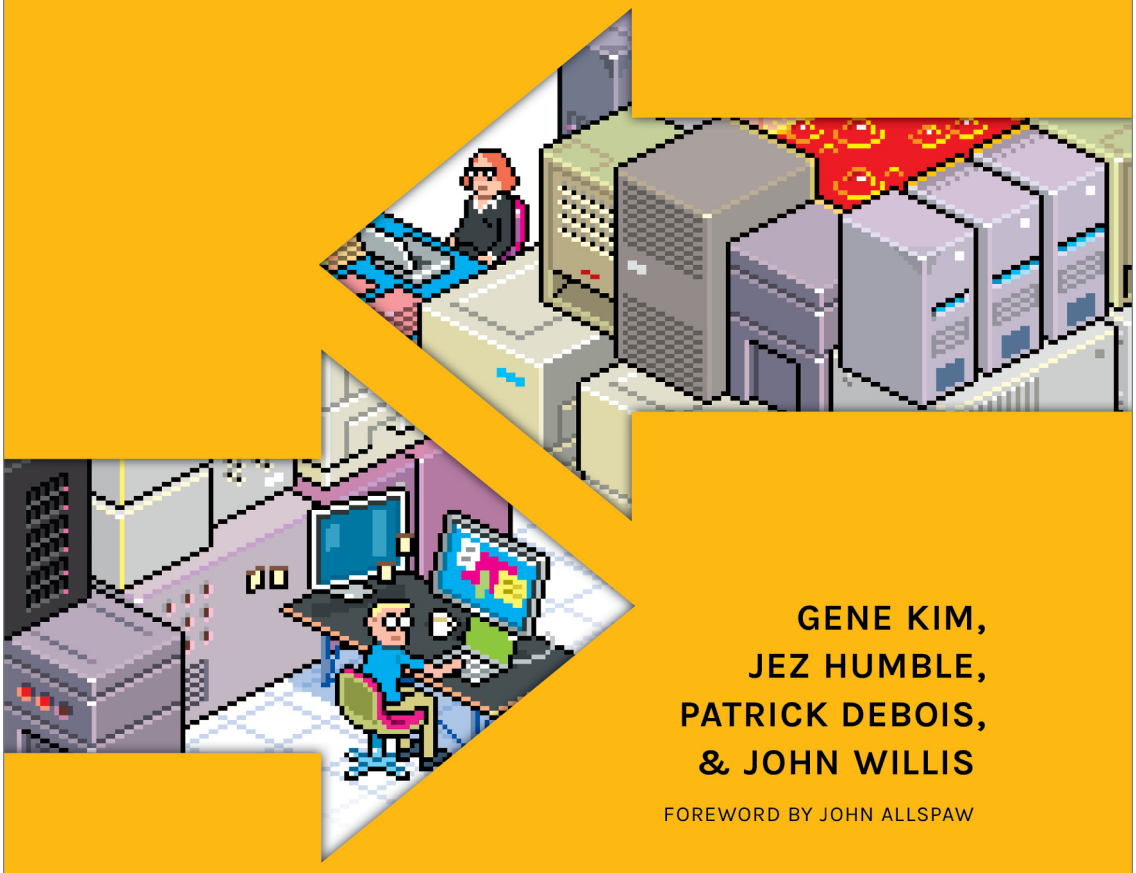
The DevOps Handbook

HOW TO CREATE WORLD-CLASS AGILITY, RELIABILITY, & SECURITY IN TECHNOLOGY ORGANIZATIONS



GENE KIM,
JEZ HUMBLE,
PATRICK DEBOIS,
& JOHN WILLIS

FOREWORD BY JOHN ALLSPAW

THE DEVOPS HANDBOOK

How to Create World-Class Agility, Reliability, & Security in Technology Organizations

By Gene Kim, Jez Humble, Patrick Debois, and John Willis

IT Revolution Press, LLC
25 NW 23rd Pl, Suite 6314
Portland, OR 97210

First Edition

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Cover design by Strauber Design Studio

Cover illustration by eboy

Book design by Mammoth Collective

ISBN: 978-1942788003

Publisher's note to readers: Many of the ideas, quotations, and paraphrases attributed to different thinkers and industry leaders herein are excerpted from informal conversations, correspondence, interviews, conference roundtables, and other forms of oral communication that took place over the last six years during the development and writing of this book. Although the authors and publisher have made every effort to ensure that the information in this book was correct at press time, the authors and publisher do not assume and hereby disclaim any liability to any party for any loss, damage, or disruption caused by errors or omissions, whether such errors or omissions result from negligence, accident, or any other cause.

For information about special discounts for bulk purchases or for information on booking authors for an event, please visit ITRevolution.com.

THE DEVOPS HANDBOOK

TABLE OF CONTENTS

THE DEVOPS HANDBOOK

Preface
Aha!

The journey to complete *The DevOps Handbook* has been a long one—it started with weekly working Skype calls between the co-authors in February of 2011, with the vision of creating a prescriptive guide that would serve as a companion to the as-yet unfinished book *The Phoenix Project: A Novel About IT, DevOps, and Helping Your Business Win*.

More than five years later, with over two thousand hours of work, *The DevOps Handbook* is finally here. Completing this book has been an extremely long process, although one that has been highly rewarding and full of incredible learning, with a scope that is much broader than we originally envisioned. Throughout the project, all the co-authors shared a belief that DevOps is genuinely important, formed in a personal "aha" moment much earlier in each of our professional careers, which I suspect many of our readers will resonate with.

Gene Kim

I've had the privilege of studying high-performing technology organizations since 1999, and one of the earliest findings was that boundary-spanning between the different functional groups of IT Operations, Information Security, and Development was critical to success. But I still remember the first time I saw the magnitude of the downward spiral that would result when these functions worked toward opposing goals.

It was 2006, and I had the opportunity to spend a week with the group who managed the outsourced IT Operations of a large airline reservation service. They described the downstream consequences of their large, annual software releases: each release would cause immense chaos and disruption for the outsourcer, as well as customers; there would be SLA (service level agreement) penalties, because of the customer-impacting outages; there would be layoffs of the most

talented and experienced staff, because of the resulting profit shortfalls; there would be much unplanned work and firefighting so that the remaining staff couldn't work on the ever-growing service request backlogs coming from customers; the contract would be held together by the heroics of middle management; and everyone felt that the contract would be doomed to be put out for re-bid in three years.

The sense of hopelessness and futility that resulted created for me the beginnings of a moral crusade. Development seemed to always be viewed as strategic, but IT Operations was viewed as tactical, often delegated away or outsourced entirely, only to return in five years in worse shape than it was first handed over.

For many years, many of us knew that there must be a better way. I remember seeing the talks coming out of the 2009 Velocity Conference, describing amazing outcomes enabled by architecture, technical practices, and cultural norms that we now know as DevOps. I was so excited, because it clearly pointed to the better way that we had all been searching for. And helping spread that word was one of my personal motivations to co-author *The Phoenix Project*. You can imagine how incredibly rewarding it was to see the broader community react to that book, describing how it helped them achieve their own "aha" moments.

Jez Humble

My DevOps "aha" moment was at a start-up in 2000—my first job after graduating. For some time, I was one of two technical staff. I did everything: networking, programming, support, systems administration. We deployed software to production by FTP directly from our workstations.

Then in 2004 I got a job at ThoughtWorks, a consultancy where my first gig was working on a project involving about seventy people. I was on a team of eight engineers whose full-time job was to deploy our software into a production-like environment. In the beginning, it was really stressful. But over a few months we went from manual deployments that took two weeks to an automated deployment that took one hour, where we could roll forward and back in milliseconds using the blue-green deployment pattern during normal business hours.

That project inspired a lot of the ideas in both the *Continuous Delivery* (Addison-Wesley, 2000) book and this one. A lot of what drives me

and others working in this space is the knowledge that, whatever your constraints, we can always do better, and the desire to help people on their journey.

Patrick Debois

For me, it was a collection of moments. In 2007 I was working on a data center migration project with some Agile teams. I was jealous that they had such high productivity—able to get so much done in so little time.

For my next assignment, I started experimenting with Kanban in Operations and saw how the dynamic of the team changed. Later, at the Agile Toronto 2008 conference I presented my IEEE paper on this, but I felt it didn't resonate widely in the Agile community. We started an Agile system administration group, but I overlooked the human side of things.

After seeing the 2009 Velocity Conference presentation "10 Deploys per Day" by John Allspaw and Paul Hammond, I was convinced others were thinking in a similar way. So I decided to organize the first DevOpsDays, accidently coining the term DevOps.

The energy at the event was unique and contagious. When people started to thank me because it changed their life for the better, I understood the impact. I haven't stopped promoting DevOps since.

John Willis

In 2008, I had just sold a consulting business that focused on large-scale, legacy IT operations practices around configuration management and monitoring (Tivoli) when I first met Luke Kanies (the founder of Puppet Labs). Luke was giving a presentation on Puppet at an O'Reilly open source conference on configuration management (CM).

At first I was just hanging out at the back of the room killing time and thinking, "What could this twenty-year-old tell me about configuration management?" After all, I had literally been working my entire life at some of the largest enterprises in the world, helping them architect CM and other operations management solutions. However, about five minutes into his session, I moved up to the first row and realized everything I had been doing for the last twenty years was wrong. Luke was describing what I now call second generation CM.

After his session I had an opportunity to sit down and have coffee with him. I was totally sold on what we now call infrastructure as code. However, while we met for coffee, Luke started going even further, explaining his ideas. He started telling me he believed that operations was going to have to start behaving like software developers. They were going to have to keep their configurations in source control and adopt CI/CD delivery patterns for their workflow. Being the old IT Operations person at the time, I think I replied to him with something like, "That idea is going to sink like Led Zeppelin with Ops folk." (I was clearly wrong.)

Then about a year later in 2009 at another O'Reilly conference, Velocity, I saw Andrew Clay Shafer give a presentation on Agile Infrastructure. In his presentation, Andrew showed this iconic picture of a wall between developers and operations with a metaphorical depiction of work being thrown over the wall. He coined this "the wall of confusion." The ideas he expressed in that presentation codified what Luke was trying to tell me a year earlier. That was the light bulb for me. Later that year, I was the only American invited to the original DevOpsDays in Ghent. By the time that event was over, this thing we call DevOps was clearly in my blood.

Clearly, the co-authors of this book all came to a similar epiphany, even if they came there from very different directions. But there is now an overwhelming weight of evidence that the problems described above happen almost everywhere, and that the solutions associated with DevOps are nearly universally applicable.

The goal of writing this book is to describe how to replicate the DevOps transformations we've been a part of or have observed, as well as dispel many of the myths of why DevOps won't work in certain situations. Below are some of the most common myths we hear about DevOps.

Myth—*DevOps is Only for Startups:* While DevOps practices have been pioneered by the web-scale, Internet "unicorn" companies such as Google, Amazon, Netflix, and Etsy, each of these organizations has, at some point in their history, risked going out of business because of the problems associated with more traditional "horse" organizations: highly dangerous code releases that were prone to catastrophic failure, inability to release features fast enough to beat the competition, compliance concerns, an inability to scale, high levels of distrust between Development and Operations, and so forth.

However, each of these organizations was able to transform their architecture, technical practices, and culture to create the amazing outcomes that we associate with DevOps. As Dr. Branden Williams, an information security executive, quipped, "Let there be no more talk of DevOps unicorns or horses but only thoroughbreds and horses heading to the glue factory."

Myth—*DevOps Replaces Agile:* DevOps principles and practices are compatible with Agile, with many observing that DevOps is a logical continuation of the Agile journey that started in 2001. Agile often serves as an effective enabler of DevOps, because of its focus on small teams continually delivering high quality code to customers.

Many DevOps practices emerge if we continue to manage our work beyond the goal of "potentially shippable code" at the end of each iteration, extending it to having our code always in a deployable state, with developers checking into trunk daily, and that we demonstrate our features in production-like environments.

Myth—*DevOps is incompatible with ITIL:* Many view DevOps as a backlash to ITIL or ITSM (IT Service Management), which was originally published in 1989. ITIL has broadly influenced multiple generations of Ops practitioners, including one of the co-authors, and is an ever-evolving library of practices intended to codify the processes and practices that underpin world-class IT Operations, spanning service strategy, design, and support.

DevOps practices can be made compatible with ITIL process. However, to support the shorter lead times and higher deployment frequencies associated with DevOps, many areas of the ITIL processes become fully automated, solving many problems associated with the configuration and release management processes (e.g., keeping the configuration management database and definitive software libraries up to date). And because DevOps requires fast detection and recovery when service incidents occur, the ITIL disciplines of service design, incident, and problem management remain as relevant as ever.

Myth—*DevOps is Incompatible with Information Security and Compliance:* The absence of traditional controls (e.g., segregation of duty, change approval processes, manual security reviews at the end of the project) may dismay information security and compliance professionals.

However, that doesn't mean that DevOps organizations don't have effective controls. Instead of security and compliance activities only being performed

at the end of the project, controls are integrated into every stage of daily work in the software development life cycle, resulting in better quality, security, and compliance outcomes.

Myth—*DevOps Means Eliminating IT Operations, or "NoOps:"* Many misinterpret DevOps as the complete elimination of the IT Operations function. However, this is rarely the case. While the nature of IT Operations work may change, it remains as important as ever. IT Operations collaborates far earlier in the software life cycle with Development, who continues to work with IT Operations long after the code has been deployed into production.

Instead of IT Operations doing manual work that comes from work tickets, it enables developer productivity through APIs and self-serviced platforms that create environments, test and deploy code, monitor and display production telemetry, and so forth. By doing this, IT Operations become more like Development (as do QA and Infosec), engaged in product development, where the product is the platform that developers use to safely, quickly, and securely test, deploy, and run their IT services in production.

Myth—*DevOps is Just "Infrastructure as Code" or Automation:* While many of the DevOps patterns shown in this book require automation, DevOps also requires cultural norms and an architecture that allows for the shared goals to be achieved throughout the IT value stream. This goes far beyond just automation. As Christopher Little, a technology executive and one of the earliest chroniclers of DevOps, wrote, "DevOps isn't about automation, just as astronomy isn't about telescopes."

Myth—*DevOps is Only for Open Source Software:* Although many DevOps success stories take place in organizations using software such as the LAMP stack (Linux, Apache, MySQL, PHP), achieving DevOps outcomes is independent of the technology being used. Successes have been achieved with applications written in Microsoft.NET, COBOL, and mainframe assembly code, as well as with SAP and even embedded systems (e.g., HP LaserJet firmware).

SPREADING THE AHA! MOMENT

Each of the authors has been inspired by the amazing innovations happening in the DevOps community and the outcomes they are creating: they are creating safe systems of work, and enabling small teams to quickly and independently develop and validate code that can be safely deployed to customers. Given our belief that DevOps is a manifestation of creating dynamic, learning organi-

zations that continually reinforce high-trust cultural norms, it is inevitable that these organizations will continue to innovate and win in the marketplace.

It is our sincere hope that *The DevOps Handbook* will serve as a valuable resource for many people in different ways: a guide for planning and executing DevOps transformations, a set of case studies to research and learn from, a chronicle of the history of DevOps, a means to create a coalition that spans Product Owners, Architecture, Development, QA, IT Operations, and Information Security to achieve common goals, a way to get the highest levels of leadership support for DevOps initiatives, as well as a moral imperative to change the way we manage technology organizations to enable better effectiveness and efficiency, as well as enabling a happier and more humane work environment, helping everyone become lifelong learners—this not only helps everyone achieve their highest goals as human beings, but also helps their organizations win.

Foreword

In the past, many fields of engineering have experienced a sort of notable evolution, continually "leveling-up" its understanding of its own work. While there are university curriculums and professional support organizations situated within specific disciplines of engineering (civil, mechanical, electrical, nuclear, etc.), the fact is, modern society needs all forms of engineering to recognize the benefits of and work in a multidisciplinary way.

Think about the design of a high-performance vehicle. Where does the work of a mechanical engineer end and the work of an electrical engineer begin? Where (and how, and when) should someone with domain knowledge of aerodynamics (who certainly would have well-formed opinions on the shape, size, and placement of windows) collaborate with an expert in passenger ergonomics? What about the chemical influences of fuel mixture and oil on the materials of the engine and transmission over the lifetime of the vehicle? There are other questions we can ask about the design of an automobile, but the end result is the same: success in modern technical endeavors absolutely requires multiple perspectives and expertise to collaborate.

In order for a field or discipline to progress and mature, it needs to reach a point where it can thoughtfully reflect on its origins, seek out a diverse set of perspectives on those reflections, and place that synthesis into a context that is useful for how the community pictures the future.

This book represents such a synthesis and should be seen as a seminal collection of perspectives on the (I will argue, still emerging and quickly evolving) field of software engineering and operations.

No matter what industry you are in, or what product or service your organization provides, this way of thinking is paramount and necessary for survival for every business and technology leader.

—John Allspaw, CTO, Etsy
Brooklyn, NY, August 2016

Imagine a World Where Dev and Ops Become DevOps

An Introduction to The DevOps Handbook

Imagine a world where product owners, Development, QA, IT Operations, and Infosec work together, not only to help each other, but also to ensure that the overall organization succeeds. By working toward a common goal, they enable the fast flow of planned work into production (e.g., performing tens, hundreds, or even thousands of code deploys per day), while achieving world-class stability, reliability, availability, and security.

In this world, cross-functional teams rigorously test their hypotheses of which features will most delight users and advance the organizational goals. They care not just about implementing user features, but also actively ensure their work flows smoothly and frequently through the entire value stream without causing chaos and disruption to IT Operations or any other internal or external customer.

Simultaneously, QA, IT Operations, and Infosec are always working on ways to reduce friction for the team, creating the work systems that enable developers to be more productive and get better outcomes. By adding the expertise of QA, IT Operations, and Infosec into delivery teams and automated self-service tools and platforms, teams are able to use that expertise in their daily work without being dependent on other teams.

This enables organizations to create a safe system of work, where small teams are able to quickly and independently develop, test, and deploy code and value quickly, safely, securely, and reliably to customers. This allows organizations to maximize developer productivity, enable organizational learning, create high employee satisfaction, and win in the marketplace.

These are the outcomes that result from DevOps. For most of us, this is not the world we live in. More often than not, the system we work in is broken, resulting in extremely poor outcomes that fall well short of our true potential. In our world, Development and IT Operations are adversaries; testing and Infosec activities happen only at the end of a project, too late to correct any problems found; and almost any critical activity requires too much manual effort and too many handoffs, leaving us to always be waiting. Not only does this contribute to extremely long lead times to get anything done, but the quality of our work, especially production deployments, is also problematic and chaotic, resulting in negative impacts to our customers and our business.

As a result, we fall far short of our goals, and the whole organization is dissatisfied with the performance of IT, resulting in budget reductions and frustrated, unhappy employees who feel powerless to change the process and its outcomes.[†] The solution? We need to change how we work; DevOps shows us the best way forward.

To better understand the potential of the DevOps revolution, let us look at the Manufacturing Revolution of the 1980s. By adopting Lean principles and practices, manufacturing organizations dramatically improved plant productivity, customer lead times, product quality, and customer satisfaction, enabling them to win in the marketplace.

Before the revolution, average manufacturing plant order lead times were six weeks, with fewer than 70% of orders being shipped on time. By 2005, with the widespread implementation of Lean practices, average product lead times had dropped to less than three weeks, and more than 95% of orders were being shipped on time. Organizations that did not implement Lean practices lost market share, and many went out of business entirely.

Similarly, the bar has been raised for delivering technology products and services—what was good enough in previous decades is not good enough now. For each of the last four decades, the cost and time required to develop and deploy strategic business capabilities and features has dropped by orders of magnitude. During the 1970s and 1980s, most new features required one to five years to develop and deploy, often costing tens of millions of dollars.

By the 2000's, because of advances in technology and the adoption of Agile principles and practices, the time required to develop new functionality had

† This is just a small sample of the problems found in typical IT organizations.

dropped to weeks or months, but deploying into production would still require weeks or months, often with catastrophic outcomes.

