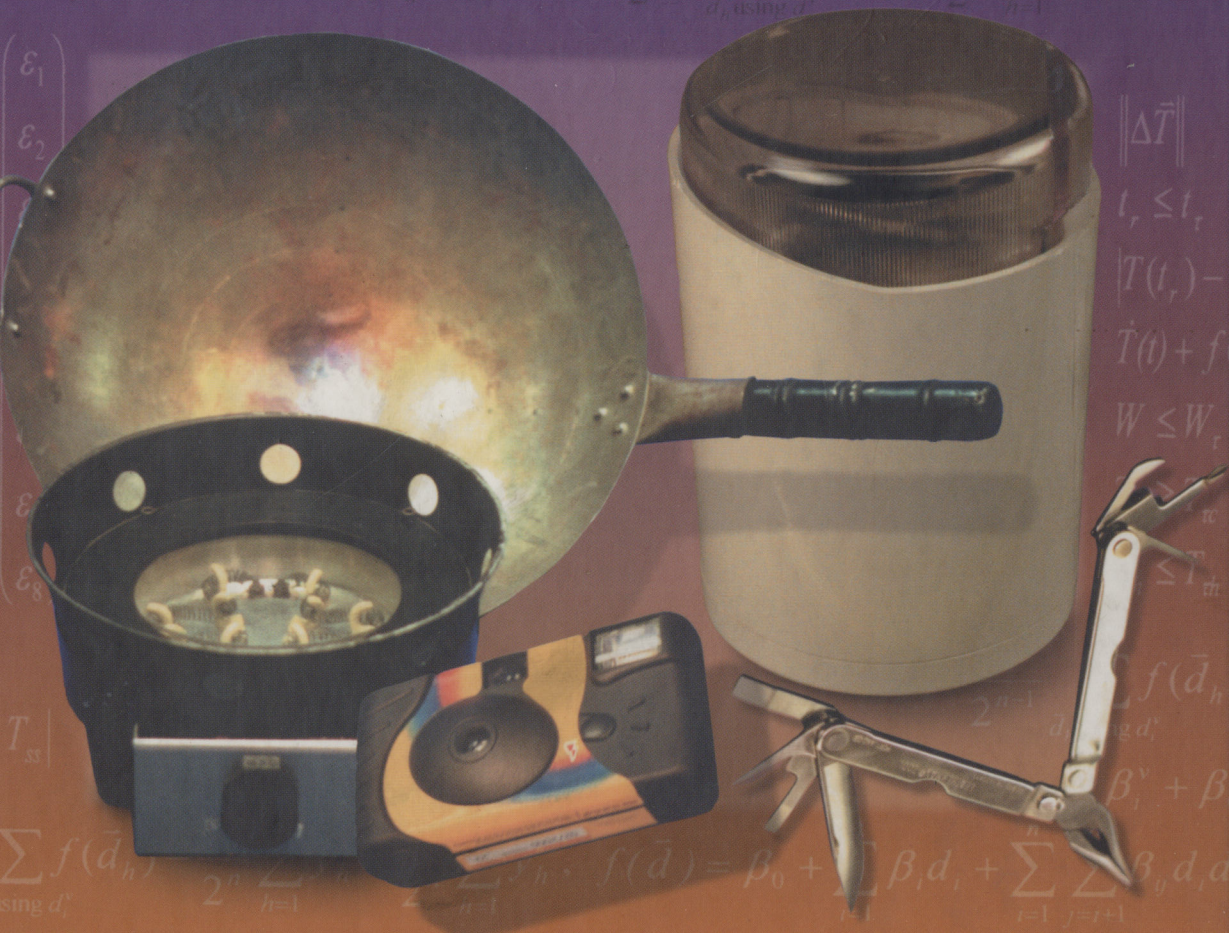
Product Design

Techniques in Reverse Engineering and New Product Development



KEVIN OTTO & KRISTIN WOOD

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Techniques in Reverse Engineering and New Product Development

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Dedicated to Ginger—my wonderful wife, partner, companion and friend, whom I dearly love.

