



THE

# LEAN MINDSET

**ASK THE RIGHT QUESTIONS**

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*with* HENRIK KNIBERG

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# Introduction

Back in the 1990s, when open source was an outlier and eBay was a startup, most people believed that economic transactions—at least important ones—required a trustworthy company to back them up. And trustworthy companies required a management structure to make sure that important work got done.

When economists first stumbled upon Linux, their instinctive reaction was “This is impossible!”<sup>1</sup> How can a deeply complex operating system that was developed and maintained by volunteers be reliable enough for widespread adoption by businesses? But today Linux, along with GNU, is arguably the most successful operating system in the world. Apache HTTP Server has powered over 60% of all Web servers since 2000. Sendmail and its commercial derivatives deliver 65% of e-mail worldwide. All this was accomplished without traditional management structures or work practices.

eBay faced a different dilemma; it needed to find a way to create trust between buyers and sellers who were strangers. The company devised a review and ranking system that quickly exposed bad behavior. This widely imitated reputation system has kept instances of fraud in consumer-to-consumer transactions amazingly low, paving the path for a broad range of trust-based businesses.

While the Internet was growing up, it was used mostly by scientists. They developed it into a tool to support the way they worked; it helped

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1. See Peter Kollock, “The Economies of Online Cooperation: Gifts and Public Goods in Cyberspace,” Chapter 9 of *Communities in Cyberspace*, ed. Marc A. Smith and Peter Kollock, pp. 219–40 (Routledge, 1999).

them find information, share knowledge, collaborate with peers, and establish a reputation. By the time the Web became available for commercial use in the mid-1990s, it was a well-developed research tool, and its capabilities nudged newcomers toward the same work practices that scientists used. So it should be no surprise that early users of the commercial Internet tended to favor the academic model of working, which is light on management but strong on guidance by a master in the field; light on efficiency and strong on experimentation; light on proprietary knowledge while strongly encouraging information sharing and collaboration across disciplines.

Early Internet users included many software developers, who were comfortable with the primitive user interfaces available at the time. A group of developers used the Internet as a collaboration platform to spawn a movement aimed at changing the work practices commonly used in software development. They lobbied for a customer-focused, team-based, experimental approach to their work, mirroring the academic practices already supported by the Internet. Over time these agile development practices gained widespread acceptance and emerged as a credible—even superior—approach to developing software-intensive products. It turns out that the academic approach to learning works quite well for creating innovative new products and services.

The arc of change toward collaborative work practices<sup>2</sup> has followed the growing sophistication and accessibility of Web-based tools that support knowledge sharing and collaboration. Consider Karen, our oldest granddaughter, who is about to head off to college. She is perhaps the quintessential digital native: proficient at surfing the Internet before she was ten, posting her thoughts on Facebook by 12, engaged in a stream of text messages for several years. It won't be long before Karen and her cohorts will be the only kind of college graduates available to fill the jobs that our organizations create.

Digital natives have been immersed in an environment of readily available knowledge and instant access to colleagues for as long as they can remember. They know how to leverage the advantages of this environment, and they will expect to find it in their workplace. They will expect easy, transparent access to information; they will expect to collaborate with a wide range of people; they will expect anywhere,

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2. We first heard of this Arc of Change from Yochai Benkler of Harvard Law School in his keynote talk at Lean Software and Systems 2012, Boston, May 16, 2012. See also Yochai Benkler, "The Unselfish Gene," *Harvard Business Review*, July–August 2011.

anytime access to their network of peers; they will probably not make much distinction between work and personal activities; they will certainly expect to be trusted.

Of course, organizations should not blindly cater to the expectations of the new kids in the company. But it turns out that the academic approach to working is a good model for bringing out the best in knowledge workers of all ages. The kids are on to something that works really well—for everyone.

This is a book about the design, development, and delivery of exceptional products and services. Therefore, it is a book about creating work environments where Karen and her colleagues routinely leverage a growing body of knowledge and multiple perspectives to create and launch brilliant products and services. It is a book about learning: learning about customers and creating experiences they love. It is about discovering effective ways to develop and deliver those experiences. Finally, this is a book about gaining the insight and adaptability to thrive in a rapidly changing world.

## Lean Is a Mindset

Lean is a mindset—a mental model of how the world works. In this book we present a mental model of how to design and deliver amazing products that delight customers. We start with two foundational questions: *What is the purpose of a business? What kind of work systems are best for accomplishing that purpose?* Next we explore ways to create an environment that energizes the people whose intelligence and creativity are essential to creating great products. Then we turn our attention to the process of creating products and services that work well and delight customers. We move on to consider efficiency—because this is a book about lean, after all, and lean has always been associated with efficiency. We demonstrate that genuine efficiency in product development is about developing the right product, creating a steady flow of new knowledge, and linking the design and delivery processes together to gain rapid customer feedback. Finally, we move beyond efficiency to innovation and discuss how great products come from changing the focus . . . from productivity to impact . . . from predictability to experimentation . . . from efficiency to decentralization . . . and from product to problem.

Through research results and case studies, the book builds a mental model of how lean design and development should look and feel in

order to foster a lean mindset in organizations that create products and services. The case studies in the book are not to be emulated so much as absorbed, because developing a mindset is not about copying practices—it's about developing the expertise to ask the right questions, solve the right problems, and do the right thing in the situation at hand.

## How Mindsets Work

Our minds are amazing. It appears to us that we make decisions thoughtfully and deliberately, but research has shown that most of the time we make decisions instinctively, based on the mindset we have developed over time. It's almost as if we have two minds—one that builds our mindset and corrects it from time to time, and another that reacts quickly to situations as they develop, drawing on the currently available mindset to arbitrate trade-offs.

The idea that we have two rather different decision-making processes is not a new one; the literature is filled with many varied descriptions of our two minds. One mind might be intuitive, the other analytical; one mind could be emotional, the other rational; one reflexive, the other reflective. One mind might look for patterns, the other follows rules; one mind acts on tacit knowledge, the other prefers explicit information; one mind makes snap decisions, the other takes time to think things through.

Psychologists Keith Stanovich and Richard West proposed that we take all of these different theories about people being of two minds and combine them into a single theory: the **Dual Processing Theory**.<sup>3</sup> The theory works something like this: Humans have two different methods for processing information, and each method operates more or less independently of the other one, exchanging information at appropriate times. Sometimes the two processes arrive at different conclusions, and that's when we become aware of the fact that we have two minds, because they are in conflict with each other.

In order to avoid a bias toward any particular way of describing our two “minds,” Stanovich and West proposed that we simply call them **System 1** and **System 2**.

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3. See K. E. Stanovich, *Who Is Rational? Studies of Individual Differences in Reasoning* (Lawrence Erlbaum Associates, 1999); and K. E. Stanovich and R. F. West, “Individual Differences in Reasoning: Implications for the Rationality Debate,” *Behav. Brain Sci.* 2000 (23): 645–726.



## System 1 and System 2

An excellent description of System 1 and System 2 can be found in Nobel laureate Daniel Kahneman's book *Thinking, Fast and Slow*.<sup>4</sup> Kahneman describes System 1 as our fast-thinking self, the one that makes decisions based on intuition, is influenced by emotions, uses tacit knowledge, and operates out of habit. If you have ever walked into your home after a long day at work and wondered how you got there, you can be sure that System 1 brought you home all by itself while you were distracted with other things. For getting the everyday things in life done, we can't beat System 1; we might think of it as our autopilot mode.

System 2 is the part of us that analyzes situations, considers alternatives, plans for the future, and does the math. Whenever we find ourselves pausing to consider something carefully, it's like switching from autopilot to manual mode; our analytical mind takes over from our intuition and works out rational choices. Although System 2 is not actively directing us most of the time, it regularly checks up on System 1 to see if it needs to intervene. When we develop a decision tree to make sure we consider all of the alternatives before making a decision, System 2 is in charge. When we are quiet and polite even though we are angry, System 2 is keeping System 1 in check.

Generally speaking, we operate in autopilot mode. If unusual circumstances arise, we switch out of autopilot and over to manual mode. And it is in this manual mode that we develop or modify our mindsets. We will need to spend a good amount of time in manual mode, with System 2 fully engaged, in order to change an established mindset. But there's a problem: System 2 is slow. It takes much longer than System 1 to make decisions and get things done. In addition, System 2 is lazy; its preferred approach is to turn as much work as possible over to System 1. So modifying a mindset takes deliberate effort and considerable time—time spent reading a book, for example.

We would like to introduce you to Otto and Anna:



Otto represents our System 1 mind, so he is on autopilot much of the time. He is intuitive and moves easily, adjusting rapidly to whatever happens. He has a lot of

4. Daniel Kahneman, *Thinking, Fast and Slow* (Farrar, Straus and Giroux, 2011).

experience in his specialty area and is comfortable trusting his expertise and intuition to guide his actions.



**Anna** represents our System 2 mind; she analyzes situations before she acts. She knows that the best decisions are those based on evidence. She is good at gathering data, running experiments, and weighing the impact of various choices before making a decision.

Otto and Anna are very opinionated. They will be reading this book along with you, and they will ask questions and challenge our ideas on a regular basis. We put our dialog with Otto and Anna in a sidebar so you can follow along with your favorite co-reader.

## The Fabric of Lean

Lean principles are woven throughout this book, just as they must be woven throughout the fabric of an organization with a lean mindset.

**Chapter 1: The Purpose of Business** emphasizes the principle *Optimize the Whole*, taking the Shareholder Value Theory to task for the short-term thinking it produces. The alternative is to *Focus on Customers*, whose loyalty determines the long-term success of any business. It is one thing for business leaders to have a vision of who their customers are, but quite another to put the work systems in place to serve those customers well. In the end, the front-line workers in a company are the ones who make or break the customer experience.

It turns out that the “rational” thinking behind the Shareholder Value Theory has had a strong influence on the way workers are treated. It all boils down to Douglas McGregor’s Theory X and Theory Y. Theory X assumes that people don’t like work and will do as little as possible. Theory Y assumes the opposite: Most people are eager to work and want to do a good job. The lean principle *Energize Workers* is solidly based on Theory Y—start with the assumption that workers care about their company and their customers, and this will be a self-fulfilling prophecy. The principle of reciprocity is at work here—if you treat workers well, they will treat customers well, and customers will reward the company with their business.

Reciprocity was the basis of human cooperation long before money was invented, and it remains central to human behavior today. However, reciprocity is local. It depends on group (or team) size, team member engagement, and norms for creating and enforcing mutual

obligations. When designing work systems that *Energize Workers* and help them *Focus on Customers*, leverage the power of peers, rather than incentives, to steer behavior in the right direction.

**Chapter 2: Energized Workers** is based on the work of Mihaly Csikszentmihalyi, who found that the most energizing human experience is pursuing a well-framed challenge. Energized workers have a purpose that is larger than the company and a direct line of sight between their effort and achieving that purpose. They strive to reach their full potential through challenging work that requires increasing skill and expertise. They thrive on the right kind of challenge—a challenge that is not so easy as to be boring and not so hard as to be discouraging, a challenge that appeals to aspirations or to duty, depending on the “regulatory fit.”

Regulatory fit is a theory that says some people (and some companies—startups, for example) are biased toward action and experimentation and respond well to aspirational challenges. Other people (and companies—big ones, for example) prefer to be safe rather than sorry. For them, challenges that focus on duty and failure prevention are more inspiring. But either way, a challenge that is well matched to the people and the situation is one of the best ways to energize workers.

One of the most important challenges in a lean environment is to *Constantly Improve*. Whether it is a long-term journey to improve product development practices or an ongoing fault injection practice to hone emergency response skills, striving to constantly get better engages teams and brings out the best in people.

**Chapter 3: Delighted Customers** urges readers to *Focus on Customers*, understand what they really need, and make sure that the right products and services are developed. This is the first step in the quest to *Eliminate Waste*, especially in software development, where building the wrong thing is the biggest waste of all.

Some products present extraordinary technical challenges—inventing the airplane or finding wicked problems in a large data management system. Other products need insightful design in order to really solve customer problems. Before diving into development, it is important to *Learn First* to understand the essential system issues and customer problems before attempting to solve them.

When developing a product, it is important to look beyond what customers ask for, because working from a list of requirements is not likely to create products that customers *love*. Instead, leaders like GE

Healthcare's Doug Dietz, who saw a terrified child approach his MRI scanner, understand that a product is not finished until the customer experience is as well designed as the hardware and software.

Great products are designed by teams that are able to empathize with customers, ask the right questions, identify critical problems, examine multiple possibilities, and then develop products and services that delight customers.

**Chapter 4: Genuine Efficiency** starts by emphasizing that authentic, sustainable efficiency does *not* mean layoffs, low costs, and controlling work systems. Development is only a small portion of a product's life cycle, but it has a massive influence on the product's success. It is folly to cut corners in development only to end up with costly or underperforming products in the end. Those who *Optimize the Whole* understand that in product development, efficiency is first and foremost about building the right thing.

Two case studies from Ericsson Networks demonstrate that small batches, rapid flow, autonomous feature teams, and pull from the market can dramatically increase both predictability and time to market on large products. Here we see the lean principles of *Focus on Customers*, *Deliver Fast*, *Energize Workers*, and *Build Quality In* at work.

A case study from CareerBuilder further emphasizes how focusing on the principle of *Deliver Fast* leads to every other lean principle, especially *Build Quality In* and *Focus on Customers*. A look at Lean Startup techniques shows that constant experiments by the product team can rapidly refine the business model for a new product as well as uncover its most important features. Here the lean principles of *Optimize the Whole*, *Deliver Fast*, and *Keep Getting Better* are particularly apparent.

Finally, a discussion of how Spotify develops products summarizes most of the lean principles one more time, with a particular emphasis on customer focus, data-driven experiments, empowered teams, and rapid feedback.

**Chapter 5: Breakthrough Innovation** starts with a cautionary tale about how vulnerable businesses are—even simple businesses like newspapers can lose their major source of revenue seemingly overnight. But disruptive technologies don't usually change things quite that fast; threatened companies are usually blind to the threat until it's too late. How can it be that industry after industry is overrun with disruptive innovation and incumbent companies are unable to respond?

The problem, it seems, is too much focus on today's operations—maybe even too much focus on the lean principle of *Eliminate Waste*—and not enough focus on the bigger picture, on *Optimize the Whole*. Too much focus on adding features for today's customers and not enough focus on potential customers who need lower prices and fewer features. Too much focus on predictability and not enough focus on experimentation. Too much focus on productivity and not enough focus on impact. Too much focus on the efficiency of centralization and not enough appreciation for the resiliency of decentralization.

Lean organizations appreciate that the real knowledge resides at the place where work is done, in the teams that develop the products, in the customers who are struggling with problems. Several case studies—including Harman, Intuit, and GE Healthcare—show how the lean principles of *Focus on Customers*, *Energize Workers*, *Learn First*, and *Deliver Fast* help companies develop breakthrough innovations before they get blindsided by someone else's disruptive innovations.

Developing a lean mindset is a process that takes time and deliberate practice, just like developing any other kind of expertise. No matter how well you “know” the ideas presented in this book, actually using them in your work on a day-to-day basis requires that you spend time trying the ideas out, experimenting with them, making mistakes, and learning.

Cultivating a lean mindset—especially in an organization—is a continuing journey. We hope this book brings you another step along the path.

# 1

## The Purpose of Business

### The Rise of Rational Economics

In 1950, as George Merck retired from his job as president of pharmaceutical giant Merck & Co., he summarized the underlying philosophy that drove its success:

We try never to forget that medicine is for the patient. It is not for profits. The profits follow; and if we have remembered this, they have never failed to appear. The better we have remembered it, the larger they have been.<sup>1</sup>

The idea that the purpose of business is to serve customers was widely accepted at the time. The Second World War had recently ended, and the homecoming of untold numbers of soldiers triggered a boom in births as well as in business. After years of austerity, demand was particularly high, and businesses were eager to supply new products to a growing population. The economy had nowhere to go but up.

But if we fast-forward 25 years to 1975, we find that business opportunities were not so plentiful anymore. The war generation was retiring, and a new cohort of business leaders was faced with slower growth, broader competition, and limited memories of depression and war-era hard times. The conventional wisdom that companies should preserve cash and take care of their employees was feeling a bit outdated to this new generation of business leaders.

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1. Jim Collins and Jerry I. Porras, *Built to Last: Successful Habits of Visionary Companies* (Harper Business, 2004), p. 48.

In 1974 Peter Drucker, a leading management thinker of the twentieth century, published his seminal book on management.<sup>2</sup> He wrote that the purpose of business is to create a customer—to discover a customer need and find a way to satisfy that need. However, managers were struggling with companies that had grown large and complex and were experiencing stagnant growth. They were certainly trying to create new customers, but it was difficult.

About this time an attractive new idea appeared on the scene—one that seemed a bit more actionable and better suited to the slowing economy. The idea was based on the proposition that professional managers are agents of the owners (shareholders) of a firm.<sup>3</sup> As agents, managers make decisions for the owners, but like all agents, they are probably utility maximizers (interested in maximizing their own personal gain). Therefore, there's a good chance that a company's top managers will work to further their own interests at the expense of shareholder interests. One way to guard against this conflict of interest is to hold top managers accountable for making sure that shareholders receive the best possible return on their investment. The new theory could be stated simply: **The purpose of business is to maximize shareholder value.**



At the time there was widespread faith in the intelligence and efficiency of markets, which made the Shareholder Value Theory look very attractive.<sup>4</sup> Letting the market decide whether or not a CEO was doing a good job seemed like an obvious way to ensure that the best interests of a company were being served by its leader.

It is impossible to understate the influence of the Shareholder Value Theory on business practices, especially in the United States. In order to increase shareholder value (or its proxy, share prices), companies shifted from “retain and reinvest” strategies to “downsize and distribute” strategies.<sup>5</sup> Instead of investing in people and research, companies outsourced

2. Peter Drucker, *Management: Tasks, Responsibilities, Practices* (Harper & Row, 1974).

3. Michael C. Jensen and William H. Meckling, “Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure,” *Journal of Financial Economics*, October 1976.

4. Jeffrey Pfeffer, “Shareholders First? Not So Fast . . .,” *Harvard Business Review*, August 2009.

5. Justin Fox and Jay W. Lorsch, “What Good Are Shareholders?” *Harvard Business Review*, July–August 2012.

jobs and distributed profits to shareholders. To keep CEOs properly focused, their compensation was increasingly tied to share price.

These strategies increased profits in the short run, but companies struggled over the long term. Not only did a vast number of jobs disappear, but the skill embedded in those jobs also disappeared. Within a decade of outsourcing manufacturing, companies found they could no longer engineer complex technical products and scale them up, so engineering jobs disappeared as well.<sup>6</sup> Of course, costs were lower, but over time innovation stalled, sales flattened, and share prices faltered.

Did the Shareholder Value Theory work in practice? The short answer is: Probably not. Roger Martin of the University of Toronto points out that the rate of return on shareholder investments has not improved since 1976—if anything it has declined.<sup>7</sup>

But the theory worked pretty well for CEOs, especially in the United States. In 1976 U.S. CEO income was 36 times that of an average worker; in 1993 it was 131 times higher; by 2010, CEOs in the United States made 369 times more than the average worker.<sup>8</sup>

Rosabeth Moss Kanter of the Harvard Business School has spent years studying truly successful companies and how they think. She sums up her findings this way:

Traditionally, economists and financiers have argued that the sole purpose of business is to make money—the more the better. That conveniently narrow image, deeply embedded in the American capitalist system, molds the actions of most corporations, constraining them to focus on maximizing short-term profits and delivering returns to shareholders. . . .

Rather than viewing organizational processes as ways of extracting more economic value, great companies create frameworks that use societal value and human values as decision-making criteria. They believe that corporations have a purpose and meet stakeholders' needs in many ways: by producing goods and services that improve the lives of users; by providing jobs and

6. Andy Grove, "Andy Grove: How America Can Create Jobs," *Bloomberg Business Week*, July 1, 2010.

7. Roger Martin (Dean of the Rotman School of Management, University of Toronto), "The Age of Customer Capitalism," *Harvard Business Review*, January–February 2010.

8. Dan Ariely, *Predictably Irrational: The Hidden Forces That Shape Our Decisions* (HarperCollins, 2010), p. 17.



enhancing workers' quality of life; by developing a strong network of suppliers and business partners; and by ensuring financial viability, which provides resources for improvements, innovations, and returns to investors.<sup>9</sup>



**Anna:** Why not focus on maximizing *long-term* shareholder value?

**M&T [Mary and Tom]:** In an interview in 2009, Jack Welch said, "On the face of it, shareholder value is the dumbest idea in the world. Shareholder value is a result, not a strategy . . . your main constituencies are your employees, your customers and your products."<sup>10</sup> In other words, the best approach is not to worry about shareholder value at all, but to focus on creating energized workers, delighted customers, and breakthrough innovation. When done right, this will result in increased shareholder value over time.

## ***The Tech Generation***

Fast-forward another quarter century to the year 2000, and we find a new generation of tech-savvy leaders whose companies have set the rules about how we search, shop, connect with friends, and carry the Internet in our pockets. They don't feel the need to follow the norms of the last century. Instead they have rediscovered something that we used to know: **Purpose is the master and profit is the servant.**

Take a look at the things that fast-growing Internet companies focus on: They are obsessed with providing great experiences to their consumers and communities. They concentrate on creating a culture in which talented employees are passionate about their work and engaged in delivering exceptional value. These companies state clearly in their IPO documents that they do not intend to focus on making money for shareholders.

Amazon.com, for instance, warns its investors that it plans to make decisions for the long term, so investors looking for short-term profits should look elsewhere. Its strategy is to focus relentlessly on custom-

9. Rosabeth Moss Kanter, "How Great Companies Think Differently," *Harvard Business Review*, November 2011. Used with permission.

10. *Financial Times*, "Welch Condemns Share Price Focus," March 12, 2009, [www.ft.com/intl/cms/s/0/294ff1f2-0f27-11de-ba10-0000779fd2ac.html#axzz2EyBD8eJ2](http://www.ft.com/intl/cms/s/0/294ff1f2-0f27-11de-ba10-0000779fd2ac.html#axzz2EyBD8eJ2).

ers, hire talented employees, and take serious risks—some of which can be expected to fail.<sup>11</sup>

Google also warns potential shareholders that it will adopt a long-term focus on accomplishing its mission, which is to organize the world’s information and make it universally accessible and useful.<sup>12</sup> Eric Schmidt of Google commented:

Apple proves that if you organize around the consumer, the rest of it will follow. That’s something that I did not understand until Google. Google runs in a similar way. Try to figure out how to solve the consumer problem, and then the revenue will show up.<sup>13</sup>

Facebook says in its IPO document: “Simply put: we don’t build services to make money; we make money to build better services.”



**Otto:** What did Peter Drucker mean when he said the purpose of business is to create a customer? How do you create customers?

**M&T:** Drucker recommended that business leaders start with the question *What business are we in?* The way to answer this question is by asking another question: *Who are our customers?* That is a critical question, and it is never easy to answer. But once a company decides whom it should serve, it must develop a deep understanding of the lives, the needs, the realities, and the values of those customers. Then it must implement innovative work systems so its employees can fill those customer needs by delivering the products and services that customers will find valuable.<sup>14</sup>

# 3

## Delighted Customers

The Westerner and the Japanese mean something different when they talk of “making a decision.” With us in the West, all the emphasis is on the *answer* to the question. . . . To the Japanese, however, the important element in decision-making is *defining the question*.<sup>1</sup>

—Peter Drucker

### Ask the Right Questions

The Internet may be the platform that launched the information age, but a century earlier, the internal combustion engine was the platform that launched the transportation age. Reset your clock to the 1890s, and you will see numerous automobile companies trying to sort out what the automobile would eventually become. You will discover people attaching engines to balloons trying to figure out what kind of air travel was possible. And you will find a few intrepid inventors dreaming of flying machines that were heavier than air and could fly like birds.

#### *Learning to Fly*

One of the dreamers was Otto Lilienthal, a German engineer who built and flew gliders, logging over 2,000 glider flights. He published a highly

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1. Peter F. Drucker, “What We Can Learn from Japanese Management,” *Harvard Business Review*, March–April 1971. Emphasis added. Used with permission.

influential book, *Birdflight as the Basis of Aviation*,<sup>2</sup> which contained detailed information on wing shapes and measurements of lift, before his untimely death in a glider crash in 1896. Another aviation pioneer was the French-born American engineer Octave Chanute, who designed and tested gliders on the windy southern shores of Lake Michigan. And then there was the Secretary of the Smithsonian Institution, Samuel Pierpont Langley, who outfitted a scale-model glider with a steam engine and got it to fly for over a kilometer in 1896. But when he scaled up his design in 1903 to a human-size glider, it crashed ingloriously into the Potomac River. Luckily the pilot could swim.

Meanwhile in Dayton, Ohio, a couple of bicycle shop proprietors, brothers Wilbur and Orville Wright, were inspired by these pioneers and decided that gliding would be an interesting hobby.<sup>3</sup> They studied all the material they could get their hands on, and eventually Wilbur concluded: “You can reduce this problem to three basic systems. If you are going to invent an airplane you have to have wings that are going to generate lift, you got to have a propulsion system that will move the wings through the air and you got to have a way to control the wings once you’re in the air. Lift aerodynamics, propulsion, and control—that’s it.”<sup>4</sup>

The Wright brothers realized that the most overlooked flight system was neither the lift aerodynamics nor the propulsion system; it was the control system. They asked a question that was being ignored by almost everyone else; rather than ask, *How do we fly?* they asked, *How do we keep from falling out of the sky?* They decided it would be safest to start by solving the control problem.

In particular, the Wright brothers investigated ways to control the lateral motion, or roll, of an airplane. Most land vehicles do not need lateral control—it is provided by four wheels resting on the ground—so most of the aviation pioneers did not consider lateral stability to be a problem, or if they did, they could not imagine how to deal with it. On the other hand, bicycles do have a lateral stability problem that must

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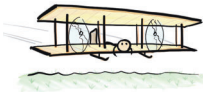
2. Otto Lilienthal, *Birdflight as the Basis of Aviation*, published in German in 1889.

3. See Orville Wright, *How We Invented the Airplane: An Illustrated History*, ed. Fred C. Kelly, first published in 1953 from text written in 1920. Republished with new material in 1988 by Dover Publications, Inc.

