



Introduction: The Author and His Work

by John Shook and Durward Sobek

It is with great enthusiasm that we introduce to you a set of important ideas and the man behind them. It is with equally great sadness that we do so posthumously.

Allen Ward completed the original manuscript in August 2001. He died in a plane crash in May 2004. In the interim, he continued to work on his ideas—trying them out, arguing them, revising them. Though his theories continued to evolve and grow with great dynamism with each new experience, we think this volume is a good representation of Al's thinking.

We, John Shook and Durward Sobek, first met Al (as friends and acquaintances knew him) in the early 1990s, when he was an assistant professor of mechanical engineering at the University of Michigan (UM). John was general manager of planning and administration at the Toyota Technical Center, USA, the North American engineering and product development arm of the Toyota Motor Corporation, where a team of UM researchers had converged to embark on a major series of research projects. John had been contacted by Professor John Campbell, who had obtained funding from the U.S. Air Force Office of Scientific Research (AFOSR) to create the university's Japan Technology Management Program. The research team included, among others, Professor of Industrial and Operations Engineering Jeff Liker, whose continuing research led to his landmark publication of *The Toyota Way*; and later, a young graduate student, Durward.

Members of the UM group seemed to fall into one of two camps. Many were researching Toyota to mine what they could find in that company for new concepts or practices. They hoped to analyze and perhaps model them in some way with the aim of presenting an objective picture of what Toyota is and does. The other camp was not that interested in Toyota but knew a good source of research funding when they saw it (the AFOSR in this case) and thought they might be able to get a paper or two published out of it.

Al was completely and obviously different from either group. He had already determined—from ideas developed during his Ph.D. research in artificial intelligence at Massachusetts Institute of Technology (MIT)—that the way product development had been conducted in conventional systems was fundamentally flawed. Further, he thought he knew how it was flawed and how to fix it. But he also had a nagging concern: He had never found a real-world example of an organization that consistently operated according to his thinking. Al was looking for a company—just one—that did things the right way. When Al first set foot in Toyota, he knew immediately that he had found what he had been seeking, and more.

Later, with Al and Jeff Liker as advisors, Durward completed a Ph.D. dissertation that painted a comprehensive picture of Toyota’s product development organization and practices compared and contrasted with those of (then) Chrysler Corporation. Though the comparisons were broad ranging and included detailed descriptions of the organization, leadership approach, communication styles, processes, and philosophy toward design, Al never was fully satisfied. In fact, when Durward met Al for a mock dissertation defense near the end of his program, Al’s verdict was, “This is not Ph.D. material.” You can imagine Durward’s disappointment—even more than that, he was incredulous!

Durward passed the defense later that week, graduated, and became an engineering professor at Montana State University. But, in retrospect, Al was right. The dissertation lacked something.

In some ways, the volume you hold in your hands is the dissertation that Al wanted to see. It draws upon much of the data from Durward’s Toyota work. But more importantly, it has that something that was missing—deep insight.

This book makes a bold statement about the state of engineering leadership in most organizations; about how we view engineering and product/process development; about learning, knowledge, and respect; about human nature, innovation, and personal growth; indeed, about what we value most as players in the product development game. As we will try to convince you in the next few pages, and as you will discover on your own as you read its pages, this book is like no other in the product development literature. What makes it stand apart, and what we think you’ll find most valuable, is the depth of insight Allen Ward had into the key foundations of highly effective, lean product development systems.

About the Author

Allen Ward's academic résumé begins with a bachelor's degree in history from the University of Oregon. He always maintained an interest in history and often used historical references in his arguments and explanations of whatever issues he studied. Upon graduation, he joined the U.S. Army, where he served 10 years. He proudly completed combat leadership training at the U.S. Army Ranger School in Fort Benning, GA, and later toured Korea and attained the rank of captain. While stationed in Hawaii, he completed a second bachelor's degree in mechanical engineering. From there, Al left the Army and entered MIT as a Ph.D. student. He joined a group in the artificial intelligence laboratory interested in developing tools to automate mechanical engineering design tasks. He developed a prototype software tool and in the process stumbled upon a new design theory that he called set-based design.