Kevin

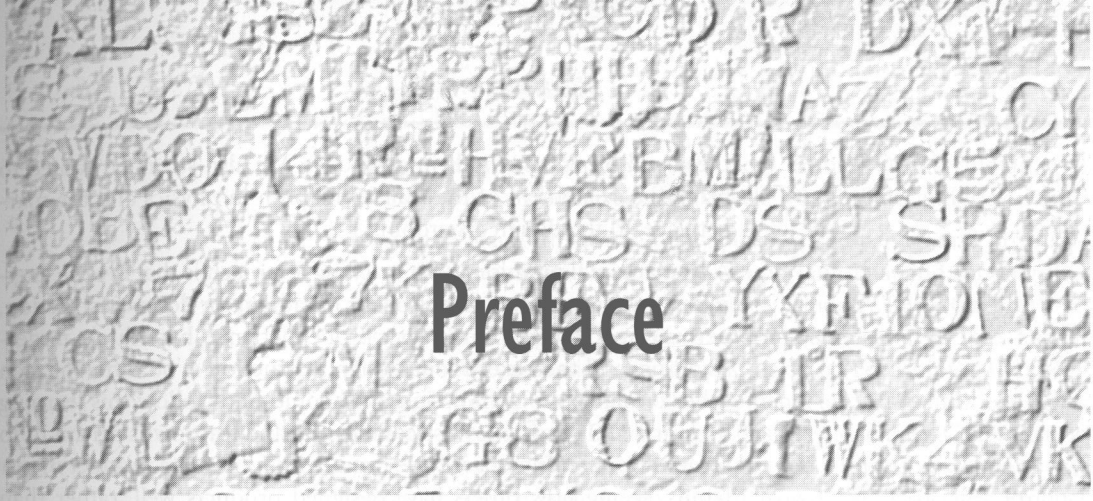
To those that bring light to my life and spirit: above all, the Lord Jesus Christ; my loving wife Laurie; my precious children Katie, Emily, and Zachariah; their grandparents, Sharon, Del, Bob, and Judith; and in special memory of my grandparents, Bert and Lee Armstrong , who first kindled my inquisitive nature.

Kristin

Foreword

Many American companies have come to realize that the ability to consistently define and deliver products to the marketplace more rapidly and efficiently than their competitors can become a source of sustainable competitive advantage. These companies have moved to view their product development capability as an end-to-end business process that can be greatly enhanced through re-engineering and can be continuously improved through total quality management. In this environment, the practice of engineering is critical to the success of the process and is as important as the implementation of the engineering sciences. K. N. Otto and K. L. Wood have presented an approach to product design based on "state of the art" engineering methods, tools, and processes that when utilized within the discipline of an overall product development process, depicts a very powerful practice of design. Both students and practitioners will find this approach not only effective and practical, but also immediately applicable to today's design challenges.

Maurice F. Holmes
Vice President, Chief Engineer of Product Design
Xerox Corporation



Preface

Product Design presents an in-depth study of structured design processes and methods. In general, we have found that the exercise of a structured design process has many benefits in education and industry. On the industrial side, a structured design process is mandatory to effectively decide what projects to bring to market, schedule this development pipeline in a changing uncertain world, and effectively create robust delightful products. On the educational side, the benefits of using structured design methods include concrete experiences with hands-on products, applications of contemporary technologies, realistic and fruitful applications of applied mathematics and scientific principles, studies of systematic experimentation, exploration of the boundaries of design methodology, and decision making for real product development. These results have proven true whether at the sophomore introductory level with students of limited practice, or at the advanced graduate student level with students having years of practical design experience.

Based on these observations, this book is intended for undergraduate, graduate, and practicing engineers. Chapter 1 of the book discusses the foundation material of product design, including our philosophy for learning and implementing product design methods. Each subsequent chapter then includes both basic and advanced techniques for particular phases of product development. Depending on the background of the reader, these methods may be understood at a rudimentary level or at a level that pushes the current frontiers of product design.

Historically, this work grew out of a partnership effort between the authors, while we were both teaching product development courses and carrying out research in mechanical design. We both share similar philosophies on design, teaching, and research. Having each developed new methods in design, we were interested in transferring

these and others' methods into practice. We also strongly wanted to bring the excitement of the real world, both in physics and the marketplace, to the design classroom.