And by 2010, with the introduction of DevOps and the neverending commoditization of hardware, software, and now the cloud, features (and even entire startup companies) could be created in weeks, quickly being deployed into production in just hours or minutes—for these organizations, deployment finally became routine and low risk. These organizations are able to perform experiments to test business ideas, discovering which ideas create the most value for customers and the organization as a whole, which are then further developed into features that can be rapidly and safely deployed into production.

Table 1. *The ever accelerating trend toward faster, cheaper, low-risk delivery of software*

	1970s–1980s	1990s	2000s–Present
Era	Mainframes	Client/Server	Commoditization and Cloud
Representative technology of era	COBOL, DB2 on MVS, etc.	C++, Oracle, Solaris, etc.	Java, MySQL, Red Hat, Ruby on Rails, PHP, etc.
Cycle time	1–5 years	3–12 months	2–12 weeks
Cost	$1M–$100M	$100k–$10M	$10k–$1M
At risk	The whole company	A product line or division	A product feature
Cost of failure	Bankruptcy, sell the company, massive layoffs	Revenue miss, CIO's job	Negligible

(Source: Adrian Cockcroft, "Velocity and Volume (or Speed Wins)," presentation at FlowCon, San Francisco, CA, November 2013.)

Today, organizations adopting DevOps principles and practices often deploy changes hundreds or even thousands of times per day. In an age where competitive advantage requires fast time to market and relentless experimentation, organizations that are unable to replicate these outcomes are destined to lose in the marketplace to more nimble competitors and could potentially go out of business entirely, much like the manufacturing organizations that did not adopt Lean principles.

These days, regardless of what industry we are competing in, the way we acquire customers and deliver value to them is dependent on the technology value stream. Put even more succinctly, as Jeffrey Immelt, CEO of General Electric, stated, "Every industry and company that is not bringing software to the core of their business will be disrupted." Or as Jeffrey Snover, Technical Fellow at Microsoft, said, "In previous economic eras, businesses created value by moving atoms. Now they create value by moving bits."

It's difficult to overstate the enormity of this problem—it affects every organization, independent of the industry we operate in, the size of our organization, whether we are profit or non-profit. Now more than ever, how technology work is managed and performed predicts whether our organizations will win in the marketplace, or even survive. In many cases, we will need to adopt principles and practices that look very different from those that have successfully guided us over the past decades. (See Appendix 1.)

Now that we have established the urgency of the problem that DevOps solves, let us take some time to explore in more detail the symptomatology of the problem, why it occurs, and why, without dramatic intervention, the problem worsens over time.

THE PROBLEM: SOMETHING IN YOUR ORGANIZATION MUST NEED IMPROVEMENT (OR YOU WOULDN'T BE READING THIS BOOK)

Most organizations are not able to deploy production changes in minutes or hours, instead requiring weeks or months. Nor are they able to deploy hundreds or thousands of changes into production per day; instead, they struggle to deploy monthly or even quarterly. Nor are production deployments routine, instead involving outages and chronic firefighting and heroics.

In an age where competitive advantage requires fast time to market, high service levels, and relentless experimentation, these organizations are at a significant competitive disadvantage. This is in large part due to their inability to resolve a core, chronic conflict within their technology organization.

THE CORE, CHRONIC CONFLICT

In almost every IT organization, there is an inherent conflict between Development and IT Operations which creates a downward spiral, resulting in

ever-slower time to market for new products and features, reduced quality, increased outages, and, worst of all, an ever-increasing amount of technical debt.

The term "technical debt" was first coined by Ward Cunningham. Analogous to financial debt, technical debt describes how decisions we make lead to problems that get increasingly more difficult to fix over time, continually reducing our available options in the future—even when taken on judiciously, we still incur interest.

One factor that contributes to this is the often competing goals of Development and IT Operations. IT organizations are responsible for many things. Among them are the two following goals, which must be pursued simultaneously:

- Respond to the rapidly changing competitive landscape
- Provide stable, reliable, and secure service to the customer

Frequently, Development will take responsibility for responding to changes in the market, deploying features and changes into production as quickly as possible. IT Operations will take responsibility for providing customers with IT service that is stable, reliable, and secure, making it difficult or even impossible for anyone to introduce production changes that could jeopardize production. Configured this way, Development and IT Operations have diametrically opposed goals and incentives.

Dr. Eliyahu M. Goldratt, one of the founders of the manufacturing management movement, called these types of configuration "the core, chronic conflict"—when organizational measurements and incentives across different silos prevent the achievement of global, organizational goals.[†]

This conflict creates a downward spiral so powerful it prevents the achievement of desired business outcomes, both inside and outside the IT organization. These chronic conflicts often put technology workers into situations that lead to poor software and service quality, and bad customer outcomes, as well as a daily need for workarounds, firefighting, and heroics, whether in Product

† In the manufacturing realm, a similar core, chronic conflict existed: the need to simultaneously ensure on-time shipments to customers and control costs. How this core, chronic conflict was broken is described in Appendix 2.

Management, Development, QA, IT Operations, or Information Security. (See Appendix 2.)

DOWNWARD SPIRAL IN THREE ACTS

The downward spiral in IT has three acts that are likely familiar to most IT practitioners.

The first act begins in IT Operations, where our goal is to keep applications and infrastructure running so that our organization can deliver value to customers. In our daily work, many of our problems are due to applications and infrastructure that are complex, poorly documented, and incredibly fragile. This is the technical debt and daily workarounds that we live with constantly, always promising that we'll fix the mess when we have a little more time. But that time never comes.

Alarmingly, our most fragile artifacts support either our most important revenue-generating systems or our most critical projects. In other words, the systems most prone to failure are also our most important and are at the epicenter of our most urgent changes. When these changes fail, they jeopardize our most important organizational promises, such as availability to customers, revenue goals, security of customer data, accurate financial reporting, and so forth.

The second act begins when somebody has to compensate for the latest broken promise—it could be a product manager promising a bigger, bolder feature to dazzle customers with or a business executive setting an even larger revenue target. Then, oblivious to what technology can or can't do, or what factors led to missing our earlier commitment, they commit the technology organization to deliver upon this new promise.

As a result, Development is tasked with another urgent project that inevitably requires solving new technical challenges and cutting corners to meet the promised release date, further adding to our technical debt—made, of course, with the promise that we'll fix any resulting problems when we have a little more time.

This sets the stage for the third and final act, where everything becomes just a little more difficult, bit by bit—everybody gets a little busier, work takes a little more time, communications become a little slower, and work queues get a little longer. Our work becomes more tightly coupled, smaller actions cause bigger failures, and we become more fearful and less tolerant of making

changes. Work requires more communication, coordination, and approvals; teams must wait just a little longer for their dependent work to get done; and our quality keeps getting worse. The wheels begin grinding slower and require more effort to keep turning. (See Appendix 3.)

Although it's difficult to see in the moment, the downward spiral is obvious when one takes a step back. We notice that production code deployments are taking ever-longer to complete, moving from minutes to hours to days to weeks. And worse, the deployment outcomes have become even more problematic, that resulting in an ever-increasing number of customer-impacting outages that require more heroics and firefighting in Operations, further depriving them of their ability to pay down technical debt.

As a result, our product delivery cycles continue to move slower and slower, fewer projects are undertaken, and those that are, are less ambitious. Furthermore, the feedback on everyone's work becomes slower and weaker, especially the feedback signals from our customers. And, regardless of what we try, things seem to get worse—we are no longer able to respond quickly to our changing competitive landscape, nor are we able to provide stable, reliable service to our customers. As a result, we ultimately lose in the marketplace.

Time and time again, we learn that when IT fails, the entire organization fails. As Steven J. Spear noted in his book *The High-Velocity Edge*, whether the damages "unfold slowly like a wasting disease" or rapidly "like a fiery crash… the destruction can be just as complete."

WHY DOES THIS DOWNWARD SPIRAL HAPPEN EVERYWHERE?

For over a decade, the authors of this book have observed this destructive spiral occur in countless organizations of all types and sizes. We understand better than ever why this downward spiral occurs and why it requires DevOps principles to mitigate. First, as described earlier, every IT organization has two opposing goals, and second, every company is a technology company, whether they know it or not.

As Christopher Little, a software executive and one of the earliest chroniclers of DevOps, said, "Every company is a technology company, regardless of what business they think they're in. A bank is just an IT company with a banking license."[†]

† In 2013, the European bank HSBC employed more software developers than Google.

To convince ourselves that this is the case, consider that the vast majority of capital projects have some reliance upon IT. As the saying goes, "It is virtually impossible to make any business decision that doesn't result in at least one IT change."

In the business and finance context, projects are critical because they serve as the primary mechanism for change inside organizations. Projects are typically what management needs to approve, budget for, and be held accountable for; therefore, they are the mechanism that achieve the goals and aspirations of the organization, whether it is to grow or even shrink.[†]

Projects are typically funded through capital spending (i.e., factories, equipment, and major projects, and expenditures are capitalized when payback is expected to take years), of which 50% is now technology related. This is even true in "low tech" industry verticals with the lowest historical spending on technology, such as energy, metal, resource extraction, automotive, and construction. In other words, business leaders are far more reliant upon the effective management of IT in order to achieve their goals than they think.[‡]

THE COSTS: HUMAN AND ECONOMIC

When people are trapped in this downward spiral for years, especially those who are downstream of Development, they often feel stuck in a system that pre-ordains failure and leaves them powerless to change the outcomes. This powerlessness is often followed by burnout, with the associated feelings of fatigue, cynicism, and even hopelessness and despair.

Many psychologists assert that creating systems that cause feelings of powerlessness is one of the most damaging things we can do to fellow human beings—we deprive other people of their ability to control their own outcomes and even create a culture where people are afraid to do the right thing because of fear of punishment, failure, or jeopardizing their livelihood. This can create

† For now, let us suspend the discussion of whether software should be funded as a "project" or a "product." This is discussed later in the book.

‡ For instance, Dr. Vernon Richardson and his colleagues published this astonishing finding. They studied the 10-K SEC filings of 184 public corporations and divided them into three groups: A) firms with material weaknesses with IT-related deficiencies, B) firms with material weaknesses with no IT-related deficiencies, and C) "clean firms" with no material weaknesses. Firms in Group A saw eight times higher CEO turnover than Group C, and there was four times higher CFO turnover in Group A than in Group C. Clearly, IT may matter far more than we typically think.

the conditions of *learned helplessness*, where people become unwilling or unable to act in a way that avoids the same problem in the future.

For our employees, it means long hours, working on weekends, and a decreased quality of life, not just for the employee, but for everyone who depends on them, including family and friends. It is not surprising that when this occurs, we lose our best people (except for those that feel like they can't leave, because of a sense of duty or obligation).

In addition to the human suffering that comes with the current way of working, the opportunity cost of the value that we could be creating is staggering—the authors believe that we are missing out on approximately $2.6 trillion of value creation per year, which is, at the time of this writing, equivalent to the annual economic output of France, the sixth largest economy in the world.

Consider the following calculation—both IDC and Gartner estimated that in 2011, approximately 5% of the worldwide gross domestic product($3.1 trillion) was spent on IT (hardware, services, and telecom). If we estimate that 50% of that $3.1 trillion was spent on operating costs and maintaining existing systems, and that one-third of that 50% was spent on urgent and unplanned work or rework, approximately $520 billion was wasted.

If adopting DevOps could enable us, through better management and increased operational excellence, to halve that waste and redeploy that human potential into something that's five times the value (a modest proposal), we could create $2.6 trillion of value per year.

THE ETHICS OF DEVOPS: THERE IS A BETTER WAY

In the previous sections, we described the problems and the negative consequences of the status quo due to the core, chronic conflict, from the inability to achieve organizational goals, to the damage we inflict on fellow human beings. By solving these problems, DevOps astonishingly enables us to simultaneously improve organizational performance, achieve the goals of all the various functional technology roles (e.g., Development, QA, IT Operations, Infosec), and improve the human condition.

This exciting and rare combination may explain why DevOps has generated so much excitement and enthusiasm in so many in such a short time, including technology leaders, engineers, and much of the software ecosystem we reside in.

BREAKING THE DOWNWARD SPIRAL WITH DEVOPS

Ideally, small teams of developers independently implement their features, validate their correctness in production-like environments, and have their code deployed into production quickly, safely and securely. Code deployments are routine and predictable. Instead of starting deployments at midnight on Friday and spending all weekend working to complete them, deployments occur throughout the business day when everyone is already in the office and without our customers even noticing—except when they see new features and bug fixes that delight them. And, by deploying code in the middle of the workday, for the first time in decades IT Operations is working during normal business hours like everyone else.

By creating fast feedback loops at every step of the process, everyone can immediately see the effects of their actions. Whenever changes are committed into version control, fast automated tests are run in production-like environments, giving continual assurance that the code and environments operate as designed and are always in a secure and deployable state.

Automated testing helps developers discover their mistakes quickly (usually within minutes), which enables faster fixes as well as genuine learning—learning that is impossible when mistakes are discovered six months later during integration testing, when memories and the link between cause and effect have long faded. Instead of accruing technical debt, problems are fixed as they are found, mobilizing the entire organization if needed, because global goals outweigh local goals.

Pervasive production telemetry in both our code and production environments ensure that problems are detected and corrected quickly, confirming that everything is working as intended and customers are getting value from the software we create.

In this scenario, everyone feels productive—the architecture allows small teams to work safely and architecturally decoupled from the work of other teams who use self-service platforms that leverage the collective experience of Operations and Information Security. Instead of everyone waiting all the time, with large amounts of late, urgent rework, teams work independently and productively in small batches, quickly and frequently delivering new value to customers.

Even high-profile product and feature releases become routine by using dark launch techniques. Long before the launch date, we put all the required code for the feature into production, invisible to everyone except internal employees

and small cohorts of real users, allowing us to test and evolve the feature until it achieves the desired business goal.

And, instead of firefighting for days or weeks to make the new functionality work, we merely change a feature toggle or configuration setting. This small change makes the new feature visible to ever-larger segments of customers, automatically rolling back if something goes wrong. As a result, our releases are controlled, predictable, reversible, and low stress.

It's not just feature releases that are calmer—all sorts of problems are being found and fixed early, when they are smaller, cheaper, and easier to correct. With every fix, we also generate organizational learnings, enabling us to prevent the problem from recurring and enabling us to detect and correct similar problems faster in the future.

Furthermore, everyone is constantly learning, fostering a hypothesis-driven culture where the scientific method is used to ensure nothing is taken for granted—we do nothing without measuring and treating product development and process improvement as experiments.

Because we value everyone's time, we don't spend years building features that our customers don't want, deploying code that doesn't work, or fixing something that isn't actually the cause of our problem.

Because we care about achieving goals, we create long-term teams that are responsible for meeting them. Instead of project teams where developers are reassigned and shuffled around after each release, never receiving feedback on their work, we keep teams intact so they can keep iterating and improving, using those learnings to better achieve their goals. This is equally true for the product teams who are solving problems for our external customers, as well as our internal platform teams who are helping other teams be more productive, safe, and secure.

Instead of a culture of fear, we have a high-trust, collaborative culture, where people are rewarded for taking risks. They are able to fearlessly talk about problems as opposed to hiding them or putting them on the backburner—after all, we must see problems in order to solve them.

And, because everyone fully owns the quality of their work, everyone builds automated testing into their daily work and uses peer reviews to gain confidence that problems are addressed long before they can impact a customer. These processes mitigate risk, as opposed to approvals from distant authorities,

allowing us to deliver value quickly, reliably, and securely—even proving to skeptical auditors that we have an effective system of internal controls.

And when something does go wrong, we conduct *blameless post-mortems*, not to punish anyone, but to better understand what caused the accident and how to prevent it. This ritual reinforces our culture of learning. We also hold internal technology conferences to elevate our skills and ensure that everyone is always teaching and learning.

Because we care about quality, we even inject faults into our production environment so we can learn how our system fails in a planned manner. We conduct planned exercises to practice large-scale failures, randomly kill processes and compute servers in production, and inject network latencies and other nefarious acts to ensure we grow ever more resilient. By doing this, we enable better resilience, as well as organizational learning and improvement.

In this world, everyone has ownership in their work, regardless of their role in the technology organization They have confidence that their work matters and is meaningfully contributing to organizational goals, proven by their low-stress work environment and their organization's success in the marketplace. Their proof is that the organization is indeed winning in the marketplace.

THE BUSINESS VALUE OF DEVOPS

We have decisive evidence of the business value of DevOps. From 2013 through 2016, as part of Puppet Labs' *State Of DevOps Report,* to which authors Jez Humble and Gene Kim contributed, we collected data from over twenty-five thousand technology professionals, with the goal of better understanding the health and habits of organizations at all stages of DevOps adoption.

The first surprise this data revealed was how much high performing organizations using DevOps practices were outperforming their non–high performing peers in the following areas:

- Throughput metrics
- Code and change deployments (thirty times more frequent)
- Code and change deployment lead time (two hundred times faster)
- Reliability metrics

- Production deployments (sixty times higher change success rate)
- Mean time to restore service (168 times faster)
- Organizational performance metrics
- Productivity, market share, and profitability goals (two times more likely to exceed)
- Market capitalization growth (50% higher over three years)

In other words, high performers were both more agile and more reliable, providing empirical evidence that DevOps enables us to break the core, chronic conflict. High performers deployed code thirty times more frequently, and the time required to go from "code committed" to "successfully running in production" was two hundred times faster—high performers had lead times measured in minutes or hours, while low performers had lead times measured in weeks, months, or even quarters.

Furthermore, high performers were twice as likely to exceed profitability, market share, and productivity goals. And, for those organizations that provided a stock ticker symbol, we found that high performers had 50% higher market capitalization growth over three years. They also had higher employee job satisfaction, lower rates of employee burnout, and their employees were 2.2 times more likely to recommend their organization to friends as a great place to work.[†] High performers also had better information security outcomes. By integrating security objectives into all stages of the development and operations processes, they spent 50% less time remediating security issues.

DEVOPS HELPS SCALE DEVELOPER PRODUCTIVITY

When we increase the number of developers, individual developer productivity often significantly decreases due to communication, integration, and testing overhead. This is highlighted in the famous book by Frederick Brook, *The Mythical Man-Month*, where he explains that when projects are late, adding

† As measured by employee Net Promoter Score (eNPS). This is a significant finding, as research has shown that "companies with highly engaged workers grew revenues two and a half times as much as those with low engagement levels. And [publicly traded] stocks of companies with a high-trust work environment outperformed market indexes by a factor of three from 1997 through 2011."

more developers not only decreases individual developer productivity but also decreases overall productivity.

On the other hand, DevOps shows us that when we have the right architecture, the right technical practices, and the right cultural norms, small teams of developers are able to quickly, safely, and independently develop, integrate, test, and deploy changes into production. As Randy Shoup, formerly a director of engineering at Google, observed, large organizations using DevOps "have thousands of developers, but their architecture and practices enable small teams to still be incredibly productive, as if they were a startup."

The *2015 State of DevOps Report* examined not only "deploys per day" but also "deploys per day per developer." We hypothesized that high performers would be able to scale their number of deployments as team sizes grew.

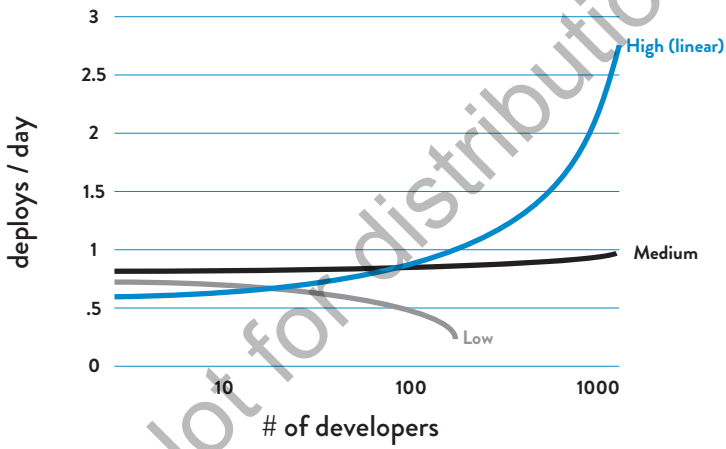


Figure 1. *Deployments/day vs. number of developers (Source: Puppet Labs,* 2015 State Of DevOps Report.)[†]

Indeed, this is what we found. Figure 1 shows that in low performers, deploys per day per developer go down as team size increases, stays constant for medium performers, and increases linearly for high performers.

In other words, organizations adopting DevOps are able to linearly increase the number of deploys per day as they increase their number of developers, just as Google, Amazon, and Netflix have done.[‡]

† Only organizations that are deploying at least once per day are shown.

‡ Another more extreme example is Amazon. In 2011, Amazon was performing approximately seven thousand deploys per day. By 2015, they were performing 130,000 deploys per day.

THE UNIVERSALITY OF THE SOLUTION

One of the most influential books in the Lean manufacturing movement is *The Goal: A Process of Ongoing Improvement* written by Dr. Eliyahu M. Goldratt in 1984. It influenced an entire generation of professional plant managers around the world. It was a novel about a plant manager who had to fix his cost and product due date issues in ninety days, otherwise his plant would be shut down.

Later in his career, Dr. Goldratt described the letters he received in response to *The Goal*. These letters would typically read, "You have obviously been hiding in our factory, because you've described my life [as a plant manager] exactly..." Most importantly, these letters showed people were able to replicate the breakthroughs in performance that were described in the book in their own work environments.

The Phoenix Project: A Novel About IT, DevOps, and Helping Your Business Win, written by Gene Kim, Kevin Behr, and George Spafford in 2013, was closely modeled after *The Goal*. It is a novel that follows an IT leader who faces all the typical problems that are endemic in IT organizations: an over-budget, behind-schedule project that must get to market in order for the company to survive. He experiences catastrophic deployments; problems with availability, security, and compliance; and so forth. Ultimately, he and his team use DevOps principles and practices to overcome those challenges, helping their organization win in the marketplace. In addition, the novel shows how DevOps practices improved the workplace environment for the team, creating lower stress and higher satisfaction because of greater practitioner involvement throughout the process.

As with *The Goal*, there is tremendous evidence of the universality of the problems and solutions described in *The Phoenix Project*. Consider some of the statements found in the Amazon reviews: "I find myself relating to the characters in *The Phoenix Project*...I've probably met most of them over the course of my career," "If you have ever worked in any aspect of IT, DevOps, or Infosec you will definitely be able to relate to this book," or "There's not a character in *The Phoenix Project* that I don't identify with myself or someone I know in real life... not to mention the problems faced and overcome by those characters."

In the remainder of this book, we will describe how to replicate the transformation described in *The Phoenix Project*, as well provide many case studies of how other organizations have used DevOps principles and practices to replicate those outcomes.

THE DEVOPS HANDBOOK: AN ESSENTIAL GUIDE

The purpose of the *DevOps Handbook* is to give you the theory, principles, and practices you need to successfully start your DevOps initiative and achieve your desired outcomes. This guidance is based on decades of sound management theory, study of high performing technology organizations, work we have done helping organizations transform, and research that validates the effectiveness of the prescribed DevOps practices. As well as interviews with relevant subject matter experts and analyses of nearly one hundred case studies presented at the DevOps Enterprise Summit.

Broken into six parts, this book covers DevOps theories and principles using the Three Ways, a specific view of the underpinning theory originally introduced in *The Phoenix Project*. *The DevOps Handbook* is for everyone who performs or influences work in the technology value stream (which typically includes Product Management, Development, QA, IT Operations, and Information Security), as well as for business and marketing leadership, where most technology initiatives originate.

The reader is not expected to have extensive knowledge of any of these domains, or of DevOps, Agile, ITIL, Lean, or process improvement. Each of these topics is introduced and explained in the book as it becomes necessary.

Our intent is to create a working knowledge of the critical concepts in each of these domains, both to serve as a primer and to introduce the language necessary to help practitioners work with all their peers across the entire IT value stream, and to frame shared goals.

This book will be of value to business leaders and stakeholders who are increasingly reliant upon the technology organization for the achievement of their goals.

Furthermore, this book is intended for readers whose organizations might not be experiencing all the problems described in the book (e.g., long deployment lead times or painful deployments). Even readers in this fortunate position will benefit from understanding DevOps principles, especially those relating to shared goals, feedback, and continual learning.

In Part I, we present a brief history of DevOps and introduce the underpinning theory and key themes from relevant bodies of knowledge that span over decades. We then present the high level principles of the Three Ways: Flow, Feedback, and Continual Learning and Experimentaion.

Part II describes how and where to start, and presents concepts such as value streams, organizational design principles and patterns, organizational adoption patterns, and case studies.

Part III describes how to accelerate Flow by building the foundations of our deployment pipeline: enabling fast and effective automated testing, continuous integration, continuous delivery, and architecting for low-risk releases.

Part IV discusses how to accelerate and amplify Feedback by creating effective production telemetry to see and solve problems, better anticipate problems and achieve goals, enable feedback so that Dev and Ops can safely deploy changes, integrate A/B testing into our daily work, and create review and coordination processes to increase the quality of our work.

Part V describes how we accelerate Continual Learning by establishing a just culture, converting local discoveries into global improvements, and properly reserving time to create organizational learning and improvements.

Finally, in Part VI we describe how to properly integrate security and compliance into our daily work, by integrating preventative security controls into shared source code repositories and services, integrating security into our deployment pipeline, enhancing telemetry to better enable detection and recovery, protecting the deployment pipeline, and achieving change management objectives.

By codifying these practices, we hope to accelerate the adoption of DevOps practices, increase the success of DevOps initiatives, and lower the activation energy required for DevOps transformations.

PART I

The Three Ways

Part I
Introduction

In Part I of *The DevOps Handbook*, we will explore how the convergence of several important movements in management and technology set the stage for the DevOps movement. We describe value streams, how DevOps is the result of applying Lean principles to the technology value stream, and the Three Ways: Flow, Feedback, and Continual Learning and Experimentation.

Primary focuses within these chapters include:

- The principles of Flow, which accelerate the delivery of work from Development to Operations to our customers
- The principles of Feedback, which enable us to create ever safer systems of work
- The principles of Continual Learning and Experimentation foster a high-trust culture and a scientific approach to organizational improvement risk-taking as part of our daily work

A BRIEF HISTORY

DevOps and its resulting technical, architectural, and cultural practices represent a convergence of many philosophical and management movements. While many organizations have developed these principles independently, understanding that DevOps resulted from a broad stroke of movements, a phenomenon described by John Willis (one of the co-authors of this book) as the "convergence of DevOps," shows an amazing progression of thinking and improbable connections. There are decades of lessons learned from manufacturing, high reliability organization, high-trust management models, and others that have brought us to the DevOps practices we know today.

DevOps is the outcome of applying the most trusted principles from the domain of physical manufacturing and leadership to the IT value stream. DevOps relies on bodies of knowledge from Lean, Theory of Constraints, the Toyota Production System, resilience engineering, learning organizations, safety culture, human factors, and many others. Other valuable contexts that DevOps draws from include high-trust management cultures, servant leadership, and organizational change management. The result is world-class quality, reliability, stability, and security at ever lower cost and effort; and accelerated flow and reliability throughout the technology value stream, including Product Management, Development, QA, IT Operations, and Infosec.

While the foundation of DevOps can be seen as being derived from Lean, the Theory of Constraints, and the Toyota Kata movement, many also view DevOps as the logical continuation of the Agile software journey that began in 2001.

THE LEAN MOVEMENT

Techniques such as Value Stream Mapping, Kanban Boards, and Total Productive Maintenance were codified for the Toyota Production System in the 1980s. In 1997, the Lean Enterprise Institute started researching applications of Lean to other value streams, such as the service industry and healthcare.

Two of Lean's major tenets include the deeply held belief that *manufacturing lead time* required to convert raw materials into finished goods was the best predictor of quality, customer satisfaction, and employee happiness, and that one of the best predictors of short lead times was small batch sizes of work.

Lean principles focus on how to create value for the customer through systems thinking by creating constancy of purpose, embracing scientific thinking, creating flow and pull (versus push), assuring quality at the source, leading with humility, and respecting every individual.

THE AGILE MANIFESTO

The Agile Manifesto was created in 2001 by seventeen of the leading thinkers in software development. They wanted to create a lightweight set of values and principles against heavyweight software development processes such as waterfall development, and methodologies such as the Rational Unified Process.

One key principle was to "deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale," emphasizing the desire for small batch sizes, incremental releases instead of large, waterfall releases. Other principles emphasized the need for small, self-motivated teams, working in a high-trust management model.

Agile is credited for dramatically increasing the productivity of many development organizations. And interestingly, many of the key moments in DevOps history also occurred within the Agile community or at Agile conferences, as described below.

AGILE INFRASTRUCTURE AND VELOCITY MOVEMENT

At the 2008 Agile conference in Toronto, Canada, Patrick Debois and Andrew Schafer held a "birds of a feather" session on applying Agile principles to infrastructure as opposed to application code. Although they were the only people who showed up, they rapidly gained a following of like-minded thinkers, including co-author John Willis.

Later, at the 2009 Velocity conference, John Allspaw and Paul Hammond gave the seminal "10 Deploys per Day: Dev and Ops Cooperation at Flickr" presentation, where they described how they created shared goals between Dev and Ops and used continuous integration practices to make deployment part of everyone's daily work. According to first hand accounts, everyone attending the presentation immediately knew they were in the presence of something profound and of historic significance.

Patrick Debois was not there, but was so excited by Allspaw and Hammond's idea that he created the first DevOpsDays in Ghent, Belgium, (where he lived) in 2009. There the term "DevOps" was coined.

THE CONTINUOUS DELIVERY MOVEMENT

Building upon the development discipline of continuous build, test, and integration, Jez Humble and David Farley extended the concept to *continuous delivery*, which defined the role of a "deployment pipeline" to ensure that code and infrastructure are always in a deployable state, and that all code checked in to trunk can be safely deployed into production. This idea was first presented at the 2006 Agile conference, and was also independently

developed in 2009 by Tim Fitz in a blog post on his website titled "Continuous Deployment."[†]

TOYOTA KATA

In 2009, Mike Rother wrote *Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results*, which framed his twenty-year journey to understand and codify the Toyota Production System. He had been one of the graduate students who flew with GM executives to visit Toyota plants and helped develop the Lean toolkit, but he was puzzled when none of the companies adopting these practices replicated the level of performance observed at the Toyota plants.

He concluded that the Lean community missed the most important practice of all, which he called the *improvement kata*. He explains that every organization has work routines, and the improvement kata requires creating structure for the daily, habitual practice of improvement work, because daily practice is what improves outcomes. The constant cycle of establishing desired future states, setting weekly target outcomes, and the continual improvement of daily work is what guided improvement at Toyota.

The above describes the history of DevOps and relevant movements that it draws upon. Throughout the rest of Part I, we look at value streams, how Lean principles can be applied to the technology value stream, and the Three Ways of Flow, Feedback, and Continual Learning and Experimentation.

† DevOps also extends and builds upon the practices of *infrastructure as code*, which was pioneered by Dr. Mark Burgess, Luke Kanies, and Adam Jacob. In infrastructure as code, the work of Operations is automated and treated like application code, so that modern development practices can be applied to the entire development stream. This further enabled fast deployment flow, including continuous integration (pioneered by Grady Booch and integrated as one of the key 12 practices of Extreme Programming), continuous delivery (pioneered by Jez Humble and David Farley), and continuous deployment (pioneered by Etsy, Wealthfront, and Eric Ries's work at IMVU).

1 Agile, Continuous Delivery, and the Three Ways

In this chapter, an introduction to the underpinning theory of Lean Manufacturing is presented, as well as the Three Ways, the principles from which all of the observed DevOps behaviors can be derived.

Our focus here is primarily on theory and principles, describing many decades of lessons learned from manufacturing, high-reliability organizations, high-trust management models, and others, from which DevOps practices have been derived. The resulting concrete principles and patterns, and their practical application to the technology value stream, are presented in the remaining chapters of the book.

THE MANUFACTURING VALUE STREAM

One of the fundamental concepts in Lean is the *value stream*. We will define it first in the context of manufacturing and then extrapolate how it applies to DevOps and the technology value stream.

Karen Martin and Mike Osterling define value stream in their book *Value Stream Mapping: How to Visualize Work and Align Leadership for Organizational Transformation* as "the sequence of activities an organization undertakes to deliver upon a customer request," or "the sequence of activities required to design, produce, and deliver a good or service to a customer, including the dual flows of information and material."

In manufacturing operations, the value stream is often easy to see and observe: it starts when a customer order is received and the raw materials are released onto the plant floor. To enable fast and predictable lead times in any value stream, there is usually a relentless focus on creating a smooth and even flow of work, using techniques such as small batch sizes, reducing work in process

(WIP), preventing rework to ensure we don't pass defects to downstream work centers, and constantly optimizing our system toward our global goals.

THE TECHNOLOGY VALUE STREAM

The same principles and patterns that enable the fast flow of work in physical processes are equally applicable to technology work (and, for that matter, for all knowledge work). In DevOps, we typically define our technology value stream as the process required to convert a business hypothesis into a technology-enabled service that delivers value to the customer.

The input to our process is the formulation of a business objective, concept, idea, or hypothesis, and starts when we accept the work in Development, adding it to our committed backlog of work.

From there, Development teams that follow a typical Agile or iterative process will likely transform that idea into user stories and some sort of feature specification, which is then implemented in code into the application or service being built. The code is then checked in to the version control repository, where each change is integrated and tested with the rest of the software system.

Because value is created only when our services are running in production, we must ensure that we are not only delivering fast flow, but that our deployments can also be performed without causing chaos and disruptions such as service outages, service impairments, or security or compliance failures.

FOCUS ON DEPLOYMENT LEAD TIME

For the remainder of this book, our attention will be on deployment lead time, a subset of the value stream described above. This value stream begins when any engineer[†] in our value stream (which includes Development, QA, IT Operations, and Infosec) checks a change into version control and ends when that change is successfully running in production, providing value to the customer and generating useful feedback and telemetry.

The first phase of work that includes Design and Development is akin to Lean Product Development and is highly variable and highly uncertain, often requiring high degrees of creativity and work that may never be performed again, resulting in high variability of process times. In contrast, the second

† Going forward, *engineer* refers to anyone working in our value stream, not just developers.

phase of work, which includes Testing and Operations, is akin to Lean Manufacturing. It requires creativity and expertise, and strives to be predictable and mechanistic, with the goal of achieving work outputs with minimized variability (e.g., short and predictable lead times, near zero defects).

Instead of large batches of work being processed sequentially through the design/development value stream and then through the test/operations value stream (such as when we have a large batch waterfall process or long-lived feature branches), our goal is to have testing and operations happening simultaneously with design/development, enabling fast flow and high quality. This method succeeds when we work in small batches and build quality into every part of our value stream.[‡]

Defining Lead Time vs. Processing Time

In the Lean community, lead time is one of two measures commonly used to measure performance in value streams, with the other being processing time (sometimes known as touch time or task time).[§]

Whereas the lead time clock starts when the request is made and ends when it is fulfilled, the process time clock starts only when we begin work on the customer request—specifically, it omits the time that the work is in queue, waiting to be processed (figure 2).

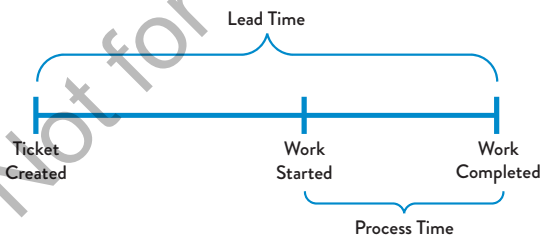


Figure 2. *Lead time vs. process time of a deployment operation*

Because lead time is what the customer experiences, we typically focus our process improvement attention there instead of on process time. However, the proportion of process time to lead time serves as an important measure

‡ In fact, with techniques such as test-driven development, testing occurs even before the first line of code is written.

§ In this book, the term *process time* will be favored for the same reason Karen Martin and Mike Osterling cite: "To minimize confusion, we avoid using the term cycle time as it has several definitions synonymous with processing time and pace or frequency of output, to name a few."

of efficiency—achieving fast flow and short lead times almost always requires reducing the time our work is waiting in queues.

The Common Scenario: Deployment Lead Times Requiring Months

In business as usual, we often find ourselves in situations where our deployment lead times require months. This is especially common in large, complex organizations that are working with tightly-coupled, monolithic applications, often with scarce integration test environments, long test and production environment lead times, high reliance on manual testing, and multiple required approval processes. When this occurs, our value stream may look like figure 3:

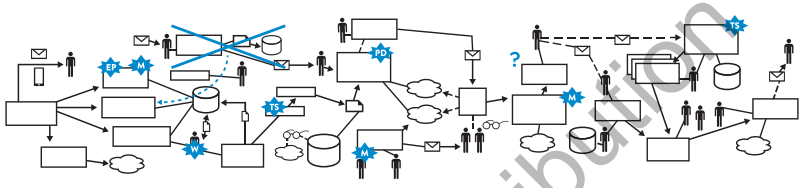


Figure 3: *A technology value stream with a deployment lead time of three months (Source: Damon Edwards, "DevOps Kaizen," 2015.)*

When we have long deployment lead times, heroics are required at almost every stage of the value stream. We may discover that nothing works at the end of the project when we merge all the development team's changes together, resulting in code that no longer builds correctly or passes any of our tests. Fixing each problem requires days or weeks of investigation to determine who broke the code and how it can be fixed, and still results in poor customer outcomes.

Our DevOps Ideal: Deployment Lead Times of Minutes

In the DevOps ideal, developers receive fast, constant feedback on their work, which enables them to quickly and independently implement, integrate, and validate their code, and have the code deployed into the production environment (either by deploying the code themselves or by others).

We achieve this by continually checking small code changes into our version control repository, performing automated and exploratory testing against it, and deploying it into production. This enables us to have a high degree of confidence that our changes will operate as designed in production and that any problems can be quickly detected and corrected.

This is most easily achieved when we have architecture that is modular, well encapsulated, and loosely-coupled so that small teams are able to work with high degrees of autonomy, with failures being small and contained, and without causing global disruptions.

In this scenario, our deployment lead time is measured in minutes, or, in the worst case, hours. Our resulting value stream map should look something like figure 4:

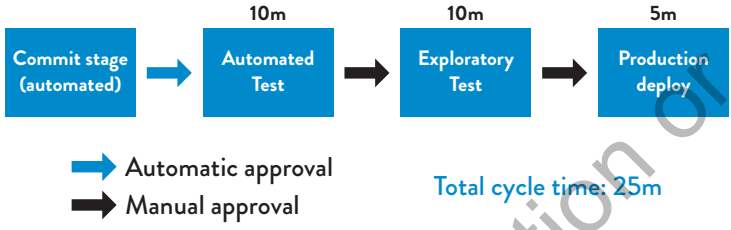


Figure 4: *A technology value stream with a lead time of minutes*

OBSERVING "%C/A" AS A MEASURE OF REWORK

In addition to lead times and process times, the third key metric in the technology value stream is percent complete and accurate (*%C/A*). This metric reflects the quality of the output of each step in our value stream. Karen Martin and Mike Osterling state that "the %C/A can be obtained by asking downstream customers what percentage of the time they receive work that is 'usable as is,' meaning that they can do their work without having to correct the information that was provided, add missing information that should have been supplied, or clarify information that should have and could have been clearer."

THE THREE WAYS: THE PRINCIPLES UNDERPINNING DEVOPS

The Phoenix Project presents the Three Ways as the set of underpinning principles from which all the observed DevOps behaviors and patterns are derived (figure 5).

The First Way enables fast left-to-right flow of work from Development to Operations to the customer. In order to maximize flow, we need to make work visible, reduce our batch sizes and intervals of work, build in quality by preventing defects from being passed to downstream work centers, and constantly optimize for the global goals.

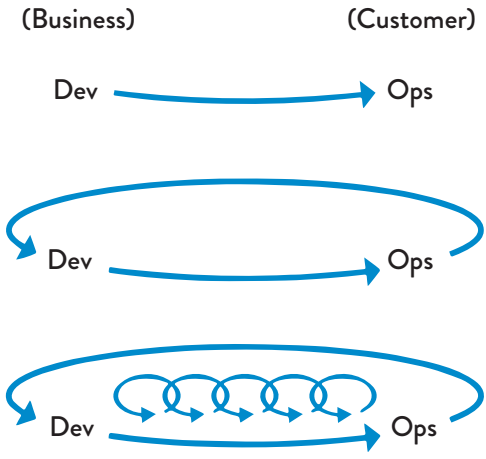


Figure 5: *The Three Ways (Source: Gene Kim, "The Three Ways: The Principles Underpinning DevOps," IT Revolution Press blog, accessed August 9, 2016, http://itrevolution.com/the-three-ways-principles-underpinning-devops/.)*

By speeding up flow through the technology value stream, we reduce the lead time required to fulfill internal or customer requests, especially the time required to deploy code into the production environment. By doing this, we increase the quality of work as well as our throughput, and boost our ability to out-experiment the competition.

The resulting practices include continuous build, integration, test, and deployment processes; creating environments on demand; limiting work in process (WIP); and building systems and organizations that are safe to change.

The Second Way enables the fast and constant flow of feedback from right to left at all stages of our value stream. It requires that we amplify feedback to prevent problems from happening again, or enable faster detection and recovery. By doing this, we create quality at the source and generate or embed knowledge where it is needed—this allows us to create ever-safer systems of work where problems are found and fixed long before a catastrophic failure occurs.

By seeing problems as they occur and swarming them until effective countermeasures are in place, we continually shorten and amplify our feedback loops, a core tenet of virtually all modern process improvement methodologies. This maximizes the opportunities for our organization to learn and improve.

The Third Way enables the creation of a generative, high-trust culture that supports a dynamic, disciplined, and scientific approach to experimentation

and risk-taking, facilitating the creation of organizational learning, both from our successes and failures. Furthermore, by continually shortening and amplifying our feedback loops, we create ever-safer systems of work and are better able to take risks and perform experiments that help us learn faster than our competition and win in the marketplace.

As part of the Third Way, we also design our system of work so that we can multiply the effects of new knowledge, transforming local discoveries into global improvements. Regardless of where someone performs work, they do so with the cumulative and collective experience of everyone in the organization.

CONCLUSION

In this chapter, we described the concepts of value streams, lead time as one of the key measures of the effectiveness for both manufacturing and technology value streams, and the high-level concepts behind each of the Three Ways, the principles that underpin DevOps.

In the following chapters, the principles for each of the Three Ways are described in greater detail. The first of these principles is Flow, which is focused on how we create the fast flow of work in any value stream, whether it's in manufacturing or technology work. The practices that enable fast flow are described in Part III.

2 The First Way: *The Principles of Flow*

In the technology value stream, work typically flows from Development to Operations, the functional areas between our business and our customers. The First Way requires the fast and smooth flow of work from Development to Operations, to deliver value to customers quickly. We optimize for this global goal instead of local goals, such as Development feature completion rates, test find/fix ratios, or Ops availability measures.

We increase flow by making work visible, by reducing batch sizes and intervals of work, and by building quality in, preventing defects from being passed to downstream work centers. By speeding up the flow through the technology value stream, we reduce the lead time required to fulfill internal and external customer requests, further increasing the quality of our work while making us more agile and able to out-experiment the competition.

Our goal is to decrease the amount of time required for changes to be deployed into production and to increase the reliability and quality of those services. Clues on how we do this in the technology value stream can be gleaned from how the Lean principles were applied to the manufacturing value stream.

MAKE OUR WORK VISIBLE

A significant difference between technology and manufacturing value streams is that our work is invisible. Unlike physical processes, in the technology value stream we cannot easily see where flow is being impeded or when work is piling up in front of constrained work centers. Transferring work between work centers is usually highly visible and slow because inventory must be physically moved.

However, in technology work the move can be done with a click of a button, such as by re-assigning a work ticket to another team. Because it is so easy,

work can bounce between teams endlessly due to incomplete information, or work can be passed onto downstream work centers with problems that remain completely invisible until we are late delivering what we promised to the customer or our application fails in the production environment.

To help us see where work is flowing well and where work is queued or stalled, we need to make our work as visible as possible. One of the best methods of doing this is using visual work boards, such as kanban boards or sprint planning boards, where we can represent work on physical or electronic cards. Work originates on the left (often being pulled from a backlog), is pulled from work center to work center (represented in columns), and finishes when it reaches the right side of the board, usually in a column labeled "done" or "in production."

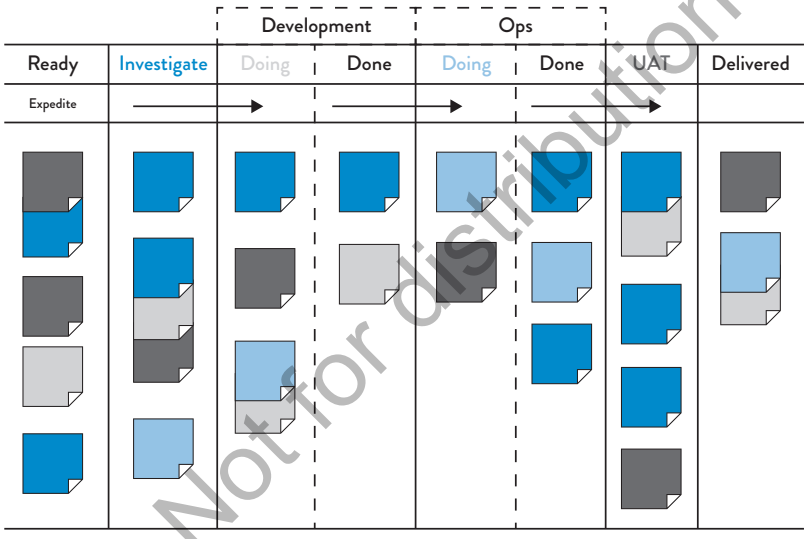


Figure 6: *An example kanban board, spanning Requirements, Dev, Test, Staging, and In Production (Source: David J. Andersen and Dominica DeGrandis,* Kanban for ITOps, *training materials for workshop, 2012.)*

Not only does our work become visible, we can also manage our work so that it flows from left to right as quickly as possible. Furthermore, we can measure lead time from when a card is placed on the board to when it is moved into the "Done" column.

Ideally, our kanban board will span the entire value stream, defining work as completed only when it reaches the right side of the board (figure 6). Work is not done when Development completes the implementation of a feature—

rather, it is only done when our application is running successfully in production, delivering value to the customer.

By putting all work for each work center in queues and making it visible, all stakeholders can more easily prioritize work in the context of global goals. Doing this enables each work center to single-task on the highest priority work until it is completed, increasing throughput.

LIMIT WORK IN PROCESS (WIP)

In manufacturing, daily work is typically dictated by a production schedule that is generated regularly (e.g., daily, weekly), establishing which jobs must be run based on customer orders, order due dates, parts available, and so forth.

In technology, our work is usually far more dynamic—this is especially the case in shared services, where teams must satisfy the demands of many different stakeholders. As a result, daily work becomes dominated by the priority *du jour*, often with requests for urgent work coming in through every communication mechanism possible, including ticketing systems, outage calls, emails, phone calls, chat rooms, and management escalations.

Disruptions in manufacturing are also highly visible and costly, often requiring breaking the current job and scrapping any incomplete work in process to start the new job. This high level of effort discourages frequent disruptions.

However, interrupting technology workers is easy, because the consequences are invisible to almost everyone, even though the negative impact to productivity may be far greater than in manufacturing. For instance, an engineer assigned to multiple projects must switch between tasks, incurring all the costs of having to re-establish context, as well as cognitive rules and goals.

Studies have shown that the time to complete even simple tasks, such as sorting geometric shapes, significantly degrades when multitasking. Of course, because our work in the technology value stream is far more cognitively complex than sorting geometric shapes, the effects of multitasking on process time is much worse.

We can limit multitasking when we use a kanban board to manage our work, such as by codifying and enforcing WIP (work in progress) limits for each

column or work center that puts an upper limit on the number of cards that can be in a column.

For example, we may set a WIP limit of three cards for testing. When there are already three cards in the test lane, no new cards can be added to the lane unless a card is completed or removed from the "in work" column and put back into queue (i.e., putting the card back to the column to the left). Nothing can can be worked on until it is represented first in a work card, reinforcing that all work must be made visible.

Dominica DeGrandis, one of the leading experts on using kanbans in DevOps value streams, notes that "controlling queue size [WIP] is an extremely powerful management tool, as it is one of the few leading indicators of lead time—with most work items, we don't know how long it will take until it's actually completed."

Limiting WIP also makes it easier to see problems that prevent the completion of work.[†] For instance, when we limit WIP, we find that we may have nothing to do because we are waiting on someone else. Although it may be tempting to start new work (i.e., "It's better to be doing something than nothing"), a far better action would be to find out what is causing the delay and help fix that problem. Bad multitasking often occurs when people are assigned to multiple projects, resulting in many prioritization problems.

In other words, as David J. Andersen, author of *Kanban: Successful Evolutionary Change for Your Technology Business*, quipped, "Stop starting. Start finishing."

REDUCE BATCH SIZES

Another key component to creating smooth and fast flow is performing work in small batch sizes. Prior to the Lean manufacturing revolution, it was common practice to manufacture in large batch sizes (or lot sizes), especially for operations where job setup or switching between jobs was time-consuming or costly. For example, producing large car body panels requires setting large and heavy dies onto metal stamping machines, a process that could take days. When changeover cost is so expensive, we would often stamp as many panels at a time as possible, creating large batches in order to reduce the number of changeovers.

† Taiichi Ohno compared enforcing WIP limits to draining water from the river of inventory in order to reveal all the problems that obstruct fast flow.

However, large batch sizes result in skyrocketing levels of WIP and high levels of variability in flow that cascade through the entire manufacturing plant. The result is long lead times and poor quality—if a problem is found in one body panel, the entire batch has to be scrapped.

One of the key lessons in Lean is that in order to shrink lead times and increase quality, we must strive to continually shrink batch sizes. The theoretical lower limit for batch size is *single-piece flow*, where each operation is performed one unit at a time.[‡]

The dramatic differences between large and small batch sizes can be seen in the simple newsletter mailing simulation described in *Lean Thinking: Banish Waste and Create Wealth in Your Corporation* by James P. Womack and Daniel T. Jones.

Suppose in our own example we have ten brochures to send and mailing each brochure requires four steps: fold the paper, insert the paper into the envelope, seal the envelope, and stamp the envelope.

The large batch strategy (i.e., "mass production") would be to sequentially perform one operation on each of the ten brochures. In other words, we would first fold all ten sheets of paper, then insert each of them into envelopes, then seal all ten envelopes, and then stamp them.

On the other hand, in the small batch strategy (i.e., "single-piece flow"), all the steps required to complete each brochure are performed sequentially before starting on the next brochure. In other words, we fold one sheet of paper, insert it into the envelope, seal it, and stamp it—only then do we start the process over with the next sheet of paper.

The difference between using large and small batch sizes is dramatic (see figure 7). Suppose each of the four operations takes ten seconds for each of the ten envelopes. With the large batch size strategy, the first completed and stamped envelope is produced only after 310 seconds.

Worse, suppose we discover during the envelope sealing operation that we made an error in the first step of folding—in this case, the earliest we would discover the error is at two hundred seconds, and we have to refold and reinsert all ten brochures in our batch again.

‡ Also known as "batch size of one" or "1x1 flow," terms that refer to batch size and a WIP limit of one.

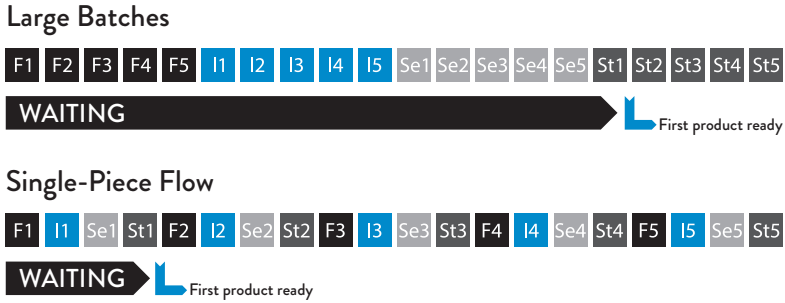


Figure 7: *Simulation of "envelope game" (fold, insert, seal, and stamp the envelope) (Source: Stefan Luyten, "Single Piece Flow: Why mass production isn't the most efficient way of doing 'stuff'," Medium.com, August 8, 2014, https://medium.com/@stefanluyten/single-piece-flow-5d2c2bec845b#.907sn74ns.)*

In contrast, in the small batch strategy the first completed stamped envelope is produced in only forty seconds, eight times faster than the large batch strategy. And, if we made an error in the first step, we only have to redo the one brochure in our batch. Small batch sizes result in less WIP, faster lead times, faster detection of errors, and less rework.

The negative outcomes associated with large batch sizes are just as relevant to the technology value stream as in manufacturing. Consider when we have an annual schedule for software releases, where an entire year's worth of code that Development has worked on is released to production deployment.

Like in manufacturing, this large batch release creates sudden, high levels of WIP and massive disruptions to all downstream work centers, resulting in poor flow and poor quality outcomes. This validates our common experience that the larger the change going into production, the more difficult the production errors are to diagnose and fix, and the longer they take to remediate.

In a post on *Startup Lessons Learned*, Eric Ries states, "The batch size is the unit at which work-products move between stages in a development [or DevOps] process. For software, the easiest batch to see is code. Every time an engineer checks in code, they are batching up a certain amount of work. There are many techniques for controlling these batches, ranging from the tiny batches needed for continuous deployment to more traditional branch-based development, where all of the code from multiple developers working for weeks or months is batched up and integrated together."

The equivalent to single piece flow in the technology value stream is realized with continuous deployment, where each change committed to version control is integrated, tested, and deployed into production. The practices that enable this are described in Part IV.

REDUCE THE NUMBER OF HANDOFFS

In the technology value stream, whenever we have long deployment lead times measured in months, it is often because there are hundreds (or even thousands) of operations required to move our code from version control into the production environment. To transmit code through the value stream requires multiple departments to work on a variety of tasks, including functional testing, integration testing, environment creation, server administration, storage administration, networking, load balancing, and information security.

Each time the work passes from team to team, we require all sorts of communication: requesting, specifying, signaling, coordinating, and often prioritizing, scheduling, deconflicting, testing, and verifying. This may require using different ticketing or project management systems; writing technical specification documents; communicating via meetings, emails, or phone calls; and using file system shares, FTP servers, and Wiki pages.

Each of these steps is a potential queue where work will wait when we rely on resources that are shared between different value streams (e.g., centralized operations). The lead times for these requests are often so long that there is constant escalation to have work performed within the needed timelines.

Even under the best circumstances, some knowledge is inevitably lost with each handoff. With enough handoffs, the work can completely lose the context of the problem being solved or the organizational goal being supported. For instance, a server administrator may see a newly created ticket requesting that user accounts be created, without knowing what application or service it's for, why it needs to be created, what all the dependencies are, or whether it's actually recurring work.

To mitigate these types of problems, we strive to reduce the number of handoffs, either by automating significant portions of the work or by reorganizing teams so they can deliver value to the customer themselves, instead of having to be constantly dependent on others. As a result, we increase flow by reducing the amount of time that our work spends waiting in queue, as well as the amount of non–value-added time. (See Appendix 4.)

CONTINUALLY IDENTIFY AND ELEVATE OUR CONSTRAINTS

To reduce lead times and increase throughput, we need to continually identify our system's constraints and improve its work capacity. In *Beyond the Goal*,

Dr. Goldratt states, "In any value stream, there is always a direction of flow, and there is always one and only constraint; any improvement not made at that constraint is an illusion." If we improve a work center that is positioned before the constraint, work will merely pile up at the bottleneck even faster, waiting for work to be performed by the bottlenecked work center.

On the other hand, if we improve a work center positioned *after* the bottleneck, it remains starved, waiting for work to clear the bottleneck. As a solution, Dr. Goldratt defined the "five focusing steps:"

- Identify the system's constraint.
- Decide how to exploit the system's constraint.
- Subordinate everything else to the above decisions.
- Elevate the system's constraint.
- If in the previous steps a constraint has been broken, go back to step one, but do not allow inertia to cause a system constraint.

In typical DevOps transformations, as we progress from deployment lead times measured in months or quarters to lead times measured in minutes, the constraint usually follows this progression:

- **Environment creation:** We cannot achieve deployments on-demand if we always have to wait weeks or months for production or test environments. The countermeasure is to create environments that are on demand and completely self-serviced, so that they are always available when we need them.
- **Code deployment:** We cannot achieve deployments on demand if each of our production code deployments take weeks or months to perform (i.e., each deployment requires 1,300 manual, error-prone steps, involving up to three hundred engineers). The countermeasure is to automate our deployments as much as possible, with the goal of being completely automated so they can be done self-service by any developer.
- **Test setup and run:** We cannot achieve deployments on demand if every code deployment requires two weeks to set up our test environments and data sets, and another four weeks to manually

execute all our regression tests. The countermeasure is to automate our tests so we can execute deployments safely and to parallelize them so the test rate can keep up with our code development rate.

- **Overly tight architecture:** We cannot achieve deployments on demand if overly tight architecture means that every time we want to make a code change we have to send our engineers to scores of committee meetings in order to get permission to make our changes. Our countermeasure is to create more loosely coupled architecture so that changes can be made safely and with more autonomy, increasing developer productivity.

After all these constraints have been broken, our constraint will likely be Development or the product owners. Because our goal is to enable small teams of developers to independently develop, test, and deploy value to customers quickly and reliably, this is where we want our constraint to be. High performers, regardless of whether an engineer is in Development, QA, Ops, or Infosec, state that their goal is to help maximize developer productivity.

When the constraint is here, we are limited only by the number of good business hypotheses we create and our ability to develop the code necessary to test these hypotheses with real customers.

The progression of constraints listed above are generalizations of typical transformations—techniques to identify the constraint in actual value streams, such as through value stream mapping and measurements, are described later in this book.

ELIMINATE HARDSHIPS AND WASTE IN THE VALUE STREAM

Shigeo Shingo, one of the pioneers of the Toyota Production System, believed that waste constituted the largest threat to business viability—the commonly used definition in Lean is "the use of any material or resource beyond what the customer requires and is willing to pay for." He defined seven major types of manufacturing waste: inventory, overproduction, extra processing, transportation, waiting, motion, and defects.

More modern interpretations of Lean have noted that "eliminating waste" can have a demeaning and dehumanizing context; instead, the goal is reframed

to reduce hardship and drudgery in our daily work through continual learning in order to achieve the organization's goals. For the remainder of this book, the term *waste* will imply this more modern definition, as it more closely matches the DevOps ideals and desired outcomes.

In the book *Implementing Lean Software Development: From Concept to Cash*, Mary and Tom Poppendieck describe waste and hardship in the software development stream as anything that causes delay for the customer, such as activities that can be bypassed without affecting the result.

The following categories of waste and hardship come from *Implementing Lean Software Development* unless otherwise noted:

- **Partially done work:** This includes any work in the value stream that has not been completed (e.g., requirement documents or change orders not yet reviewed) and work that is sitting in queue (e.g., waiting for QA review or server admin ticket). Partially done work becomes obsolete and loses value as time progresses.

- **Extra processes:** Any additional work that is being performed in a process that does not add value to the customer. This may include documentation not used in a downstream work center, or reviews or approvals that do not add value to the output. Extra processes add effort and increase lead times.

- **Extra features:** Features built into the service that are not needed by the organization or the customer (e.g., "gold plating"). Extra features add complexity and effort to testing and managing functionality.

- **Task switching:** When people are assigned to multiple projects and value streams, requiring them to context switch and manage dependencies between work, adding additional effort and time into the value stream.

- **Waiting:** Any delays between work requiring resources to wait until they can complete the current work. Delays increase cycle time and prevent the customer from getting value.

- **Motion:** The amount of effort to move information or materials from one work center to another. Motion waste can be created when people who need to communicate frequently are not

colocated. Handoffs also create motion waste and often require additional communication to resolve ambiguities.

- **Defects:** Incorrect, missing, or unclear information, materials, or products create waste, as effort is needed to resolve these issues. The longer the time between defect creation and defect detection, the more difficult it is to resolve the defect.

- **Nonstandard or manual work:** Reliance on nonstandard or manual work from others, such as using non-rebuilding servers, test environments, and configurations. Ideally, any dependencies on Operations should be automated, self-serviced, and available on demand.

- **Heroics:** In order for an organization to achieve goals, individuals and teams are put in a position where they must perform unreasonable acts, which may even become a part of their daily work (e.g., nightly 2:00 a.m. problems in production, creating hundreds of work tickets as part of every software release).†

Our goal is to make these wastes and hardships—anywhere heroics become necessary—visible, and to systematically do what is needed to alleviate or eliminate these burdens and hardships to achieve our goal of fast flow.

CONCLUSION

Improving flow through the technology value stream is essential to achieving DevOps outcomes. We do this by making work visible, limiting WIP, reducing batch sizes and the number of handoffs, continually identifying and evaluating our constraints, and eliminating hardships in our daily work.

The specific practices that enable fast flow in the DevOps value stream are presented in Part IV. In the next chapter, we present The Second Way: The Principles of Feedback.

† Although heroics is not included in the Poppendieck categories of waste, it is included here because of how often it occurs, especially in Operation shared services.

3 The Second Way: *The Principles of Feedback*

While the First Way describes the principles that enable the fast flow of work from left to right, the Second Way describes the principles that enable the reciprocal fast and constant feedback from right to left at all stages of the value stream. Our goal is to create an ever safer and more resilient system of work.

This is especially important when working in complex systems, when the earliest opportunity to detect and correct errors is typically when a catastrophic event is underway, such as a manufacturing worker being hurt on the job or a nuclear reactor meltdown in progress.

In technology, our work happens almost entirely within complex systems with a high risk of catastrophic consequences. As in manufacturing, we often discover problems only when large failures are underway, such as a massive production outage or a security breach resulting in the theft of customer data.

We make our system of work safer by creating fast, frequent, high quality information flow throughout our value stream and our organization, which includes feedback and feedforward loops. This allows us to detect and remediate problems while they are smaller, cheaper, and easier to fix; avert problems before they cause catastrophe; and create organizational learning that we integrate into future work. When failures and accidents occur, we treat them as opportunities for learning, as opposed to a cause for punishment and blame. To achieve all of the above, let us first explore the nature of complex systems and how they can be made safer.

WORKING SAFELY WITHIN COMPLEX SYSTEMS

One of the defining characteristics of a complex system is that it defies any single person's ability to see the system as a whole and understand how all

the pieces fit together. Complex systems typically have a high degree of interconnectedness of tightly coupled components, and system-level behavior cannot be explained merely in terms of the behavior of the system components.

Dr. Charles Perrow studied the Three Mile Island crisis and observed that it was impossible for anyone to understand how the reactor would behave in all circumstances and how it might fail. When a problem was underway in one component, it was difficult to isolate from the other components, quickly flowing through the paths of least resistance in unpredictable ways.

Dr. Sidney Dekker, who also codified some of the key elements of safety culture, observed another characteristic of complex systems: doing the same thing twice will not predictably or necessarily lead to the same result. It is this characteristic that makes static checklists and best practices, while valuable, insufficient to prevent catastrophes from occurring. (See Appendix 5.)

Therefore, because failure is inherent and inevitable in complex systems, we must design a safe system of work, whether in manufacturing or technology, where we can perform work without fear, confident that any errors will be detected quickly, long before they cause catastrophic outcomes, such as worker injury, product defects, or negative customer impact.

After he decoded the causal mechanism behind the Toyota Product System as part of his doctoral thesis at Harvard Business School, Dr. Steven Spear stated that designing perfectly safe systems is likely beyond our abilities, but we can make it safer to work in complex systems when the four following conditions are met:[†]

- Complex work is managed so that problems in design and operations are revealed
- Problems are swarmed and solved, resulting in quick construction of new knowledge
- New local knowledge is exploited globally throughout the organization
- Leaders create other leaders who continually grow these types of capabilities

† Dr. Spear extended his work to explain the long-lasting successes of other organizations, such as the Toyota supplier network, Alcoa, and the US Navy's Nuclear Power Propulsion Program.

Each of these capabilities are required to work safely in a complex system. In the next sections, the first two capabilities and their importance are described, as well as how they have been created in other domains and what practices enable them in the technology value stream. (The third and fourth capabilities are described in chapter 4.)

SEE PROBLEMS AS THEY OCCUR

In a safe system of work, we must constantly test our design and operating assumptions. Our goal is to increase information flow in our system from as many areas as possible, sooner, faster, cheaper, and with as much clarity between cause and effect as possible. The more assumptions we can invalidate, the faster we can find and fix problems, increasing our resilience, agility, and ability to learn and innovate.

We do this by creating feedback and feedforward loops into our system of work. Dr. Peter Senge in his book *The Fifth Discipline: The Art & Practice of the Learning Organization* described feedback loops as a critical part of learning organizations and systems thinking. Feedback and feedforward loops cause components within a system to reinforce or counteract each other.

In manufacturing, the absence of effective feedback often contribute to major quality and safety problems. In one well-documented case at the General Motors Fremont manufacturing plant, there were no effective procedures in place to detect problems during the assembly process, nor were there explicit procedures on what to do when problems were found. As a result, there were instances of engines being put in backward, cars missing steering wheels or tires, and cars even having to be towed off the assembly line because they wouldn't start.

In contrast, in high performing manufacturing operations there is fast, frequent, and high quality information flow throughout the entire value stream—every work operation is measured and monitored, and any defects or significant deviations are quickly found and acted upon. These are the foundation of what enables quality, safety, and continual learning and improvement.

In the technology value stream, we often get poor outcomes because of the absence of fast feedback. For instance, in a waterfall software project, we may develop code for an entire year and get no feedback on quality until we begin the testing phase—or worse, when we release our software to customers.

When feedback is this delayed and infrequent, it is too slow to enable us to prevent undesirable outcomes.

In contrast, our goal is to create fast feedback and fastforward loops wherever work is performed, at all stages of the technology value stream, encompassing Product Management, Development, QA, Infosec, and Operations. This includes the creation of automated build, integration, and test processes, so that we can immediately detect when a change has been introduced that takes us out of a correctly functioning and deployable state.

We also create pervasive telemetry so we can see how all our system components are operating in the production environment, so that we can quickly detect when they are not operating as expected. Telemetry also allows us to measure whether we are achieving our intended goals and, ideally, is radiated to the entire value stream so we can see how our actions affect other portions of the system as a whole.

Feedback loops not only enable quick detection and recovery of problems, but they also inform us on how to prevent these problems from occurring again in the future. Doing this increases the quality and safety of our system of work, and creates organizational learning.

As Elisabeth Hendrickson, VP of Engineering at Pivotal Software, Inc. and author of *Explore It!: Reduce Risk and Increase Confidence with Exploratory Testing*, said, "When I headed up quality engineering, I described my job as 'creating feedback cycles.' Feedback is critical because it is what allows us to steer. We must constantly validate between customer needs, our intentions and our implementations. Testing is merely one sort of feedback."

SWARM AND SOLVE PROBLEMS TO BUILD NEW KNOWLEDGE

Obviously, it is not sufficient to merely detect when the unexpected occurs. When problems occur, we must swarm them, mobilizing whoever is required to solve the problem.

According to Dr. Spear, the goal of swarming is to contain problems before they have a chance to spread, and to diagnose and treat the problem so that it cannot recur. "In doing so," he says, "they build ever-deeper knowledge about how to manage the systems for doing our work, converting inevitable up-front ignorance into knowledge."

The paragon of this principle is the Toyota *Andon cord*. In a Toyota manufacturing plant, above every work center is a cord that every worker and manager is trained to pull when something goes wrong; for example, when a part is defective, when a required part is not available, or even when work takes longer than documented.[†]

When the Andon cord is pulled, the team leader is alerted and immediately works to resolve the problem. If the problem cannot be resolved within a specified time (e.g., fifty-five seconds), the production line is halted so that the entire organization can be mobilized to assist with problem resolution until a successful countermeasure has been developed.

Instead of working around the problem or scheduling a fix "when we have more time," we swarm to fix it immediately—this is nearly the opposite of the behavior at the GM Fremont plant described earlier. Swarming is necessary for the following reasons:

- It prevents the problem from progressing downstream, where the cost and effort to repair it increases exponentially and technical debt is allowed to accumulate.
- It prevents the work center from starting new work, which will likely introduce new errors into the system.
- If the problem is not addressed, the work center could potentially have the same problem in the next operation (e.g., fifty-five seconds later), requiring more fixes and work. (See Appendix 6.)

This practice of swarming seems contrary to common management practice, as we are deliberately allowing a local problem to disrupt operations globally. However, swarming enables learning. It prevents the loss of critical information due to fading memories or changing circumstances. This is especially critical in complex systems, where many problems occur because of some unexpected, idiosyncratic interaction of people, processes, products, places, and circumstances—as time passes, it becomes impossible to reconstruct exactly what was going on when the problem occurred.

As Dr. Spear notes, swarming is part of the "disciplined cycle of real-time problem recognition, diagnosis,...and treatment (countermeasures or corrective measures in manufacturing vernacular). It [is] the discipline of the

† In some of its plants, Toyota has moved to using an Andon button.

Shewhart cycle—plan, do, check, act—popularized by W. Edwards Deming, but accelerated to warp speed."

It is only through the swarming of ever smaller problems discovered ever earlier in the life cycle that we can deflect problems before a catastrophe occurs. In other words, when the nuclear reactor melts down, it is already too late to avert worst outcomes.

To enable fast feedback in the technology value stream, we must create the equivalent of an Andon cord and the related swarming response. This requires that we also create the culture that makes it safe, and even encouraged, to pull the Andon cord when something goes wrong, whether it is when a production incident occurs or when errors occur earlier in the value stream, such as when someone introduces a change that breaks our continuous build or test processes.

When conditions trigger an Andon cord pull, we swarm to solve the problem and prevent the introduction of new work until the issue has been resolved.[†] This provides fast feedback for everyone in the value stream (especially the person who caused the system to fail), enables us to quickly isolate and diagnose the problem, and prevents further complicating factors that can obscure cause and effect.

Preventing the introduction of new work enables continuous integration and deployment, which is single-piece flow in the technology value stream. All changes that pass our continuous build and integration tests are deployed into production, and any changes that cause any tests to fail trigger our Andon cord and are swarmed until resolved.

KEEP PUSHING QUALITY CLOSER TO THE SOURCE

We may inadvertently perpetuate unsafe systems of work due to the way we respond to accidents and incidents. In complex systems, adding more inspection steps and approval processes actually increases the likelihood of future failures. The effectiveness of approval processes decreases as we push decision-making further away from where the work is performed. Doing so not only lowers the quality of decisions but also increases our cycle time, thus decreasing

† Astonishingly, when the number of Andon cord pulls drop, plant managers will actually decrease the tolerances to get an increase in the number of Andon cord pulls in order to continue to enable more learnings and improvements and to detect ever-weaker failure signals.

the strength of the feedback between cause and effect, and reducing our ability to learn from successes and failures.[‡]

This can be seen even in smaller and less complex systems. When top-down, bureaucratic command and control systems become ineffective, it is usually because the variance between "who should do something" and "who is actually doing something" is too large, due to insufficient clarity and timeliness.

Examples of ineffective quality controls include:

- Requiring another team to complete tedious, error-prone, and manual tasks that could be easily automated and run as needed by the team who needs the work performed
- Requiring approvals from busy people who are distant from the work, forcing them to make decisions without an adequate knowledge of the work or the potential implications, or to merely rubber stamp their approvals
- Creating large volumes of documentation of questionable detail which become obsolete shortly after they are written
- Pushing large batches of work to teams and special committees for approval and processing and then waiting for responses

Instead, we need everyone in our value stream to find and fix problems in their area of control as part of our daily work. By doing this, we push quality and safety responsibilities and decision-making to where the work is performed, instead of relying on approvals from distant executives.

We use peer reviews of our proposed changes to gain whatever assurance is needed that our changes will operate as designed. We automate as much of the quality checking typically performed by a QA or Information Security department as possible. Instead of developers needing to request or schedule

‡ In the 1700s, the British government engaged in a spectacular example of top-down, bureaucratic command and control, which proved remarkably ineffective. At the time, Georgia was still a colony, and despite the fact that the British government was three thousand miles away and lacked firsthand knowledge of local land chemistry, rockiness, topography, accessibility to water, and other conditions, it tried to plan Georgia's entire agricultural economy. The results of the attempt were dismal and left Georgia with the lowest levels of prosperity and population in the thirteen colonies.

a test to be run, these tests can be performed on demand, enabling developers to quickly test their own code and even deploy those changes into production themselves.

By doing this, we truly make quality everyone's responsibility as opposed to it being the sole responsibility of a separate department. Information security is not just Information Security's job, just as availability isn't merely the job of Operations.

Having developers share responsibility for the quality of the systems they build not only improves outcomes but also accelerates learning. This is especially important for developers as they are typically the team that is furthest removed from the customer. As Gary Gruver observes, "It's impossible for a developer to learn anything when someone yells at them for something they broke six months ago—that's why we need to provide feedback to everyone as quickly as possible, in minutes, not months."

ENABLE OPTIMIZING FOR DOWNSTREAM WORK CENTERS

In the 1980s, Designing for Manufacturability principles sought to design parts and processes so that finished goods could be created with the lowest cost, highest quality, and fastest flow. Examples include designing parts that are wildly asymmetrical to prevent them from being put on backwards, and designing screw fasteners so that they are impossible to over-tighten.

This was a departure from how design was typically done, which focused on the external customers but overlooked internal stakeholders, such as the people performing the manufacturing.

Lean defines two types of customers that we must design for: the external customer (who most likely pays for the service we are delivering) and the internal customer (who receives and processes the work immediately after us). According to Lean, our most important customer is our next step downstream. Optimizing our work for them requires that we have empathy for their problems in order to better identify the design problems that prevent fast and smooth flow.

In the technology value stream, we optimize for downstream work centers by designing for operations, where operational non-functional requirements (e.g., architecture, performance, stability, testability, configurability, and security) are prioritized as highly as user features.

By doing this, we create quality at the source, likely resulting in a set of codified non-functional requirements that we can proactively integrate into every service we build.

CONCLUSION

Creating fast feedback is critical to achieving quality, reliability, and safety in the technology value stream. We do this by seeing problems as they occur, swarming and solving problems to build new knowledge, pushing quality closer to the source, and continually optimizing for downstream work centers.

The specific practices that enable fast flow in the DevOps value stream are presented in Part IV. In the next chapter, we present the Third Way, the Principles of Feedback

4 The Third Way: *The Principles of Continual Learning and Experimentation*

While the First Way addresses work flow from left to right and the Second Way addresses the reciprocal fast and constant feedback from right to left, the Third Way focuses on creating a culture of continual learning and experimentation. These are the principles that enable constant creation of individual knowledge, which is then turned into team and organizational knowledge.

In manufacturing operations with systemic quality and safety problems, work is typically rigidly defined and enforced. For instance, in the GM Fremont plant described in the previous chapter, workers had little ability to integrate improvements and learnings into their daily work, with suggestions for improvement "apt to meet a brick wall of indifference."

In these environments, there is also often a culture of fear and low trust, where workers who make mistakes are punished, and those who make suggestions or point out problems are viewed as whistle-blowers and troublemakers. When this occurs, leadership is actively suppressing, even punishing, learning and improvement, perpetuating quality and safety problems.

In contrast, high-performing manufacturing operations require and actively promote learning—instead of work being rigidly defined, the system of work is dynamic, with line workers performing experiments in their daily work to generate new improvements, enabled by rigorous standardization of work procedures and documentation of the results.

In the technology value stream, our goal is to create a high-trust culture, reinforcing that we are all lifelong learners who must take risks in our daily work. By applying a scientific approach to both process improvement and product development, we learn from our successes and failures, identifying

which ideas don't work and reinforcing those that do. Moreover, any local learnings are rapidly turned into global improvements, so that new techniques and practices can be used by the entire organization.

We reserve time for the improvement of daily work and to further accelerate and ensure learning. We consistently introduce stress into our systems to force continual improvement. We even simulate and inject failures in our production services under controlled conditions to increase our resilience.

By creating this continual and dynamic system of learning, we enable teams to rapidly and automatically adapt to an ever-changing environment, which ultimately helps us win in the marketplace.

ENABLING ORGANIZATIONAL LEARNING AND A SAFETY CULTURE

When we work within a complex system, by definition it is impossible for us to perfectly predict all the outcomes for any action we take. This is what contributes to unexpected, or even catastrophic, outcomes and accidents in our daily work, even when we take precautions and work carefully.

When these accidents affect our customers, we seek to understand why it happened. The root cause is often deemed to be human error, and the all too common management response is to "name, blame, and shame" the person who caused the problem.[†] And, either subtly or explicitly, management hints that the person guilty of committing the error will be punished. They then create more processes and approvals to prevent the error from happening again.

Dr. Sidney Dekker, who codified some of the key elements of safety culture and coined the term *just culture*, wrote, "Responses to incidents and accidents that are seen as unjust can impede safety investigations, promote fear rather than mindfulness in people who do safety-critical work, make organizations more bureaucratic rather than more careful, and cultivate professional secrecy, evasion, and self-protection."

These issues are especially problematic in the technology value stream—our work is almost always performed within a complex system, and how management chooses to react to failures and accidents leads to a culture of fear,

† The "name, blame, shame" pattern is part of the Bad Apple Theory criticized by Dr. Sydney Dekker and extensively discussed in his book *The Field Guide to Understanding Human Error.*

which then makes it unlikely that problems and failure signals are ever reported. The result is that problems remain hidden until a catastrophe occurs.

Dr. Ron Westrum was one of the first to observe the importance of organizational culture on safety and performance. He observed that in healthcare organizations, the presence of "generative" cultures was one of the top predictors of patient safety. Dr. Westrum defined three types of culture:

- Pathological organizations are characterized by large amounts of fear and threat. People often hoard information, withhold it for political reasons, or distort it to make themselves look better. Failure is often hidden.

- Bureaucratic organizations are characterized by rules and processes, often to help individual departments maintain their "turf." Failure is processed through a system of judgment, resulting in either punishment or justice and mercy.

- Generative organizations are characterized by actively seeking and sharing information to better enable the organization to achieve its mission. Responsibilities are shared throughout the value stream, and failure results in reflection and genuine inquiry.

Pathological	Bureaucratic	Generative
Information is hidden	Information may be ignored	Information is actively sought
Messengers are "shot"	Messengers are tolerated	Messengers are trained
Responsibilities are shirked	Responsibilities are compartmented	Responsibilities are shared
Bridging between teams is discouraged	Bridging between teams is allowed but discouraged	Bridging between teams is rewarded
Failure is covered up	Organizatoin is just and merciful	Failure causes inquiry
New ideas are crushed	New ideas create problems	New ideas are weclomed

Figure 8: *The Westrum organizational typology model: how organizations process information (Source: Ron Westrum, "A typology of organisation culture," BMJ Quality & Safety 13, no. 2 (2004), doi:10.1136/qshc.2003.009522.)*

Just as Dr. Westrum found in healthcare organizations, a high-trust, generative culture also predicted IT and organizational performance in technology value streams.

In the technology value stream, we establish the foundations of a generative culture by striving to create a safe system of work. When accidents and failures occur, instead of looking for human error, we look for how we can redesign the system to prevent the accident from happening again.

For instance, we may conduct a blameless post-mortem after every incident to gain the best understanding of how the accident occurred and agree upon what the best countermeasures are to improve the system, ideally preventing the problem from occurring again and enabling faster detection and recovery.

By doing this, we create organizational learning. As Bethany Macri, an engineer at Etsy who led the creation of the Morgue tool to help with recording of post-mortems, stated, "By removing blame, you remove fear; by removing fear, you enable honesty; and honesty enables prevention."

Dr. Spear observes that the result of removing blame and putting organizational learning in its place is that "organizations become ever more self-diagnosing and self-improving, skilled at detecting problems [and] solving them."

Many of these attributes were also described by Dr. Senge as attributes of learning organizations. In *The Fifth Discipline,* he wrote that these characteristics help customers, ensure quality, create competitive advantage and an energized and committed workforce, and uncover the truth.

INSTITUTIONALIZE THE IMPROVEMENT OF DAILY WORK

Teams are often not able or not willing to improve the processes they operate within. The result is not only that they continue to suffer from their current problems, but their suffering also grows worse over time. Mike Rother observed in *Toyota Kata* that in the absence of improvements, processes don't stay the same—due to chaos and entropy, processes actually degrade over time.

In the technology value stream, when we avoid fixing our problems, relying on daily workarounds, our problems and technical debt accumulates until all we are doing is performing workarounds, trying to avoid disaster, with no cycles leftover for doing productive work. This is why Mike Orzen, author of

Lean IT, observed, "Even more important than daily work is the improvement of daily work."

We improve daily work by explicitly reserving time to pay down technical debt, fix defects, and refactor and improve problematic areas of our code and environments—we do this by reserving cycles in each development interval, or by scheduling *kaizen blitzes*, which are periods when engineers self-organize into teams to work on fixing any problem they want.

The result of these practices is that everyone finds and fixes problems in their area of control, all the time, as part of their daily work. When we finally fix the daily problems that we've worked around for months (or years), we can eradicate from our system the less obvious problems. By detecting and responding to these ever-weaker failure signals, we fix problems when it is not only easier and cheaper but also when the consequences are smaller.

Consider the following example that improved workplace safety at Alcoa, an aluminum manufacturer with $7.8 billion in revenue in 1987. Aluminum manufacturing requires extremely high heat, high pressures, and corrosive chemicals. In 1987, Alcoa had a frightening safety record, with 2% of the ninety thousand employee workforce being injured each year—that's seven injuries per day. When Paul O'Neill started as CEO, his first goal was to have zero injuries to employees, contractors, and visitors.

O'Neill wanted to be notified within twenty-four hours of anyone being injured on the job—not to punish, but to ensure and promote that learnings were being generated and incorporated to create a safer workplace. Over the course of ten years, Alcoa reduced their injury rate by 95%.

The reduction in injury rates allowed Alcoa to focus on smaller problems and weaker failure signals—instead of notifying O'Neill only when injuries occurred, they started reporting any close calls as well.[†] By doing this, they improved workplace safety over the subsequent twenty years and have one of the most enviable safety records in the industry.

As Dr. Spear writes, "Alcoans gradually stopped working around the difficulties, inconveniences, and impediments they experienced. Coping, fire fighting, and making do were gradually replaced throughout the organization by a

† It is astonishing, instructional, and truly moving to see the level of conviction and passion that Paul O'Neill has about the moral responsibility leaders have to create workplace safety.

dynamic of identifying opportunities for process and product improvement. As those opportunities were identified and the problems were investigated, the pockets of ignorance that they reflected were converted into nuggets of knowledge." This helped give the company a greater competitive advantage in the market.

Similarly, in the technology value stream, as we make our system of work safer, we find and fix problems from ever weaker failure signals. For example, we may initially perform blameless post-mortems only for customer-impacting incidents. Over time, we may perform them for lesser team-impacting incidents and near misses as well.

TRANSFORM LOCAL DISCOVERIES INTO GLOBAL IMPROVEMENTS

When new learnings are discovered locally, there must also be some mechanism to enable the rest of the organization to use and benefit from that knowledge. In other words, when teams or individuals have experiences that create expertise, our goal is to convert that tacit knowledge (i.e., knowledge that is difficult to transfer to another person by means of writing it down or verbalizing) into explicit, codified knowledge, which becomes someone else's expertise through practice.

This ensures that when anyone else does similar work, they do so with the cumulative and collective experience of everyone in the organization who has ever done the same work. A remarkable example of turning local knowledge into global knowledge is the US Navy's Nuclear Power Propulsion Program (also known as "NR" for "Naval Reactors"), which has over 5,700 reactor-years of operation without a single reactor-related casualty or escape of radiation.

The NR is known for their intense commitment to scripted procedures and standardized work, and the need for incident reports for any departure from procedure or normal operations to accumulate learnings, no matter how minor the failure signal—they constantly update procedures and system designs based on these learnings.

The result is that when a new crew sets out to sea on their first deployment, they and their officers benefit from the collective knowledge of 5,700 accident-free reactor-years. Equally impressive is that their own experiences at

sea will be added to this collective knowledge, helping future crews safely achieve their own missions.

In the technology value stream, we must create similar mechanisms to create global knowledge, such as making all our blameless post-mortem reports searchable by teams trying to solve similar problems, and by creating shared source code repositories that span the entire organization, where shared code, libraries, and configurations that embody the best collective knowledge of the entire organization can be easily utilized. All these mechanisms help convert individual expertise into artifacts that the rest of the organization can use.

INJECT RESILIENCE PATTERNS INTO OUR DAILY WORK

Lower performing manufacturing organizations buffer themselves from disruptions in many ways—in other words, they bulk up or add flab. For instance, to reduce the risk of a work center being idle (due to inventory arriving late, inventory that had to be scrapped, etc.), managers may choose to stockpile more inventory at each work center. However, that inventory buffer also increases WIP, which has all sorts of undesired outcomes, as previously discussed.

Similarly, to reduce the risk of a work center going down due to machinery failure, managers may increase capacity by buying more capital equipment, hiring more people, or even increasing floor space. All these options increase costs.

In contrast, high performers achieve the same results (or better) by improving daily operations, continually introducing tension to elevate performance, as well as engineering more resilience into their system.

Consider a typical experiment at one of Aisin Seiki Global's mattress factories, one of Toyota's top suppliers. Suppose they had two production lines, each capable of producing one hundred units per day. On slow days, they would send all production onto one line, experimenting with ways to increase capacity and identify vulnerabilities in their process, knowing that if overloading the line caused it to fail, they could send all production to the second line.

By relentless and constant experimentation in their daily work, they were able to continually increase capacity, often without adding any new equipment

or hiring more people. The emergent pattern that results from these types of improvement rituals not only improves performance but also improves resilience, because the organization is always in a state of tension and change. This process of applying stress to increase resilience was named *antifragility* by author and risk analyst Nassim Nicholas Taleb.

In the technology value stream, we can introduce the same type of tension into our systems by seeking to always reduce deployment lead times, increase test coverage, decrease test execution times, and even by re-architecting if necessary to increase developer productivity or increase reliability.

We may also perform *game day* exercises, where we rehearse large scale failures, such as turning off entire data centers. Or we may inject ever-larger scale faults into the production environment (such as the famous Netflix "Chaos Monkey" which randomly kills processes and compute servers in production) to ensure that we're as resilient as we want to be.

LEADERS REINFORCE A LEARNING CULTURE

Traditionally, leaders were expected to be responsible for setting objectives, allocating resources for achieving those objectives, and establishing the right combination of incentives. Leaders also establish the emotional tone for the organizations they lead. In other words, leaders lead by "making all the right decisions."

However, there is significant evidence that shows greatness is not achieved by leaders making all the right decisions—instead, the leader's role is to create the conditions so their team can discover greatness in their daily work. In other words, creating greatness requires both leaders and workers, each of whom are mutually dependent upon each other.

Jim Womack, author of *Gemba Walks,* described the complementary working relationship and mutual respect that must occur between leaders and frontline workers. According to Womack, this relationship is necessary because neither can solve problems alone—leaders are not close enough to the work, which is required to solve any problem, and frontline workers do not have the broader organizational context or the authority to make changes outside of their area of work.[†]

† Leaders are responsible for the design and operation of processes at a higher level of aggregation where others have less perspective and authority.

Leaders must elevate the value of learning and disciplined problem solving. Mike Rother formalized these methods in what he calls the *coaching kata*. The result is one that mirrors the scientific method, where we explicitly state our True North goals, such as "sustain zero accidents" in the case of Alcoa, or "double throughput within a year" in the case of Aisin.

These strategic goals then inform the creation of iterative, shorter term goals, which are cascaded and then executed by establishing target conditions at the value stream or work center level (e.g., "reduce lead time by 10% within the next two weeks").

These target conditions frame the scientific experiment: we explicitly state the problem we are seeking to solve, our hypothesis of how our proposed countermeasure will solve it, our methods for testing that hypothesis, our interpretation of the results, and our use of learnings to inform the next iteration.

The leader helps coach the person conducting the experiment with questions that may include:

- What was your last step and what happened?
- What did you learn?
- What is your condition now?
- What is your next target condition?
- What obstacle are you working on now?
- What is your next step?
- What is your expected outcome?
- When can we check?

This problem-solving approach in which leaders help workers see and solve problems in their daily work is at the core of the Toyota Production System, of learning organizations, the Improvement Kata, and high-reliability organizations. Mike Rother observes that he sees Toyota "as an organization defined primarily by the unique behavior routines it continually teaches to all its members."

In the technology value stream, this scientific approach and iterative method guides all of our internal improvement processes, but also how we perform experiments to ensure that the products we build actually help our internal and external customers achieve their goals.

CONCLUSION

The principles of the Third Way address the need for valuing organizational learning, enabling high trust and boundary-spanning between functions, accepting that failures will always occur in complex systems, and making it acceptable to talk about problems so we can create a safe system of work. It also requires institutionalizing the improvement of daily work, converting local learnings into global learnings that can be used by the entire organization, as well as continually injecting tension into our daily work.

Although fostering a culture of continual learning and experimentation is the principle of the Third Way, it is also interwoven into the First and Second Ways. In other words, improving flow and feedback requires an iterative and scientific approach that includes framing of a target condition, stating a hypothesis of what will help us get there, designing and conducting experiments, and evaluating the results.

The results are not only better performance but also increased resilience, higher job satisfaction, and improved organization adaptability.

PART I CONCLUSION

In Part I of *The DevOps Handbook* we looked back at several movements in history that helped lead to the development of DevOps. We also looked at the three main principles that form the foundation for successful DevOps organizations: the principles of Flow, Feedback, and Continual Learning and Experimentation. In Part II, we will begin to look at how to start a DevOps movement in your organization.

PART II

Where to Start

Part II
Introduction

How do we decide where to start a DevOps transformation in our organization? Who needs to be involved? How should we organize our teams, protect their work capacity, and maximize their chances of succeess? These are the questions we aim to answer in Part II of *The DevOps Handbook*.

In the following chapters we will walk through the process of initiating a DevOps transformation. We begin by evaluating the value streams in our organization, locating a good place to start, and forming a strategy to create a dedicated transformation team with specific improvement goals and eventual expansion. For each value stream being transformed, we identify the work being performed and then look at organizational design strategies and organizational archetypes that best support the transformation goals.

Primary focuses in these chapters include:

- Selecting which value streams to start with
- Understanding the work being done in our candidate value streams
- Designing our organization and architecture with Conway's Law in mind
- Enabling market-oriented outcomes through more effective collaboration between functions throughout the value stream
- Protecting and enabling our teams

Beginning any transformation is full of uncertainty—we are charting a journey to an ideal end state, but where virtually all the intermediate steps are unknown. These next chapters are intended to provide a thought process to guide our decisions, provide actionable steps we can take, and illustrate case studies as examples.

5 Selecting Which Value Stream to Start With

Choosing a value stream for DevOps transformation deserves careful consideration. Not only does the value stream we choose dictate the difficulty of our transformation, but it also dictates who will be involved in the transformation. It will affect how we need to organize into teams and how we can best enable the teams and individuals in them.

Another challenge was noted by Michael Rembetsy, who helped lead the DevOps transformation as the Director of Operations at Etsy in 2009. He observed, "We must pick our transformation projects carefully—when we're in trouble, we don't get very many shots. Therefore, we must carefully pick and then protect those improvement projects that will most improve the state of our organization."

Let us examine how the Nordstrom team started their DevOps transformation initiative in 2013, which Courtney Kissler, their VP of E-Commerce and Store Technologies, described at the DevOps Enterprise Summit in 2014 and 2015.

Founded in 1901, Nordstrom is a leading fashion retailer that is focused on delivering the best possible shopping experience to their customers. In 2015, Nordstrom had annual revenue of $13.5 billion.

The stage for Nordstrom's DevOps journey was likely set in 2011 during one of their annual board of directors meetings. That year, one of the strategic topics discussed was the need for online revenue growth. They studied the plight of Blockbusters, Borders, and Barnes & Nobles, which demonstrated the dire consequences when traditional retailers were late creating competitive e-commerce capabilities—these organizations were clearly at risk of losing their position in the marketplace or even going out of business entirely.[†]

† These organizations were sometimes known as the "Killer B's that are Dying."

At that time, Courtney Kissler was the senior director of Systems Delivery and Selling Technology, responsible for a significant portion of the technology organization, including their in-store systems and online e-commerce site. As Kissler described, "In 2011, the Nordstrom technology organization was very much optimized for cost—we had outsourced many of our technology functions, we had an annual planning cycle with large batch, 'waterfall' software releases. Even though we had a 97% success rate of hitting our schedule, budget, and scope goals, we were ill-equipped to achieve what the five-year business strategy required from us, as Nordstrom started optimizing for speed instead of merely optimizing for cost."

Kissler and the Nordstrom technology management team had to decide where to start their initial transformation efforts. They didn't want to cause upheaval in the whole system. Instead, they wanted to focus on very specific areas of the business so that they could experiment and learn. Their goal was to demonstrate early wins, which would give everyone confidence that these improvements could be replicated in other areas of the organization. How exactly that would be achieved was still unknown.

They focused on three areas: the customer mobile application, their in-store restaurant systems, and their digital properties. Each of these areas had business goals that weren't being met; thus, they were more receptive to considering a different way of working. The stories of the first two are described below.

The Nordstrom mobile application had experienced an inauspicious start. As Kissler said, "Our customers were extremely frustrated with the product, and we had uniformly negative reviews when we launched it in the App Store. Worse, the existing structure and processes (aka "the system") had designed their processes so that they could only release updates twice per year." In other words, any fixes to the application would have to wait months to reach the customer.

Their first goal was to enable faster or on-demand releases, providing faster iteration and the ability to respond to customer feedback. They created a dedicated product team that was solely dedicated to supporting the mobile application, with the goal of enabling that team to be able to independently implement, test, and deliver value to the customer. By doing this, they would no longer have to depend on and coordinate with scores of other teams inside Nordstrom. Furthermore, they moved from planning once per year to a continuous planning process. The result was a single prioritized backlog of work for the mobile app based on customer need—gone were all the conflicting priorities when the team had to support multiple products.

Over the following year, they eliminated testing as a separate phase of work, instead integrating it into everyone's daily work.[†] They doubled the features being delivered per month and halved the number of defects—creating a successful outcome.

Their second area of focus was the systems supporting their in-store *Café Bistro* restaurants. Unlike the mobile app value stream where the business need was to reduce time to market and increase feature throughput, the business need here was to decrease cost and increase quality. In 2013, Nordstrom had completed eleven "restaurant re-concepts" which required changes to the in-store applications, causing a number of customer-impacting incidents. Disturbingly, they had planned forty-four more of these re-concepts for 2014—four times as many as in the previous year.

As Kissler stated, "One of our business leaders suggested that we triple our team size to handle these new demands, but I proposed that we had to stop throwing more bodies at the problem and instead improve the way we worked."

They were able to identify problematic areas, such as in their work intake and deployment processes, which is where they focused their improvement efforts. They were able to reduce code deployment lead times by 60% and reduce the number of production incidents 60% to 90%.

These successes gave the teams confidence that DevOps principles and practices were applicable to a wide variety of value streams. Kissler was promoted to VP of E-Commerce and Store Technologies in 2014.

In 2015, Kissler said that in order for the selling or customer-facing technology organization to enable the business to meet their goals, "...we needed to increase productivity in all our technology value streams, not just in a few. At the management level, we created an across-the-board mandate to reduce cycle times by 20% for all customer-facing services."

She continued, "This is an audacious challenge. We have many problems in our current state—process and cycle times are not consistently measured across teams, nor are they visible. Our first target condition requires us to help all our teams measure, make it visible, and perform experiments to start reducing their process times, iteration by iteration."

† The practice of relying on a stabilization phase or hardening phase at the end of a project often has very poor outcomes, because it means problems are not being found and fixed as part of daily work and are left unaddressed, potentially snowballing into larger issues.

Kissler concluded, "From a high level perspective, we believe that techniques such as value stream mapping, reducing our batch sizes toward single-piece flow, as well as using continuous delivery and microservices will get us to our desired state. However, while we are still learning, we are confident that we are heading in the right direction, and everyone knows that this effort has support from the highest levels of management."

In this chapter, various models are presented that will enable us to replicate the thought processes that the Nordstrom team used to decide which value streams to start with. We will evaluate our candidate value streams in many ways, including whether they are a *greenfield* or *brownfield* service, a *system of engagement* or a *system of record*. We will also estimate the risk/reward balance of transforming and assess the likely level of resistance we may get from the teams we would work with.

GREENFIELD VS. BROWNFIELD SERVICES

We often categorize our software services or products as either greenfield or brownfield. These terms were originally used for urban planning and building projects. Greenfield development is when we build on undeveloped land. Brownfield development is when we build on land that was previously used for industrial purposes, potentially contaminated with hazardous waste or pollution. In urban development, many factors can make greenfield projects simpler than brownfield projects—there are no existing structures that need to be demolished nor are there toxic materials that need to be removed.

In technology, a greenfield project is a new software project or initiative, likely in the early stages of planning or implementation, where we build our applications and infrastructure anew, with few constraints. Starting with a greenfield software project can be easier, especially if the project is already funded and a team is either being created or is already in place. Furthermore, because we are starting from scratch, we can worry less about existing code bases, processes, and teams.

Greenfield DevOps projects are often pilots to demonstrate feasibility of public or private clouds, piloting deployment automation, and similar tools. An example of a greenfield DevOps project is the Hosted LabVIEW product in 2009 at National Instruments, a thirty-year-old organization with five thousand employees and $1 billion in annual revenue. To bring this product to market quickly, a new team was created and allowed to operate outside of the existing IT processes and explore the use of public clouds. The initial team included

an applications architect, a systems architect, two developers, a system automation developer, an operations lead, and two offshore operations staff. By using DevOps practices, they were able to deliver Hosted LabVIEW to market in half the time of their normal product introductions.

On the other end of the spectrum are brownfield DevOps projects, these are existing products or services that are already serving customers and have potentially been in operation for years or even decades. Brownfield projects often come with significant amounts of technical debt, such as having no test automation or running on unsupported platforms. In the Nordstrom example presented earlier in this chapter, both the in-store restaurant systems and e-commerce systems were brownfield projects.

Although many believe that DevOps is primarily for greenfield projects, DevOps has been used to successfully transform brownfield projects of all sorts. In fact, over 60% of the transformation stories shared at the DevOps Enterprise Summit in 2014 were for brownfield projects. In these cases, there was a large performance gap between what the customer needed and what the organization was currently delivering, and the DevOps transformations created tremendous business benefit.

Indeed, one of the findings in the 2015 *State of DevOps Report* validated that the age of the application was not a significant predictor of performance; instead, what predicted performance was whether the application was architected (or could be re-architected) for testability and deployability.

Teams supporting brownfield projects may be very receptive to experimenting with DevOps, particularly when there is a widespread belief that traditional methods are insufficient to achieve their goals—and especially if there is a strong sense of urgency around the need for improvement.[†]

When transforming brownfield projects, we may face significant impediments and problems, especially when no automated testing exists or when there is a tightly-coupled architecture that prevents small teams from developing, testing, and deploying code independently. How we overcome these issues are discussed throughout this book.

Examples of successful brownfield transformations include:

† That the services that have the largest potential business benefit are brownfield systems shouldn't be surprising. After all, these are the systems that are most relied upon and have the largest number of existing customers or highest amount of revenue depending upon them.

- **CSG (2013):** In 2013, CSG International had $747 million in revenue and over 3,500 employees, enabling over ninety thousand customer service agents to provide billing operations and customer care to over fifty million video, voice, and data customers, executing over six billion transactions, and printing and mailing over seventy million paper bill statements every month. Their initial scope of improvement was bill printing, one of their primary businesses, and involved a COBOL mainframe application and the twenty surrounding technology platforms. As part of their transformation, they started performing daily deployments into a production-like environment, and doubled the frequency of customer releases from twice annually to four times annually. As a result, they significantly increased the reliability of the application and reduced code deployment lead times from two weeks to less than one day.

- **Etsy (2009):** In 2009, Etsy had thirty-five employees and was generating $87 million in revenue, but after they "barely survived the holiday retail season," they started transforming virtually every aspect of how the organization worked, eventually turning the company into one of the most admired DevOps organizations and set the stage for a successful 2015 IPO.

CONSIDER BOTH SYSTEMS OF RECORD AND SYSTEMS OF ENGAGEMENT

The Gartner research firm has recently popularized the notion of *bimodal IT*, referring to the wide spectrum of services that typical enterprises support. Within bimodal IT there are *systems of record*, the ERP-like systems that run our business (e.g., MRP, HR, financial reporting systems), where the correctness of the transactions and data are paramount; and *systems of engagement*, which are customer-facing or employee-facing systems, such as e-commerce systems and productivity applications.

Systems of record typically have a slower pace of change and often have regulatory and compliance requirements (e.g., SOX). Gartner calls these types of systems "Type 1," where the organization focuses on "doing it right."

Systems of engagement typically have a much higher pace of change to support rapid feedback loops that enable them to conduct experimentation to discover

how to best meet customer needs. Gartner calls these types of systems "Type 2," where the organization focuses on "doing it fast."

It may be convenient to divide up our systems into these categories; however, we know that the core, chronic conflict between "doing it right" and "doing it fast" can be broken with DevOps. The data from Puppet Labs' State of DevOps Reports—following the lessons of Lean manufacturing—shows that high performing organizations are able to simultaneously deliver higher levels of throughput and reliability.

Furthermore, because of how interdependent our systems are, our ability to make changes to any of these systems is limited by the system that is most difficult to safely change, which is almost always a system of record.

Scott Prugh, VP of Product Development at CSG, observed, "We've adopted a philosophy that rejects bi-modal IT, because every one of our customers deserve speed and quality. This means that we need technical excellence, whether the team is supporting a 30 year old mainframe application, a Java application, or a mobile application."

Consequently, when we improve brownfield systems, we should not only strive to reduce their complexity and improve their reliability and stability, we should also make them faster, safer, and easier to change. Even when new functionality is added just to greenfield systems of engagement, they often cause reliability problems in the brownfield systems of record they rely on. By making these downstream systems safer to change, we help the entire organization more quickly and safely achieve its goals.

START WITH THE MOST SYMPATHETIC AND INNOVATIVE GROUPS

Within every organization, there will be teams and individuals with a wide range of attitudes toward the adoption of new ideas. Geoffrey A. Moore first depicted this spectrum in the form of the technology adoption life cycle in *Crossing The Chasm*, where the chasm represents the classic difficulty of reaching groups beyond the *innovators* and *early adopters* (see figure 9).

In other words, new ideas are often quickly embraced by innovators and early adopters, while others with more conservative attitudes resist them (the *early*

majority, *late majority*, and *laggards*). Our goal is to find those teams that already believe in the need for DevOps principles and practices, and who possess a desire and demonstrated ability to innovate and improve their own processes. Ideally, these groups will be enthusiastic supporters of the DevOps journey.

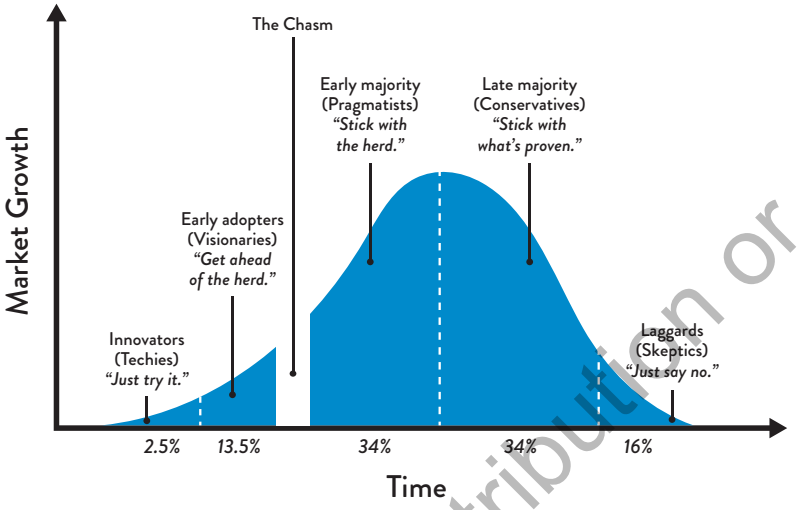


Figure 9: *The Technology Adoption Curve (Source: Moore and McKenna,* Crossing The Chasm, *15.)*

Especially in the early stages, we will not spend much time trying to convert the more conservative groups. Instead, we will focus our energy on creating successes with less risk-averse groups and build out our base from there (a process that is discussed further in the next section). Even if we have the highest levels of executive sponsorship, we will avoid the *big bang approach* (i.e., starting everywhere all at once), choosing instead to focus our efforts in a few areas of the organization, ensuring that those initiatives are successful, and expanding from there.[†]

EXPANDING DEVOPS ACROSS OUR ORGANIZATION

Regardless of how we scope our initial effort, we must demonstrate early wins and broadcast our successes. We do this by breaking up our larger improvement

† Big bang, top-down transformations are possible, such as the Agile transformation at PayPal in 2012 that was led by their vice president of technology, Kirsten Wolberg. However, as with any sustainable and successful transformation, this required the highest level of management support and a relentless, sustained focus on driving the necessary outcomes.

goals into small, incremental steps. This not only creates our improvements faster, it also enables us to discover when we have made the wrong choice of value stream—by detecting our errors early, we can quickly back up and try again, making different decisions armed with our new learnings.

As we generate successes, we earn the right to expand the scope of our DevOps initiative. We want to follow a safe sequence that methodically grows our levels of credibility, influence, and support. The following list, adapted from a course taught by Dr. Roberto Fernandez, a William F. Pounds Professor in Management at MIT, describes the ideal phases used by change agents to build and expand their coalition and base of support:

1. **Find Innovators and Early Adopters:** In the beginning, we focus our efforts on teams who actually want to help—these are our kindred spirits and fellow travelers who are the first to volunteer to start the DevOps journey. In the ideal, these are also people who are respected and have a high degree of influence over the rest of the organization, giving our initiative more credibility.

2. **Build Critical Mass and Silent Majority:** In the next phase, we seek to expand DevOps practices to more teams and value streams with the goal of creating a stable base of support. By working with teams who are receptive to our ideas, even if they are not the most visible or influential groups, we expand our coalition who are generating more successes, creating a "bandwagon effect" that further increases our influence. We specifically bypass dangerous political battles that could jeopardize our initiative.

3. **Identify the Holdouts:** The "holdouts" are the high profile, influential detractors who are most likely to resist (and maybe even sabotage) our efforts. In general, we tackle this group only after we have achieved a silent majority, when we have established enough successes to successfully protect our initiative.

Expanding DevOps across an organization is no small task. It can create risk to individuals, departments, and the organization as a whole. But as Ron van Kemenade, CIO of ING, who helped transform the organization into one of the most admired technology organizations, said, "Leading change requires courage, especially in corporate environments where people are scared and fight you. But if you start small, you really have nothing to fear. Any leader needs to be brave enough to allocate teams to do some calculated risk-taking."

CONCLUSION

Peter Drucker, a leader in the development of management education, observed that "little fish learn to be big fish in little ponds." By choosing carefully where and how to start, we are able to experiment and learn in areas of our organization that create value without jeopardizing the rest of the organization. By doing this, we build our base of support, earn the right to expand the use of DevOps in our organization, and gain the recognition and gratitude of an ever-larger constituency.

6 Understanding the Work in Our Value Stream, Making it Visible, and Expanding it Across the Organization

Once we have identified a value stream to which we want to apply DevOps principles and patterns, our next step is to gain a sufficient understanding of how value is delivered to the customer: what work is performed and by whom, and what steps can we take to improve flow.

In the previous chapter, we learned about the DevOps transformation led by Courtney Kissler and the team at Nordstrom. Over the years, they have learned that one of the most efficient ways to start improving any value stream is to conduct a workshop with all the major stakeholders and perform a value stream mapping exercise—a process (described later in this chapter) designed to help capture all the steps required to create value.

Kissler's favorite example of the valuable and unexpected insights that can come from value stream mapping is when they tried to improve the long lead times associated with requests going through the Cosmetics Business Office application, a COBOL mainframe application that supported all the floor and department managers of their in-store beauty and cosmetic departments.

This application allowed department managers to register new salespeople for various product lines carried in their stores, so that they could track sales commissions, enable vendor rebates, and so forth.

Kissler explained:

> I knew this particular mainframe application well—earlier in my career, I supported this technology team, so I know firsthand that for nearly a decade, during each annual planning cycle, we would debate about how we needed to get this application off the mainframe. Of

course, like in most organizations, even when there was full management support, we never seemed to get around to migrating it.

My team wanted to conduct a value stream mapping exercise to determine whether the COBOL application really was the problem, or maybe there was a larger problem that we needed to address. They conducted a workshop that assembled everyone with any accountability for delivering value to our internal customers, including our business partners, the mainframe team, the shared service teams, and so forth.

What they discovered was that when department managers were submitting the 'product line assignment' request form, we were asking them for an employee number, which they didn't have—so they would either leave it blank or put in something like 'I don't know.' Worse, in order to fill out the form, department managers would have to inconveniently leave the store floor in order to use a PC in the back office. The end result was all this wasted time, with work bouncing back and forth in the process.

During the workshop, the participants conducted several experiments, including deleting the employee number field in the form and letting another department get that information in a downstream step. These experiments, conducted with the help of department managers, showed a four-day reduction in processing time. The team later replaced the PC application with an iPad application, which allowed managers to submit the necessary information without leaving the store floor, and the processing time was further reduced to seconds.

She said proudly, "With those amazing improvements, all the demands to get this application off the mainframe disappeared. Furthermore, other business leaders took notice and started coming to us with a whole list of further experiments they wanted to conduct with us in their own organizations. Everyone in the business and technology teams were excited by the outcome because they solved a real business problem, and, most importantly, they learned something in the process."

In the remainder of this chapter, we will go through the following steps: identifying all the teams required to create customer value, creating a value stream map to make visible all the required work, and using it to guide the teams in how to better and more quickly create value. By doing this, we can replicate the amazing outcomes described in this Nordstrom example.

IDENTIFYING THE TEAMS SUPPORTING OUR VALUE STREAM

As this Nordstrom example demonstrates, in value streams of any complexity, no one person knows all the work that must be performed in order to create value for the customer—especially since the required work must be performed by many different teams, often far removed from each other on the organization charts, geographically, or by incentives.

As a result, after we select a candidate application or service for our DevOps initiative, we must identify all the members of the value stream who are responsible for working together to create value for the customers being served. In general, this includes:

- **Product owner:** the internal voice of the business that defines the next set of functionality in the service
- **Development:** the team responsible for developing application functionality in the service
- **QA:** the team responsible for ensuring that feedback loops exist to ensure the service functions as desired
- **Operations:** the team often responsible for maintaining the production environment and helping ensure that required service levels are met
- **Infosec:** the team responsible for securing systems and data
- **Release managers:** the people responsible for managing and coordinating the production deployment and release processes
- **Technology executives or value stream manager:** in Lean literature, someone who is responsible for "ensuring that the value stream meets or exceeds the customer [and organizational] requirements for the overall value stream, from start to finish"

CREATE A VALUE STREAM MAP TO SEE THE WORK

After we identify our value stream members, our next step is to gain a concrete understanding of how work is performed, documented in the form

of a value stream map. In our value stream, work likely begins with the product owner, in the form of a customer request or the formulation of a business hypothesis. Some time later, this work is accepted by Development, where features are implemented in code and checked in to our version control repository. Builds are then integrated, tested in a production-like environment, and finally deployed into production, where they (ideally) create value for our customer.

In many traditional organizations, this value stream will consist of hundreds, if not thousands, of steps, requiring work from hundreds of people. Because documenting any value stream map this complex likely requires multiple days, we may conduct a multi-day workshop, where we assemble all the key constituents and remove them from the distractions of their daily work.

Our goal is not to document every step and associated minutiae, but to sufficiently understand the areas in our value stream that are jeopardizing our goals of fast flow, short lead times, and reliable customer outcomes. Ideally, we have assembled those people with the authority to change their portion of the value stream.[†]

Damon Edwards, co-host of *DevOps Café* podcast, observed, "In my experience, these types of value stream mapping exercises are always an eye-opener. Often, it is the first time when people see how much work and heroics are required to deliver value to the customer. For Operations, it may be the first time that they see the consequences that result when developers don't have access to correctly configured environments, which contributes to even more crazy work during code deployments. For Development, it may be the first time they see all the heroics that are required by Test and Operations in order to deploy their code into production, long after they flag a feature as 'completed.'"

Using the full breadth of knowledge brought by the teams engaged in the value stream, we should focus our investigation and scrutiny on the following areas:

- Places where work must wait weeks or even months, such as getting production-like environments, change approval processes, or security review processes
- Places where significant rework is generated or received

† Which makes it all the more important that we limit the level of detail being collected—everyone's time is valuable and scarce.

Our first pass of documenting our value stream should only consist of high-level process blocks. Typically, even for complex value streams, groups can create a diagram with five to fifteen process blocks within a few hours. Each process block should include the lead time and process time for a work item to be processed, as well as the %C/A as measured by the downstream consumers of the output.‡

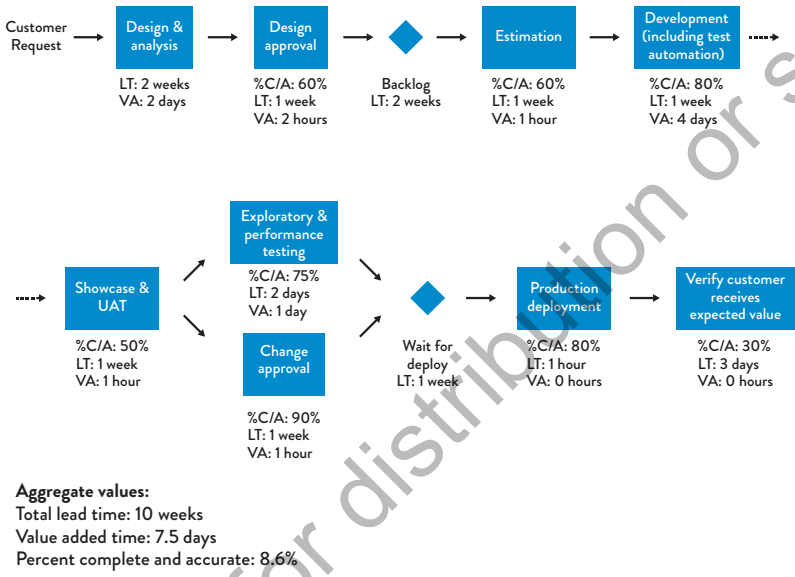


Figure 10: *An example of a value stream map (Source: Humble, Molesky, and O'Reilly,* Lean Enterprise, *139.)*

We use the metrics from our value stream map to guide our improvement efforts. In the Nordstrom example, they focused on the low %C/A rates on the request form submitted by department managers due to the absence of employee numbers. In other cases, it may be long lead times or low %C/A rates when delivering correctly configured test environments to Development teams, or it might be the long lead times required to execute and pass regression testing before each software release.

Once we identify the metric we want to improve, we should perform the next level of observations and measurements to better understand the problem

‡ Conversely, there are many examples of using tools in a way that guarantees no behavior changes occur. For instance, an organization commits to an agile planning tool but then configures it for a waterfall process, which merely maintains status quo.

and then construct an idealized, future value stream map, which serves as a target condition to achieve by some date (e.g., usually three to twelve months).

Leadership helps define this future state and then guides and enables the team to brainstorm hypotheses and countermeasures to achieve the desired improvement to that state, perform experiments to test those hypotheses, and interpret the results to determine whether the hypotheses were correct. The teams keep repeating and iterating, using any new learnings to inform the next experiments.

CREATING A DEDICATED TRANSFORMATION TEAM

One of the inherent challenges with initiatives such as DevOps transformations is that they are inevitably in conflict with ongoing business operations. Part of this is a natural outcome of how successful businesses evolve. An organization that has been successful for any extended period of time (years, decades, or even centuries) has created mechanisms to perpetuate the practices that made them successful, such as product development, order administration, and supply chain operations.

Many techniques are used to perpetuate and protect how current processes operate, such as specialization, focus on efficiency and repeatability, bureaucracies that enforce approval processes, and controls to protect against variance. In particular, bureaucracies are incredibly resilient and are designed to survive adverse conditions—one can remove half the bureaucrats, and the process will still survive.

While this is good for preserving status quo, we often need to change how we work to adapt to changing conditions in the marketplace. Doing this requires disruption and innovation, which puts us at odds with groups who are currently responsible for daily operations and the internal bureaucracies, and who will almost always win.

In their book *The Other Side of Innovation: Solving the Execution Challenge,* Dr. Vijay Govindarajan and Dr. Chris Trimble, both faculty members of Dartmouth College's Tuck School of Business, described their studies of how disruptive innovation is achieved despite these powerful forces of daily operations. They documented how customer-driven auto insurance products were successfully developed and marketed at Allstate, how the profitable digital publishing business was created at the *Wall Street Journal*, the development of the break-

through trail-running shoe at Timberland, and the development of the first electric car at BMW.

Based on their research, Dr. Govindarajan and Dr. Trimble assert that organizations need to create a dedicated transformation team that is able to operate outside of the rest of the organization that is responsible for daily operations (which they call the "dedicated team" and "performance engine" respectively).

First and foremost, we will hold this dedicated team accountable for achieving a clearly defined, measurable, system-level result (e.g., reduce the deployment lead time from "code committed into version control to successfully running in production" by 50%). In order to execute such an initiative, we do the following:

- Assign members of the dedicated team to be solely allocated to the DevOps transformation efforts (as opposed to "maintain all your current responsibilities, but spend 20% of your time on this new DevOps thing.").
- Select team members who are generalists, who have skills across a wide variety of domains.
- Select team members who have longstanding and mutually respectful relationships with the rest of the organization.
- Create a separate physical space for the dedicated team, if possible, to maximize communication flow within the team, and creating some isolation from the rest of the organization.

If possible, we will free the transformation team from many of the rules and policies that restrict the rest of the organization, as National Instruments did, described in the previous chapter. After all, established processes are a form of institutional memory—we need the dedicated team to create the new processes and learnings required to generate our desired outcomes, creating new institutional memory.

Creating a dedicated team is not only good for the team, but also good for the performance engine. By creating a separate team, we create the space for them to experiment with new practices, protecting the rest of the organization from the potential disruptions and distractions associated with it.

AGREE ON A SHARED GOAL

One of the most important parts of any improvement initiative is to define a measurable goal with a clearly defined deadline, between six months and two years in the future. It should require considerable effort but still be achievable. And achievement of the goal should create obvious value for the organization as a whole and to our customers.

These goals and the time frame should be agreed upon by the executives and known to everyone in the organization. We also want to limit the number of these types of initiatives going on simultaneously to prevent us from overly taxing the organizational change management capacity of leaders and the organization. Examples of improvement goals might include:

- Reduce the percentage of the budget spent on product support and unplanned work by 50%.
- Ensure lead time from code check-in to production release is one week or less for 95% of changes.
- Ensure releases can always be performed during normal business hours with zero downtime.
- Integrate all the required information security controls into the deployment pipeline to pass all required compliance requirements.

Once the high-level goal is made clear, teams should decide on a regular cadence to drive the improvement work. Like product development work, we want transformation work to be done in an iterative, incremental manner. A typical iteration will be in the range of two to four weeks. For each iteration, the teams should agree on a small set of goals that generate value and makes some progress toward the long-term goal. At the end of each iteration, teams should review their progress and set new goals for the next iteration.

KEEP OUR IMPROVEMENT PLANNING HORIZONS SHORT

In any DevOps transformation project, we need to keep our planning horizons short, just as if we were in a startup doing product or customer development. Our initiative should strive to generate measurable improvements or actionable data within weeks (or, in the worst case, months).

By keeping our planning horizons and iteration intervals short, we achieve the following:

- Flexibility and the ability to reprioritize and replan quickly
- Decrease the delay between work expended and improvement realized, which strengthens our feedback loop, making it more likely to reinforce desired behaviors—when improvement initiatives are successful, it encourages more investment
- Faster learning generated from the first iteration, meaning faster integration of our learnings into the next iteration
- Reduction in activation energy to get improvements
- Quicker realization of improvements that make meaningful differences in our daily work
- Less risk that our project is killed before we can generate any demonstrable outcomes

RESERVE 20% OF CYCLES FOR NON-FUNCTIONAL REQUIREMENTS AND REDUCING TECHNICAL DEBT

A problem common to any process improvement effort is how to properly prioritize it—after all, organizations that need it most are those that have the least amount of time to spend on improvement. This is especially true in technology organizations because of technical debt.

Organizations that struggle with financial debt only make interest payments and never reduce the loan principal, and may eventually find themselves in situations where they can no longer service the interest payments. Similarly, organizations that don't pay down technical debt can find themselves so burdened with daily workarounds for problems left unfixed that they can no longer complete any new work. In other words, they are now only making the interest payment on their technical debt.

We will actively manage this technical debt by ensuring that we invest at least 20% of all Development and Operations cycles on refactoring, investing in automation work and architecture and non-functional requirements (NFRs,

sometimes referred to as the "ilities"), such as maintainability, manageability, scalability, reliability, testability, deployability, and security.

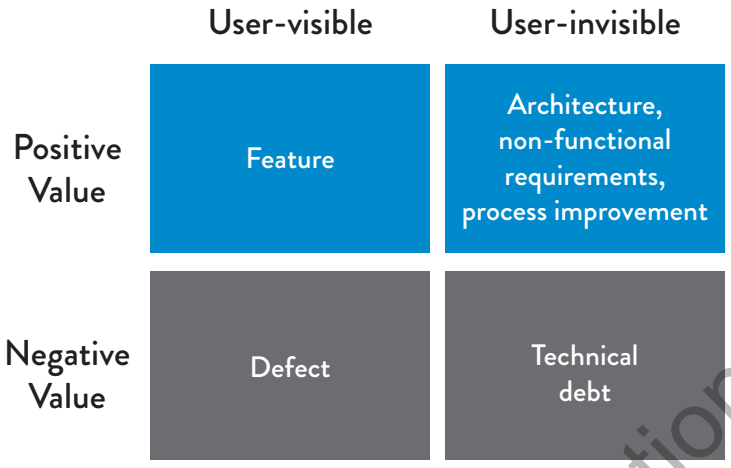


Figure 11: *Invest 20% of cycles on those that create positive, user-invisible value (Source: "Machine Learning and Technical Debt with D. Sculley," Software Engineering Daily podcast, November 17, 2015, http://softwareengineeringdaily.com/2015/11/17/machine-learning-and-technical-debt-with-d-sculley/.)*

After the near-death experience of eBay in the late 1990s, Marty Cagan, author of *Inspired: How To Create Products Customers Love*, the seminal book on product design and management, codified the following lesson:

> The deal [between product owners and] engineering goes like this: Product management takes 20% of the team's capacity right off the top and gives this to engineering to spend as they see fit. They might use it to rewrite, re-architect, or re-factor problematic parts of the code base…whatever they believe is necessary to avoid ever having to come to the team and say, 'we need to stop and rewrite [all our code].' If you're in really bad shape today, you might need to make this 30% or even more of the resources. However, I get nervous when I find teams that think they can get away with much less than 20%.

Cagan notes that when organizations do not pay their "20% tax," technical debt will increase to the point where an organization inevitably spends all of its cycles paying down technical debt. At some point, the services become so fragile that feature delivery grinds to a halt because all the engineers are working on reliability issues or working around problems.

By dedicating 20% of our cycles so that Dev and Ops can create lasting countermeasures to the problems we encounter in our daily work, we ensure that

technical debt doesn't impede our ability to quickly and safely develop and operate our services in production. Elevating added pressure of technical debt from workers can also reduce levels of burnout.

Case Study
Operation InVersion at LinkedIn (2011)

LinkedIn's Operation InVersion presents an interesting case study that illustrates the need to pay down technical debt as a part of daily work. Six months after their successful IPO in 2011, LinkedIn continued to struggle with problematic deployments that became so painful that they launched Operation InVersion, where they stopped all feature development for two months in order to overhaul their computing environments, deployments, and architecture.

LinkedIn was created in 2003 to help users "connect to your network for better job opportunities." By the end of their first week of operation, they had 2,700 members. One year later, they had over one million members, and have grown exponentially since then. By November 2015, LinkedIn had over 350 million members, who generate tens of thousands of requests per second, resulting in millions of queries per second on the LinkedIn backend systems.

From the beginning, LinkedIn primarily ran on their homegrown Leo application, a monolithic Java application that served every page through servlets and managed JDBC connections to various backend Oracle databases. However, to keep up with growing traffic in their early years, two critical services were decoupled from Leo: the first handled queries around the member connection graph entirely in-memory, and the second was member search, which layered over the first.

By 2010, most new development was occurring in new services, with nearly one hundred services running outside of Leo. The problem was that Leo was only being deployed once every two weeks.

Josh Clemm, a senior engineering manager at LinkedIn, explained that by 2010, the company was having significant problems with Leo. Despite vertically scaling Leo by adding memory and CPUs, "Leo was often going down in production, it was difficult to troubleshoot and recover, and difficult to release new code....It was clear we needed to 'Kill Leo' and break it up into many small functional and stateless services."

In 2013, journalist Ashlee Vance of Bloomberg described how "when LinkedIn would try to add a bunch of new things at once, the site would crumble into a broken mess, requiring engineers to work long into the night and fix the problems." By Fall 2011, late nights were no longer a rite of passage or a bonding activity, because the problems had become intolerable. Some of LinkedIn's top engineers, including Kevin Scott, who had joined as the LinkedIn VP of Engineering three months before their initial public offering, decided to completely stop engineering work on new features and dedicate the whole department to fixing the site's core infrastructure. They called the effort Operation InVersion.

Scott launched Operation InVersion as a way to "inject the beginnings of a cultural manifesto into his team's engineering culture. There would be no new feature development until LinkedIn's computing architecture was revamped—it's what the business *and* his team needed."

Scott described one downside, "You go public, have all the world looking at you, and then we tell management that we're not going to deliver anything new while all of engineering works on this [InVersion] project for the next two months. It was a scary thing."

However, Vance described the massively positive results of Operation InVersion. "LinkedIn created a whole suite of software and tools to help it develop code for the site. Instead of waiting weeks for their new features to make their way onto LinkedIn's main site, engineers could develop a new service, have a series of automated systems examine the code for any bugs and issues the service might have interacting with existing features, and launch it right to the live LinkedIn site...LinkedIn's engineering corps [now] performs major upgrades to the site three times a day." By creating a safer system of work, the value they created included fewer late night cram sessions, with more time to develop new, innovative features.

As Josh Clemm described in his article on scaling at LinkedIn, "Scaling can be measured across many dimensions, including organizational.... [Operation InVersion] allowed the entire engineering organization to focus on improving tooling and deployment, infrastructure, and developer productivity. It was successful in enabling the engineering agility we need to build the scalable new products we have today....[In] 2010, we already had over 150 separate services. Today, we have over 750 services."

Kevin Scott stated, "Your job as an engineer and your purpose as a technology team is to help your company win. If you lead a team of engineers, it's better

to take a CEO's perspective. Your job is to figure out what it is that your company, your business, your marketplace, your competitive environment needs. Apply that to your engineering team in order for your company to win."

By allowing LinkedIn to pay down nearly a decade of technical debt, Project InVersion enabled stability and safety, while setting the next stage of growth for the company. However, it required two months of total focus on non-functional requirements, at the expense of all the promised features made to the public markets during an IPO. By finding and fixing problems as part of our daily work, we manage our technical debt so that we avoid these "near death" experiences.

INCREASE THE VISIBILITY OF WORK

In order to be able to know if we are making progress toward our goal, it's essential that everyone in the organization knows the current state of work. There are many ways to make the current state visible, but what's most important is that the information we display is up to date, and that we constantly revise what we measure to make sure it's helping us understand progress toward our current target conditions.

The following section discusses patterns that can help create visibility and alignment across teams and functions.

USE TOOLS TO REINFORCE DESIRED BEHAVIOR

As Christopher Little, a software executive and one of the earliest chroniclers of DevOps, observed, "Anthropologists describe tools as a cultural artifact. Any discussion of culture after the invention of fire must also be about tools." Similarly, in the DevOps value stream, we use tools to reinforce our culture and accelerate desired behavior changes.

One goal is that our tooling reinforces that Development and Operations not only have shared goals, but have a common backlog of work, ideally stored in a common work system and using a shared vocabulary, so that work can be prioritized globally.

By doing this, Development and Operations may end up creating a shared work queue, instead of each silo using a different one (e.g., Development uses JIRA while Operations uses ServiceNow). A significant benefit of this is that when production incidents are shown in the same work systems as develop-

ment work, it will be obvious when ongoing incidents should halt other work, especially when we have a kanban board.

Another benefit of having Development and Operations using a shared tool is a unified backlog, where everyone prioritizes improvement projects from a global perspective, selecting work that has the highest value to the organization or most reduces technical debt. As we identify technical debt, we add it to our prioritized backlog if we can't address it immediately. For issues that remain unaddressed, we can use our "20% time for non-functional requirements" to fix the top items from our backlog.

Other technologies that reinforce shared goals are chat rooms, such as IRC channels, HipChat, Campfire, Slack, Flowdock, and OpenFire. Chat rooms allow the fast sharing of information (as opposed to filling out forms that are processed through predefined workflows), the ability to invite other people as needed, and history logs that are automatically recorded for posterity and can be analyzed during post-mortem sessions.

An amazing dynamic is created when we have a mechanism that allows any team member to quickly help other team members, or even people outside their team—the time required to get information or needed work can go from days to minutes. In addition, because everything is being recorded, we may not need to ask someone else for help in the future—we simply search for it.

However, the rapid communication environment facilitated by chat rooms can also be a drawback. As Ryan Martens, the founder and CTO of Rally Software, observes, "In a chat room, if someone doesn't get an answer in a couple of minutes, it's totally accepted and expected that you can bug them again until they get what they need."

The expectations of immediate response can, of course, lead to undesired outcomes. A constant barrage of interruptions and questions can prevent people from getting necessary work done. As a result, teams may decide that certain types of requests should go through more structured and asynchronous tools.

CONCLUSION

In this chapter, we identified all the teams supporting our value stream and captured in a value stream map what work is required in order to deliver value to the customer. The value stream map provides the basis for understanding

our current state, including our lead time and %C/A metrics for problematic areas, and informs how we set a future state.

This enables dedicated transformation teams to rapidly iterate and experiment to improve performance. We also make sure that we allocate a sufficient amount of time for improvement, fixing known problems and architectural issues, including our non-functional requirements. The case studies from Nordstrom and LinkedIn demonstrate how dramatic improvements can be made in lead times and quality when we find problems in our value stream and pay down technical debt.

7 How to Design Our Organization and Architecture with Conway's Law in Mind

In the previous chapters, we identified a value stream to start our DevOps transformation and established shared goals and practices to enable a dedicated transformation team to improve how we deliver value to the customer.

In this chapter, we will start thinking about how to organize ourselves to best achieve our value stream goals. After all, how we organize our teams affects how we perform our work. Dr. Melvin Conway performed a famous experiment in 1968 with a contract research organization that had eight people who were commissioned to produce a COBOL and an ALGOL compiler. He observed, "After some initial estimates of difficulty and time, five people were assigned to the COBOL job and three to the ALGOL job. The resulting COBOL compiler ran in five phases, the ALGOL compiler ran in three."

These observations led to what is now known as Conway's Law, which states that "organizations which design systems…are constrained to produce designs which are copies of the communication structures of these organizations…. The larger an organization is, the less flexibility it has and the more pronounced the phenomenon." Eric S. Raymond, author of the book *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*, crafted a simplified (and now, more famous) version of Conway's Law in his Jargon File: "The organization of the software and the organization of the software team will be congruent; commonly stated as 'if you have four groups working on a compiler, you'll get a 4-pass compiler.'"

In other words, how we organize our teams has a powerful effect on the software we produce, as well as our resulting architectural and production outcomes. In order to get fast flow of work from Development into Operations, with high quality and great customer outcomes, we must organize our teams

and our work so that Conway's Law works to our advantage. Done poorly, Conway's Law will prevent teams from working safely and independently; instead, they will be tightly coupled together, all waiting on each other for work to be done, with even small changes creating potentially global, catastrophic consequences.

An example of how Conway's Law can either impede or reinforce our goals can be seen in a technology that was developed at Etsy called Sprouter. Etsy's DevOps journey began in 2009, and is one of the most admired DevOps organizations, with 2014 revenue of nearly $200 million and a successful IPO in 2015.

Originally developed in 2007, Sprouter connected people, processes, and technology in ways that created many undesired outcomes. Sprouter, shorthand for "stored procedure router," was originally designed to help make life easier for the developers and database teams. As Ross Snyder, a senior engineer at Etsy, said during his presentation at Surge 2011, "Sprouter was designed to allow the Dev teams to write PHP code in the application, the DBAs to write SQL inside Postgres, with Sprouter helping them meet in the middle."

Sprouter resided between their front-end PHP application and the Postgres database, centralizing access to the database and hiding the database implementation from the application layer. The problem was that adding any changes to business logic resulted in significant friction between developers and the database teams. As Snyder observed, "For nearly any new site functionality, Sprouter required that the DBAs write a new stored procedure. As a result, every time developers wanted to add new functionality, they would need something from the DBAs, which often required them to wade through a ton of bureaucracy." In other words, developers creating new functionality had a dependency on the DBA team, which needed to be prioritized, communicated, and coordinated, resulting in work sitting in queues, meetings, longer lead times, and so forth. This is because Sprouter created a tight coupling between the development and database teams, preventing developers from being able to independently develop, test, and deploy their code into production.

Also, the database stored procedures were tightly coupled to Sprouter—any time a stored procedure was changed, it required changes to Sprouter too. The result was that Sprouter became an ever-larger single point of failure. Snyder explained that everything was so tightly coupled and required such a high level of synchronization as a result, that almost every deployment caused a mini-outage.

Both the problems associated with Sprouter and their eventual solution can be explained by Conway's Law. Etsy initially had two teams, the developers and the DBAs, who were each responsible for two layers of the service, the application logic layer and stored procedure layer. Two teams working on two layers, as Conway's Law predicts. Sprouter was intended to make life easier for both teams, but it didn't work as expected—when business rules changed, instead of changing only two layers, they now needed to make changes to three layers (in the application, in the stored procedures, and now in Sprouter). The resulting challenges of coordinating and prioritizing work across three teams significantly increased lead times and caused reliability problems.

In the spring of 2009, as part of what Snyder called "the great Etsy cultural transformation," Chad Dickerson joined as their new CTO. Dickerson put into motion many things, including a massive investment into site stability, having developers perform their own deployments into production, as well as beginning a two-year journey to eliminate Sprouter.

To do this, the team decided to move all the business logic from the database layer into the application layer, removing the need for Sprouter. They created a small team that wrote a PHP Object Relational Mapping (ORM) layer,[†] enabling the front-end developers to make calls directly to the database and reducing the number of teams required to change business logic from three teams down to one team.

As Snyder described, "We started using the ORM for any new areas of the site and migrated small parts of our site from Sprouter to the ORM over time. It took us two years to migrate the entire site off of Sprouter. And even though we all grumbled about Sprouter the entire time, it remained in production throughout."

By eliminating Sprouter, they also eliminated the problems associated with multiple teams needing to coordinate for business logic changes, decreased the number of handoffs, and significantly increased the speed and success of production deployments, improving site stability. Furthermore, because small teams could independently develop and deploy their code without requiring another team to make changes in other areas of the system, developer productivity increased.

† Among many things, an ORM abstracts a database, enabling developers to do queries and data manipulation as if they were merely another object in the programming language. Popular ORMs include Hibernate for Java, SQLAlchemy for Python, and ActiveRecord for Ruby on Rails.

Sprouter was finally removed from production and Etsy's version control repositories in early 2001. As Snyder said, "Wow, it felt good."[†]

As Snyder and Etsy experienced, how we design our organization dictates how work is performed, and, therefore, the outcomes we achieve. Throughout the rest of this chapter we will explore how Conway's Law can negatively impact the performance of our value stream, and, more importantly, how we organize our teams to use Conway's Law to our advantage.

ORGANIZATIONAL ARCHETYPES

In the field of decision sciences, there are three primary types of organizational structures that inform how we design our DevOps value streams with Conway's Law in mind: *functional*, *matrix*, and *market*. They are defined by Dr. Roberto Fernandez as follows:

- Functional-oriented organizations optimize for expertise, division of labor, or reducing cost. These organizations centralize expertise, which helps enable career growth and skill development, and often have tall hierarchical organizational structures. This has been the prevailing method of organization for Operations, (i.e., server admins, network admins, database admins, and so forth are all organized into separate groups).

- Matrix-oriented organizations attempt to combine functional and market orientation. However, as many who work in or manage matrix organizations observe, matrix organizations often result in complicated organizational structures, such as individual contributors reporting to two managers or more, and sometimes achieving neither of the goals of functional or market orientation.

- Market-oriented organizations optimize for responding quickly to customer needs. These organizations tend to be flat, composed of multiple, cross-functional disciplines (e.g., marketing, engineering, etc.), which often lead to potential redundancies across the organization. This is how many prominent organizations adopting DevOps operate—in extreme examples, such as at

† Sprouter was one of many technologies used in development and production that Etsy eliminated as part of their transformation.

Amazon or Netflix, each service team is simultaneously responsible for feature delivery and service support.‡

With these three categories of organizations in mind, let's explore further how an overly functional orientation, especially in Operations, can cause undesired outcomes in the technology value stream, as Conway's Law would predict.

PROBLEMS OFTEN CAUSED BY OVERLY FUNCTIONAL ORIENTATION ("OPTIMIZING FOR COST")

In traditional IT Operations organizations, we often use functional orientation to organize our teams by their specialties. We put the database administrators in one group, the network administrators in another, the server administrators in a third, and so forth. One of the most visible consequences of this is long lead times, especially for complex activities like large deployments where we must open up tickets with multiple groups and coordinate work handoffs, resulting in our work waiting in long queues at every step.

Compounding the issue, the person performing the work often has little visibility or understanding of how their work relates to any value stream goals (e.g., "I'm just configuring servers because someone told me to."). This places workers in a creativity and motivation vacuum.

The problem is exacerbated when each Operations functional area has to serve multiple value streams (i.e., multiple Development teams) who all compete for their scarce cycles. In order for Development teams to get their work done in a timely manner, we often have to escalate issues to a manager or director, and eventually to someone (usually an executive) who can finally prioritize the work against the global organizational goals instead of the functional silo goals. This decision must then get cascaded down into each of the functional areas to change the local priorities, and this, in turn, slows down other teams. When every team expedites their work, the net result is that every project ends up moving at the same slow crawl.

In addition to long queues and long lead times, this situation results in poor handoffs, large amounts of re-work, quality issues, bottlenecks, and delays.

‡ However, as will be explained later, equally prominent organizations such as Etsy and GitHub have functional orientation.

This gridlock impedes the achievement of important organizational goals, which often far outweigh the desire to reduce costs.[†]

Similarly, functional orientation can also be found with centralized QA and Infosec functions, which may have worked fine (or at least, well enough) when performing less frequent software releases. However, as we increase the number of Development teams and their deployment and release frequencies, most functionally-oriented organizations will have difficulty keeping up and delivering satisfactory outcomes, especially when their work is being performed manually. