuse can be expensive for those who must design and build reusable components. Studies indicate that designing and building reusable components can cost between 25 to 200 percent more than targeted software. In some cases, the cost differential cannot be justified.

WebRef
The Software Project Managers Network at **www.spmn.com** can help you dispel these and other myths.

Management myths. Managers with software responsibility, like managers in most disciplines, are often under pressure to maintain budgets, keep schedules from slipping, and improve quality. Like a drowning person who grasps at a straw, a software manager often grasps at belief in a software myth, if that belief will lessen the pressure (even temporarily).

Myth: *We already have a book that's full of standards and procedures for building software. Won't that provide my people with everything they need to know?*

Reality: The book of standards may very well exist, but is it used? Are software practitioners aware of its existence? Does it reflect modern software engineering practice? Is it complete? Is it adaptable? Is it streamlined to improve time-to-delivery while still maintaining a focus on quality? In many cases, the answer to all of these questions is "no."

Myth: *If we get behind schedule, we can add more programmers and catch up (sometimes called the "Mongolian horde" concept).*

Reality: Software development is not a mechanistic process like manufacturing. In the words of Brooks [Bro95]: "adding people to a late software project makes it later." At first, this statement may seem counterintuitive. However, as new people are added, people who were working must spend time educating the newcomers, thereby reducing the amount of time spent on productive development effort. People can be added but only in a planned and well-coordinated manner.

Myth: *If I decide to outsource the software project to a third party, I can just relax and let that firm build it.*

Reality: If an organization does not understand how to manage and control software projects internally, it will invariably struggle when it outsources software projects.

Customer myths. A customer who requests computer software may be a person at the next desk, a technical group down the hall, the marketing/sales department, or an outside company that has requested software under contract. In many cases, the customer believes myths about software because software managers and practitioners do little to correct misinformation. Myths lead to false expectations (by the customer) and, ultimately, dissatisfaction with the developer.

Work very hard to understand what you have to do before you start. You may not be able to develop every detail, but the more you know, the less risk you take.

Myth: *A general statement of objectives is sufficient to begin writing programs—we can fill in the details later.*

Reality: Although a comprehensive and stable statement of requirements is not always possible, an ambiguous "statement of objectives" is a recipe for disaster. Unambiguous requirements (usually derived

iteratively) are developed only through effective and continuous communication between customer and developer.

Myth: *Software requirements continually change, but change can be easily accommodated because software is flexible.*

Reality: It is true that software requirements change, but the impact of change varies with the time at which it is introduced. When requirements changes are requested early (before design or code has been started), the cost impact is relatively small.[16] However, as time passes, the cost impact grows rapidly—resources have been committed, a design framework has been established, and change can cause upheaval that requires additional resources and major design modification.

Whenever you think, we don't have time for software engineering, ask yourself, "Will we have time to do it over again?"

Practitioner's myths. Myths that are still believed by software practitioners have been fostered by over 50 years of programming culture. During the early days, programming was viewed as an art form. Old ways and attitudes die hard.

Myth: *Once we write the program and get it to work, our job is done.*

Reality: Someone once said that "the sooner you begin 'writing code,' the longer it'll take you to get done." Industry data indicate that between 60 and 80 percent of all effort expended on software will be expended after it is delivered to the customer for the first time.

Myth: *Until I get the program "running" I have no way of assessing its quality.*

Reality: One of the most effective software quality assurance mechanisms can be applied from the inception of a project—*the technical review.* Software reviews (described in Chapter 15) are a "quality filter" that have been found to be more effective than testing for finding certain classes of software defects.

Myth: *The only deliverable work product for a successful project is the working program.*

Reality: A working program is only one part of a software configuration that includes many elements. A variety of work products (e.g., models, documents, plans) provide a foundation for successful engineering and, more important, guidance for software support.

Myth: *Software engineering will make us create voluminous and unnecessary documentation and will invariably slow us down.*

Reality: Software engineering is not about creating documents. It is about creating a quality product. Better quality leads to reduced rework. And reduced rework results in faster delivery times.

16 Many software engineers have adopted an "agile" approach that accommodates change incrementally, thereby controlling its impact and cost. Agile methods are discussed in Chapter 3.

Many software professionals recognize the fallacy of the myths just described. Regrettably, habitual attitudes and methods foster poor management and technical practices, even when reality dictates a better approach. Recognition of software realities is the first step toward formulation of practical solutions for software engineering.

1.7 How It All Starts

Every software project is precipitated by some business need—the need to correct a defect in an existing application; the need to adapt a "legacy system" to a changing business environment; the need to extend the functions and features of an existing application; or the need to create a new product, service, or system.