4. From a talk that Tom Crouch (Senior Curator of Aeronautics at the National Air and Space Museum of the Smithsonian Institution) gave on August 19, 2007, at the Wright Brothers National Memorial, Kill Devil Hills, NC, <http://wrightstories.com/tom-crouch-talks-wright-brothers/>.

be taken into account in the design of the bike. So it's not a surprise that a couple of bicycle mechanics realized that the critical problem in aircraft design was controlling the roll of the plane.

Glider pilots controlled roll by shifting their weight, but this was not going to work with powered flight, and it clearly wasn't working very well for gliders either. Upon reflection, the Wright brothers came up with the idea of controlling lateral motion with wing warping (dynamically changing the shape of the wings). In 1899 they built a large kite to test this idea and it seemed to work well. In 1900 they built a glider that incorporated wing warping, using the Lilienthal tables of air pressure and a bi-wing design from Chanute.



Wilbur and Orville Wright searched for a windy place to test their glider and settled on the Outer Banks of North Carolina. They transported their glider from Dayton and set up camp near Kitty Hawk, expecting to be able to glide for hours at a time in the coastal winds. They were disappointed; the glider would not lift unless the winds were very strong, and it did not stay in the air very long. However, when it did fly, the lateral control worked rather well. They did a series of experiments gliding down a nearby hill called Kill Devil Hill to try to find out what was wrong with their design.

The Wright brothers wrote to Chanute to ask for advice, and he suggested that their wing design needed to more closely match Lilienthal's. So they decided to build another glider over the winter, but when they tested it in 1901, they found it was a step backward. They modified the wing shape and got some improvement, but after several hundred flights they were very discouraged. Finally they came to ask their second key question: *Are the accepted aerodynamic design tables right? Is the coefficient of lift that has been around for 100 years correct?*

Wilbur and Orville Wright didn't have the time or money to build more gliders, so they devised an experiment carried out on a bicycle to prove to themselves that the published data was wrong. Then they asked themselves, *Can we generate the data we need—here in our bike shop over the winter?* They built a simple wooden wind tunnel that allowed them to test multiple configurations of airfoils against each other. In the winter of 1901–2, the Wright brothers carefully ran thousands of experiments; by the end of the winter they had developed a revised body of knowledge about aerodynamic lift.

With the problem correctly framed and valid data in hand, the Wright brothers knew what kind of wing shapes and angles would

work best. The glider they built in 1902 worked remarkably well, with its lift matching predictions. As they flew the glider, the brothers realized that when turning in crosswinds, controlling the roll of the plane (rotation around the front-to-back axis) was not enough; they also needed to control yaw (rotation around the vertical axis), so they added a vertical rudder. By fall, Wilbur and Orville Wright knew they had solved the most important problem facing glider flight—the control problem—and they had made major advances in solving the lift problem as well. It's worth noting that their control approach and wing designs are used in aircraft design to this day.

However, if they were going to glide in the air for hours, the brothers knew that an engine would be needed. So they asked, *What kind of engine and propeller would we need to change the glider into a flier?* Wind tunnel experiments showed that a light engine that could produce at least 8 horsepower would be adequate. They could not get an engine manufacturer to build such an engine at a price they could afford, so they worked with their bicycle shop mechanic, Charlie Taylor, to build an engine themselves. The simple engine was made of aluminum, a novel material at the time. It produced 12 horsepower—more than enough for flight. The next step was to design a propeller, so it was back to the wind tunnel to find the best shape. The resulting propeller ended up being one of the most efficient propellers of its day. The propellers were connected to the motor with bicycle chains, and *voilà!* A powered glider (the Wright Flyer) was ready to take off.

The Flyer was assembled and tested at the oceanside camp in the fall of 1903. After many experiments and propeller repairs, the brothers finally flew the Flyer in controlled flight on December 17. Orville and Wilbur each flew the Flyer twice; the longest flight lasted about a minute and covered about a quarter of a kilometer. At that point the Flyer was caught by heavy wind and destroyed.

Orville and Wilbur Wright returned home knowing that they had solved the basic problems of heavier-than-air flight. They built Flyer II and tested it the next year at Huffman Prairie, a field near their home in Dayton. It was underpowered and difficult to control, but by late 1905 the brothers had learned enough to redesign the aircraft again. Flyer III worked much better than its two predecessors; it might be called the first practical airplane.

After that, airplane development proceeded rapidly both in the United States and in Europe. In 1919, a mere 16 years after the first flight, an airplane was able to fly nonstop across the Atlantic Ocean.



**Anna:** I am impressed by the amount of analysis the Wright brothers did and the effort they went through to gather all that data. Was there anything in their education or background that explains why they did all of that analysis?

**M&T:** The Wright brothers had been encouraged from childhood to read widely and learn as much as possible, but their formal education ended after high school. They ran a print shop and then a bicycle shop, which fueled their love of books and gave them a lot of practical mechanical experience. The brothers were passionate about flying and considered it a hobby, so they dedicated all of their spare time to learning everything they could about it.



**Otto:** It's interesting to see how the mechanical experience of the Wright brothers gave them the intuition to ask the right questions.

**M&T:** One of the things that drove the brothers to ask the right questions was that they didn't have a lot of money, so they couldn't afford the random trial-and-error experiments that were common at the time. (This is an example of the conventional wisdom that constraints tend to drive innovation.) The Wright brothers tried to learn as much as they possibly could before they built anything. We like to call this **learn-first development**.<sup>5</sup> It's an important approach when every learning cycle is costly and takes a long time.

## Solve the Right Problems

Customers never buy a product; they buy the satisfaction of a want, according to Peter Drucker. He wrote:

True marketing starts out . . . with the customer, his demographics, his realities, his needs, his values. It does not ask, "What do we have to sell?" It asks, "What does the customer want to buy?" It does not say, "This is what our product or service does." It says, "These are the satisfactions the customer looks for, values, and needs." . . . The aim of marketing is to know and understand the customer so well that the product or service fits him and sells itself.<sup>6</sup>

5. This is the approach recommended by Michael Kennedy in *Ready, Set, Dominate* (Oaklea Press, 2008), and it is widely used in hardware product development.

6. Peter Drucker was introduced in Chapter 1. This quote is from *Management*.

Drucker was not alone in this view. Harvard Business School professor Theodore Levitt often told his students, “People don’t want to buy a quarter-inch drill. They want a quarter-inch hole!” In his classic article “Marketing Myopia,”<sup>7</sup> Levitt wrote, “. . . the entire corporation must be viewed as a customer-creating and customer-satisfying organism.”

In that article, Levitt observed that some companies “are in the felicitous position of having to fill, not find, markets, of not having to discover what the customer needs and wants but of having the customer voluntarily come forward with specific new product demands.” He goes on to say that this situation is actually not such a good deal after all, because if scientists and engineers simply depend on customers to tell them what products to deliver, it is unlikely that they will develop a customer-oriented viewpoint.

How can this be? How can delivering what customers ask for be a bad thing? The problem, Levitt explains, is that if the development organization delivers exactly what customers ask for—a drill, for example—they will learn nothing about the kinds of holes the customer needs, what problem the holes are solving, and whether there might be a better way to address that problem. In fact, focusing on what existing customers are asking for is exactly what leads companies to ignore new, disruptive technologies until it’s too late, as we will discuss further in Chapter 5.

### **What Are Requirements?**



Many engineers, particularly software engineers, are under the impression that their work should start out with a list of requirements (or perhaps a backlog of stories) that come from someone else. But a detailed list of requirements is not the starting point for good engineering. The Wright brothers did not start with requirements; they started out with an idea: Build a glider and learn to fly it and then add power (and don’t get killed in the process). When they asked Charlie Taylor to build an engine, the “requirements” were the constraints imposed by the laws of physics: a weight limit and a horsepower minimum. Everything else was design.

The Wright brothers did not have enough money to waste effort on solving the wrong problems. They dove into deeply complex technical

7. Theodore Levitt, “Marketing Myopia,” *Harvard Business Review*, July–August 1960.



problems with fearless vigor and amazingly disciplined attention to detail. They tackled the three flight systems one at a time. First they designed a control system—to keep from crashing; then they studied lift aerodynamics in detail and learned how to design the wings. Only after those two problems were solved did they add a propulsion system. This methodical approach enabled them to solve three extremely demanding technical problems in three years.

Great problem solvers start by developing a deep understanding of the situation through direct experience. They collaborate with people who have different perspectives and knowledge. They are creative, efficient, and highly disciplined in uncovering the essential problems and designing possible solutions. They test multiple ideas and focus on learning as much as they can. They ask a lot of questions and challenge assumptions, even their own assumptions. They regularly step back and reframe the situation to be sure they are solving the right problem.

If you are an entrepreneur today, you probably proceed more or less in this fashion. But if you are in a big company or a government department, you probably do not approach the development of a difficult system as a design problem; you are more likely to see it as an execution problem or a project management problem. But proceeding with a solution absent a good understanding of the underlying problem is all too often a recipe for disaster.