During his time at UM, Al pursued an aggressive research agenda. Some of his students were developing design automation software that put his theory into computer code, leading Al to discover that standard set propagation theory was inadequate for multidimensional design problems. So he had other students develop new mathematical representations and logical operations to tackle these problems. Still other students were working on enhancing existing design methodologies using his new theory. And finally, Al was interested to know if any human engineers practiced a form of his set-based design theory—the interest that led him to Toyota and affiliates.

Al's first trip to Toyota's headquarters in Japan was in 1993, with Yasuko Ward—his wife and a Ford Motor Company engineer—serving as interpreter. The ideas and hypotheses flew rapidly and furiously. The hypotheses were helpful to John, who was himself trying to figure how to conceptualize and articulate Toyota's product development system. Unlike the company's manufacturing processes—already famous by that time as the Toyota Production System—the product development system had never been fully described. Even inside the company, while engineers and managers understood concretely how the system worked and how to manage it effectively, describing it simply and holistically was another matter.

This topic became the subject of Durward's Ph.D. research. Durward studied Japanese intensively for a year-and-a-half, then spent six months in Japan interviewing Toyota engineers and engineering managers about all aspects of

Toyota's product development system. Toward the end of this stay, Al made another study trip to Japan, sleeping on tatami mats in Durward's apartment to save money. This cost-saving measure had an unexpected side benefit: discussion of the day's interviews continued into the long hours of the evening. The research continued after the trip, as we interviewed American and Japanese engineers working in Toyota's U.S. operations in Ann Arbor, MI, and Erlanger, KY. The preliminary synthesis of the ideas for this book began during the many hours of debate, clarification, and theory-building Al and Durward had while preparing presentations and workshops based on the Toyota research.

As Durward was finishing his Ph.D. work, Al left academia and started a consulting and specialty machine design company. In this capacity, he was in the unique position to a) observe conventional product development systems in many companies, b) continue to contemplate and develop the ideas that came out of the Toyota research, c) experiment with the ideas in his own design activities, and d) learn by helping companies try out the concepts and dramatically improve performance.

Over the ensuing years, John had the opportunity to work with Al to assist companies in their pursuit to become lean enterprises. John was often Al's sounding board. As he discovered each new aspect of Toyota's product development world—or just of Toyota—Al would offer up his analysis or assessment. Before the hypotheses, though, were always the questions, such as: “Lean is about eliminating waste, so what is ‘waste’ in product development and why is it that engineers never talk about it? Does the lean concept of ‘takt time’ apply to the product development world? How much of an engineer's time is spent doing actual engineering work? How much of his or her time should be spent doing engineering work?” Through discussing and even arguing these ideas, slowly but steadily a comprehensive sense of “lean product development” began to emerge.

Work continued and the pace quickened, as more companies became intrigued with Al's ideas and sought his consulting help. His ideas continued to evolve, and were reflected in his presentation materials to clients and in his workshops. Business continued to pick up. He hired a team of bright young graduates to support him, began the process of capturing his knowledge with interactive video, and was brimming over with enthusiasm for his work.

To become more efficient and serve his clients better (and at the same time pursue a lifelong love of flying), Al purchased a light aircraft with which he could fly between client locations without being beholden to the schedules and routes of the commercial airlines. Tragically, en route to deliver a workshop at a client site on the West Coast, Al and the two passengers on board died in an airplane crash on May 31, 2004.

Why We're Publishing This Book

Al created this manuscript in 2001. We think it represents the most complete and concise record of his ideas and insights. We remain struck with the power and relevance of the ideas presented in these pages.

- He asks basic questions that drive at the fundamentals of product development.
- He observes the sources (aka “wastes”) of the most common maladies that plague many product development organizations.
- He distills what might be termed “cornerstones” from the practices of lean product developers—most notably Toyota and its partners—which differ remarkably from conventional practice.
- He uniquely melds observations of effective teamwork from his military background, engineering fundamentals from his education and personal experience, design methodology from his research, and theories about management, cognition, and learning from his understanding of history and interactions with clients.
- He carries the implications of his theories into specific, practical recommendations.
- He employs systems thinking in all aspects of thought and investigation.