A fundamental premise of our teaching approach is that reverse engineering and teardowns offer a better paradigm for design instruction, permitting a modern learning cycle of experience, hypothesis, understanding, and then execution. Design instruction is no different than other domains; to learn design one should both follow this learning cycle and DO design. Reverse engineering and teardowns permit us to achieve this combined goal. We begin with a concrete product in our hands, seeing how others have designed products well, rather than rushing straight to the execution stage. With this in mind, we both independently set out to teach and successfully apply advanced methods, such as customer needs analysis, functional modeling, optimization, and designed experiments on real products.

We quickly started sharing experiences, what worked and what did not, and progressively began to string together a series of techniques and that fit naturally together. When one of us had a success, we would brag to the other, or when something failed, we'd lament together. After a bit of systematic testing, we developed the methodology presented in this book, which has proved remarkably robust when applied.

We would like to extend our special thanks to the many persons who directly contributed to this book. These include John Baker, Joseph Beaman, Geoffrey Boothroyd, Ilene Busch-Vishniac, Jim Claypool, Richard Crawford, David Cutherell, Michael Fang, Conger Gable, Javier Gonzales-Zugasti, Matthew Haggerty, Nicholas Hirschi, Maurice Holmes, Jerry Jackson, Jerry Jones, Jennie Kwo, Doug Lefever, Aaron Little, Michael Manente, Robert Matulka, Dan McAdams, David Meeker, Jon Miller, Steve Moore, Jeff Norrell, Caroline Pan, Erick Rios, David Roggenkamp, JoRuetta Roberson, Phil Schmidt, Stephen Shuler, R. S. Srinivasan, Robert Stone, Carlos Tapia, David Wallace, Joe Wysocki, Janet Yu, and Erik Zamirowski. Without their intellectual help, this book would not be.

Many others have sparked our thoughts and inspired us in many ways. These persons include Erik Antonsson, Wolfgang Beitz, Joe Bezdek, Bert Bras, Jonathon Cagan, Uichung Cho, Chin-Seng Chu, Don Clausing, Jim Coles, Ray Corvair, Michael Cusumano, Jack Dixon, John Elder, Steven Eppinger, Rolf Faste, Woodie Flowers, Mark Foohey, Chee-Seng Foong, Douglas Hart, John Hauser, Chester Hearn, Alberto Hernandez, Steve Hoover, Kos Ishii, Gerry Johnson, Nathan Kane, Paul Koeneman, Sridhar Kota, Bill Maddox, Spencer Magleby, David Masser, Ryan Ratliff, David Rosen, Bernard Roth, Warren Seering, Jami Shah, Sheri Sheppard, Alexander Slocum,

George Stiny, David Thompson, Irem Tumer, David Ullman, Bill Weldon, Daniel Whitney, Joseph Wieck, Doug Wilde, and Rick Zayed.

We would like to thank the many persons, companies, and organizations that contributed case studies, important data, and funding that make the examples real world. These include A.T.&T. Corp., W. E. Bassett Co., Design Edge Inc., Desktop Manufacturing Co., Digital Equipment Corporation, Eastman Kodak Co., Ford Motor Co., MIT Bernard Gordon Curriculum Development Fund, June and Gene Gillis, General Electric Inc., International Business Machines Corp., Keurig Inc., Microsoft Corporation, NASA Jet Propulsion Laboratory, National Science Foundation, Robert Noyce, Pré Associates, Product Genesis Inc., Polaroid Corporation, Raychem Corp., Raytheon Corp., Texas Instruments Inc., Verein Deutches Ingineur, and the Xerox Corp.

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We would also like to thank the colleagues who reviewed early drafts of the book and provided constructive criticisms. A special group of early reviewers are the faculty of the United States Air Force Academy, Engineering Mechanics Department, including Col. Cary Fisher, Dr. Dan Jensen, Maj. John Wood, Capt. Michael Murphy, and Maj. Mark Nowak. We appreciate their assistance in implementing the material in their courses during Dr. Wood's sabbatical. They truly tested, twisted, shaped, and criticized the material at the most fundamental of levels.

Many others have contributed to the organization and form of the book. In particular, the authors wish to thank Neal Blumhagen, who created the cover artwork and a number of hand drawings in the text. Ann Weeks, artist, Erik Zumalt, digital artist, Michael Young, media coordinator, and Sicily Dickenson, director of the UT Instructional Media Lab, contributed wonderfully to the numerous illustrations and photographs in the book. Finally, Laurie Wood contributed her creativity to a number of the illustrations.

Kevin Otto
Kristin Wood

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