At the beginning of a software project, the business need is often expressed informally as part of a simple conversation. The conversation presented in the sidebar is typical.

SafeHome[17]

How a Project Starts

The scene: Meeting room at CPI Corporation, a (fictional) company that makes consumer products for home and commercial use.

The players: Mal Golden, senior manager, product development; Lisa Perez, marketing manager; Lee Warren, engineering manager; Joe Camalleri, executive VP, business development

The conversation:

Joe: Okay, Lee, what's this I hear about your folks developing a what? A generic universal wireless box?

Lee: It's pretty cool . . . about the size of a small matchbook . . . we can attach it to sensors of all kinds, a digital camera, just about anything. Using the 802.11g wireless protocol. It allows us to access the device's output without wires. We think it'll lead to a whole new generation of products.

Joe: You agree, Mal?

Mal: I do. In fact, with sales as flat as they've been this year, we need something new. Lisa and I have been doing a little market research, and we think we've got a line of products that could be big.

Joe: How big . . . bottom line big?

Mal (avoiding a direct commitment): Tell him about our idea, Lisa.

Lisa: It's a whole new generation of what we call "home management products." We call 'em *SafeHome*. They use the new wireless interface, provide homeowners or small-business people with a system that's controlled by their PC—home security, home surveillance, appliance and device control—you know, turn down the home air conditioner while you're driving home, that sort of thing.

Lee (jumping in): Engineering's done a technical feasibility study of this idea, Joe. It's doable at low manufacturing cost. Most hardware is off-the-shelf. Software is an issue, but it's nothing that we can't do.

Joe: Interesting. Now, I asked about the bottom line.

Mal: PCs have penetrated over 70 percent of all households in the USA. If we could price this thing right, it could be a killer-App. Nobody else has our wireless box . . . it's proprietary. We'll have a 2-year jump on the competition. Revenue? Maybe as much as 30 to 40 million dollars in the second year.

Joe (smiling): Let's take this to the next level. I'm interested.

17 The *SafeHome* project will be used throughout this book to illustrate the inner workings of a project team as it builds a software product. The company, the project, and the people are purely fictitious, but the situations and problems are real.

With the exception of a passing reference, software was hardly mentioned as part of the conversation. And yet, software will make or break the *SafeHome* product line. The engineering effort will succeed only if *SafeHome* software succeeds. The market will accept the product only if the software embedded within it properly meets the customer's (as yet unstated) needs. We'll follow the progression of *SafeHome* software engineering in many of the chapters that follow.

1.8 Summary

Software is the key element in the evolution of computer-based systems and products and one of the most important technologies on the world stage. Over the past 50 years, software has evolved from a specialized problem solving and information analysis tool to an industry in itself. Yet we still have trouble developing high-quality software on time and within budget.

Software—programs, data, and descriptive information—addresses a wide array of technology and application areas. Legacy software continues to present special challenges to those who must maintain it.

Web-based systems and applications have evolved from simple collections of information content to sophisticated systems that present complex functionality and multimedia content. Although these WebApps have unique features and requirements, they are software nonetheless.

Software engineering encompasses process, methods, and tools that enable complex computer-based systems to be built in a timely manner with quality. The software process incorporates five framework activities—communication, planning, modeling, construction, and deployment—that are applicable to all software projects. Software engineering practice is a problem solving activity that follows a set of core principles.

A wide array of software myths continue to lead managers and practitioners astray, even as our collective knowledge of software and the technologies required to build it grows. As you learn more about software engineering, you'll begin to understand why these myths should be debunked whenever they are encountered.

Problems and Points to Ponder

1.1. Provide at least five additional examples of how the law of unintended consequences applies to computer software.

1.2. Provide a number of examples (both positive and negative) that indicate the impact of software on our society.

1.3. Develop your own answers to the five questions asked at the beginning of Section 1.1. Discuss them with your fellow students.

1.4. Many modern applications change frequently—before they are presented to the end user and then after the first version has been put into use. Suggest a few ways to build software to stop deterioration due to change.

1.5. Consider the seven software categories presented in Section 1.1.2. Do you think that the same approach to software engineering can be applied for each? Explain your answer.

1.6. Figure 1.3 places the three software engineering layers on top of a layer entitled "a quality focus." This implies an organizational quality program such as total quality management. Do a bit of research and develop an outline of the key tenets of a total quality management program.

1.7. Is software engineering applicable when WebApps are built? If so, how might it be modified to accommodate the unique characteristics of WebApps?

1.8. As software becomes more pervasive, risks to the public (due to faulty programs) become an increasingly significant concern. Develop a doomsday but realistic scenario in which the failure of a computer program could do great harm (either economic or human).

1.9. Describe a process framework in your own words. When we say that framework activities are applicable to all projects, does this mean that the same work tasks are applied for all projects, regardless of size and complexity? Explain.

1.10. Umbrella activities occur throughout the software process. Do you think they are applied evenly across the process, or are some concentrated in one or more framework activities.

1.11. Add two additional myths to the list presented in Section 1.6. Also state the reality that accompanies the myth.

Further Readings and Information Sources[18]

There are literally thousands of books written about computer software. The vast majority discuss programming languages or software applications, but a few discuss software itself. Pressman and Herron (*Software Shock,* Dorset House, 1991) presented an early discussion (directed at the layperson) of software and the way professionals build it. Negroponte's best-selling book (*Being Digital*, Alfred A. Knopf, Inc., 1995) provides a view of computing and its overall impact in the twenty-first century. DeMarco (*Why Does Software Cost So Much?* Dorset House, 1995) has produced a collection of amusing and insightful essays on software and the process through which it is developed.

Minasi (*The Software Conspiracy: Why Software Companies Put out Faulty Products, How They Can Hurt You, and What You Can Do,* McGraw-Hill, 2000) argues that the "modern scourge" of software bugs can be eliminated and suggests ways to accomplish this. Compaine (*Digital Divide: Facing a Crisis or Creating a Myth,* MIT Press, 2001) argues that the "divide" between those who have access to information resources (e.g., the Web) and those that do not is narrowing as we move into the first decade of this century. Books by Greenfield (*Everyware: The Dawning Age of Ubiquitous Computing,* New Riders Publishing, 2006) and Loke (*Context-Aware Pervasive Systems: Architectures for a New Breed of Applications,* Auerbach, 2006) introduce the concept of "open-world" software and predict a wireless environment in which software must adapt to requirements that emerge in real time.

The current state of the software engineering and the software process can best be determined from publications such as *IEEE Software, IEEE Computer, CrossTalk,* and *IEEE Transactions on Software Engineering.* Industry periodicals such as *Application Development Trends* and *Cutter*

18 The *Further Reading and Information Sources* section presented at the conclusion of each chapter presents a brief overview of print sources that can help to expand your understanding of the major topics presented in the chapter. I have created a comprehensive website to support *Software Engineering: A Practitioner's Approach at* **www.mhhe.com/compsci/pressman**. Among the many topics addressed within the website are chapter-by-chapter software engineering resources to Web-based information that can complement the material presented in each chapter. An Amazon.com link to every book noted in this section is contained within these resources.

IT Journal often contain articles on software engineering topics. The discipline is "summarized" every year in the *Proceeding of the International Conference on Software Engineering,* sponsored by the IEEE and ACM, and is discussed in depth in journals such as *ACM Transactions on Software Engineering and Methodology, ACM Software Engineering Notes,* and *Annals of Software Engineering.* Tens of thousands of websites are dedicated to software engineering and the software process.

Many books addressing the software process and software engineering have been published in recent years. Some present an overview of the entire process, while others delve into a few important topics to the exclusion of others. Among the more popular offerings (in addition to this book!) are

Abran, A., and J. Moore, *SWEBOK: Guide to the Software Engineering Body of Knowledge,* IEEE, 2002.

Andersson, E., et al., *Software Engineering for Internet Applications,* The MIT Press, 2006.

Christensen, M., and R. Thayer, *A Project Manager's Guide to Software Engineering Best Practices,* IEEE-CS Press (Wiley), 2002.

Glass, R., *Fact and Fallacies of Software Engineering,* Addison-Wesley, 2002.

Jacobson, I., *Object-Oriented Software Engineering: A Use Case Driven Approach,* 2d ed., Addison-Wesley, 2008.

Jalote, P., *An Integrated Approach to Software Engineering,* Springer, 2006.

Pfleeger, S., *Software Engineering: Theory and Practice,* 3d ed., Prentice-Hall, 2005.

Schach, S., *Object-Oriented and Classical Software Engineering,* 7th ed., McGraw-Hill, 2006.

Sommerville, I., *Software Engineering,* 8th ed., Addison-Wesley, 2006.

Tsui, F., and O. Karam, *Essentials of Software Engineering,* Jones & Bartlett Publishers, 2006.

Many software engineering standards have been published by the IEEE, ISO, and their standards organizations over the past few decades. Moore (*The Road Map to Software Engineering: A Standards-Based Guide,* Wiley-IEEE Computer Society Press, 2006) provides a useful survey of relevant standards and how they apply to real projects.

A wide variety of information sources on software engineering and the software process are available on the Internet. An up-to-date list of World Wide Web references that are relevant to the software process can be found at the SEPA website: **www.mhhe.com/engcs/compsci/pressman/professional/olc/ser.htm.**