Much research has been conducted on and a great deal written about product development over the past 20 years or more. This work runs the gamut, from sophisticated analytical models focused on some narrow aspect of development, to sweeping attempts to describe product development as a complete system; and

from tools to aid specific tasks such as developing customer requirements or devising project plans, to involved statistical analysis relating certain practices or organizational characteristics to measures of performance such as number of patents filed, market share, or sales growth. Nearly all of this work has been conducted within the same set of paradigms that are so deeply engrained that they are often taken for granted, or in some cases not even recognized. Al believed a number of these paradigms are fundamentally flawed, if not in concept then in implementation. If that is the case, then a set of new paradigms could radically alter forever the way we think about product development. This book represents Allen Ward's proposal for a new set of paradigms.

Of course, there is still plenty of room for debate and additional investigation. But if the ideas are not publicized, we might forever lose the opportunity to have that debate, and thereby not benefit from a life's work by a gifted scholar and engineer—a second tragedy that makes the first even worse.

But there is a problem. The manuscript Al left was not quite finished. We also know that his thinking evolved beyond that captured in the manuscript, that some of the examples used are out of date, and that the work in lean development has continued. Yet his ideas remain powerful, his insights valuable, and his recommendations potentially revolutionary! How can we get this out where people can read it, debate it, and put it to profitable use?

Our approach to the first edition was to leave the manuscript as intact as possible, in order to preserve the author's original intent and, to the extent possible, reflect his personality. We did minimal editing, and we added a few editorial notes where we thought additional clarification may be useful to the reader. In this second edition, however, we have taken a bit more editorial license to clarify explanations, update examples, and incorporate new cases. In addition, the work in lean product development has continued over the years since the original manuscript was published. New tools and applications have emerged, and we have many more case examples now of companies applying lean principles to their development systems. So we have incorporated additional content in an attempt to reflect the most contemporary thinking and provide actual examples of the ideas in practice.

What you will find as you read these pages is prose that still reflects Al's personality and style. He will tell you in no uncertain terms what he believes, and what he believes you should do. He will look you in the eye to see if you blink. At times,

he is pedantic, which may offend some readers. (We hope not; though, on the other hand, Al probably would not have minded—he liked to issue challenges, and sometimes they would sting!) Like a tough professor, he suggests assignments that are probably unrealistically difficult. As a purely academic work, this book might not stand as rigorous research. But ivory tower academic “rigor” was not what Al was about. He was about understanding, insight, and the rigor of engineering as a discipline in the real world. The following is an overview of some of the insights Al shares.

The Foundations of Lean Product and Process Development

If we are going to design high-performing, super-efficient product-process development systems, we need razor-sharp clarity on four fundamental questions:

- What is the purpose of product development?
- What does it produce?
- What is a good development system?
- What is “value” (or “value added” or “value creating”) in product development?

It is Al’s opinion (and we agree), most companies have poor answers to these questions! And if we do not have good clarity on, for example, what exactly does a product development process produce, how can we possibly do it well? Thus the first insights are to be found in the answers to these four fundamental questions. Rigorous discussion of these basic questions will lead directly to a set of proposed performance measures for product development.

The author’s second insight is that many product development organizations evaluate and reward the wrong things. Thus most of chapter 2 describes six measures for evaluating product development effectiveness.

In chapter 3, the author shares his observation that many product development organizations are hopelessly out of control—in “death spirals” of one sort or another. A death spiral in product development might look like this: Engineers in a company are overburdened and facing management pressure to meet deadlines. They overlook things or cut corners to meet management’s expectations, and

mistakes occur. In response, management implements more checks in the system to try to catch the mistakes, usually consisting of more reviews and reports. This creates more work for the engineers, increasing their burden, resulting in more mistakes (or missed deadlines). So more checks are put in place, and the cycle continues until the organization is crippled and management decides product development is no longer a “core competence.”

Conventional thinking often makes these situations worse because the natural reactions reinforce the downward spiral. Al observes that at the root of most product development death spirals is a handful of wastes—scatter, hand off, and wishful thinking being the main culprits. The way out of the downward spirals is to attack the wastes at the center of the negatively reinforcing feedback loops. His explanation in chapter 3 powerfully demonstrates the inadequacy of conventional thinking, and sets the stage for an entirely new way of thinking about product development.

In chapters 4–8, Al articulates his vision for a totally new approach to product development. The starting point is focusing on value. The value of product development is in creating (re)usable knowledge and profitable operational value streams. His core thesis is that the very aim of the product development process is to create profitable operational value streams, and that creating knowledge that is applicable now and reusable in future projects is the key to doing so predictably, efficiently, and effectively.

To create (re)usable knowledge requires learning, Al presents a basic learning model for development that serves as the basis for all product development activity and support structures: the LAMDA principle. LAMDA stands for:

- **Look**—as in, go and see for yourself,
- **Ask**—get to the root cause,
- **Model**—using engineering analysis, simulation, or prototypes,
- **Discuss**—with peer reviewers, mentors, and developers of interfacing subsystems, and
- **Act**—test your understanding experimentally.

When you finish the cycle, look again. What AI observed at Toyota and other lean developers is a view of learning and knowledge creation that differs substantially from conventional practice. This view encourages *in situ* observation, because problems almost always arise because of a gap between what we think we understand and reality. It advocates deep investigation, using appropriate engineering tools and principles. It recognizes that knowledge creation and sense-making is often socially co-constructed, and that we have much to learn from each other. And it strongly implies that knowledge must be validated, continually, forever.

AI then turns his attention to the major pieces of the value stream that must be aligned among themselves and with the customer: development organizational structure, manufacturing system, and suppliers. Chapters 5–8 (approximately half of the book) delve into the following four cornerstones of lean product development, each of which turns conventional thinking about product development on its head.

1. Lead with Entrepreneur System Designers (ESDs)

The lean development organization makes one person responsible for both the engineering and aesthetic design, and the market and business success of the product—the entrepreneur system designer. This person cuts across departmental boundaries to create integration knowledge and bring the organization’s focus onto the entire value stream (from suppliers through manufacturing to customers).

The ESD has little administrative responsibility, and is supported by strong functional groups that have developed deep repositories of knowledge in specialty areas. The ESD leads the development effort to integrate that knowledge into a successful product. This idea runs directly counter to the common paradigm that product development projects should be led by well-oiled, cooperative multi-disciplinary teams—not that lean developers don’t appreciate teamwork, but how it is implemented in practice is very different.

2. Innovate by Aggressively Evaluating Sets of Alternatives at Every Level

Lean developers recognize that learning rates increase geometrically by considering redundant concepts or design alternatives at every level of the system. This also increases the likelihood of success to the point that if correctly managed, creates a highly robust, reliable, and therefore predictable product development cycle.

However, to avoid eating up excessive resources, lean developers devise methods to aggressively eliminate weak alternatives. Furthermore, they systematically synthesize learning into design space maps such as trade-off curves—knowledge that can be reused on subsequent projects, with the effect of greatly increasing both the speed and quality of design.

This idea runs counter to a common paradigm: that design is iterative in nature. Product development teams try an idea, analyze it to find its weak points, change it, analyze it again, and so on, until they have an acceptable design. The problem is, this almost never works well! Al first introduced the idea of set-based concurrent engineering in a paper about “The Second Toyota Paradox.”¹ In it, he and his colleagues argue that a better paradigm for product development is one in which participants reason and communicate about sets of ideas, and gradually narrow those sets to converge on a final design that meets the needs and requirements of everyone concerned. This is the model we observed at Toyota.

Still today, nearly 20 years after its publication, Durward gets requests for copies of the article. And faculty members at institutions around the country still have the article as required reading for their product development or engineering design courses. Chapter 6 provides a substantial expansion and refinement of set-based concurrent engineering, including practical methods for application.

3. Manage Turbulence through Cadence, Pull, and Flow

Managers of lean development organizations reject the scientific management notion that managers plan and workers do. Rather, developers plan their own work and work their own plans, under the guidance of a coach. But what do they plan to do? One of management’s responsibilities is to release projects on a regular cadence into the organization, in order to level the workload. Projects are defined by integrating events or milestones (set by the ESD), and developers plan their work to meet those events. In this way, engineering work is pulled rather than scheduled. Communication networks are similarly established so that information is pulled by the person needing to know, rather than pushed onto developers according to some centrally planned schedule. The result is the elimination of wasteful management structures and reports, and continuous cycles of improvement and waste reduction.

This cornerstone takes aim at typical implementations of stage-gate theory for managing development projects. Why? Because they are basically push systems. Toyota already has demonstrated that pull systems are more efficient and profitable than push systems in manufacturing. Al argues that Toyota also has demonstrated it in the development world.

4. Build Teams of Responsible Experts

Lean product development organizations develop personnel management systems that reward individuals and teams for creating and teaching knowledge that contributes to robust profitability. Functional department heads of the organization lead the knowledge-creating process, ensure that knowledge captured is reusable, and enable dissemination systems to apply knowledge effectively.

Interestingly, having strong discipline-focused groups forces a natural tension with the ESD. This seems to differ from many of the undertones of product development literature where words such as “cooperation” and “teamwork” are viewed as positive, and “conflict” viewed as negative. However, Al recognized that this “creative tension” is one of the keys to simultaneously reconciling diverse perspectives and fostering innovation.

Chapter 9 brings the book to a close by offering a few suggestions about getting started on the change from conventional to lean. It is brief. Had Al been able to see this book through to publication, we are quite sure that he would’ve had much more to say here. But in this edition we have added five in-depth case studies that describe remarkable results achieved by development organizations that have taken lean development principles to heart. The chapter invites both individual readers and the larger product development community to discuss, experiment, observe, ask why, and experiment some more, to come to their own consensus on how to make the transformation.

Invitation to Read On

With this as background, we invite you to read on, but with some words of advice. First, be warned that the idea density in some sections of this book is very high! Be prepared to take frequent breaks to reflect and fully absorb the ideas. Do not hesitate to reread sections, multiple times if necessary. We did.

Second, we don't necessarily agree with everything Al wrote and don't expect you to either. Nor would Al even want you to. Rather, the purpose of this publication is to introduce some insightful observations and innovative ideas that could potentially change engineering and product design practice fundamentally—while encouraging conversation, discussion, and debate.

You may not find all of the arguments compelling, but we hope that you will do more than take them at face value. We hope that you will think deeply about them because, even if in the end you are not convinced, we trust that the exercise of having done so will prove beneficial.

Third, we encourage you to not stop at discussion, but to actually get your hands dirty and try these ideas. Some of the exercises suggested may sound overwhelming, but we still encourage you to give them a try, even if a scaled-down version (for example, the assignment may suggest doing something for all of your company's products, which may be daunting; but maybe you could do it for one product family). If they don't work as expected, investigate the root cause, and experiment some more. After all, if the current system is in a death spiral, doing the same things more earnestly will only make things worse.

Al's ideas have continued to have life and influence since his untimely passing. We hope this volume will introduce Al's important ideas to as broad an audience as possible. Al would never ask that you take everything between the covers of this book as gospel. But he would ask that you take the ideas seriously, give them a try, challenge them where you disagree, and take it upon yourself to push the thinking forward in new, perhaps unexpected, directions. He would want you to listen, change the way you think and work, and then argue passionately about what you've tried that worked, what didn't, and why. We are convinced that anyone who gives the ideas serious thought and even a try will find them as rewarding as Al's students and colleagues already know them to be.

It is our honor and privilege to present this work as a tribute to our colleague, mentor, and friend. We hope you are blessed by him in this volume as we were in knowing him. Now prepare yourself for a fascinating journey, with Al Ward as your captain!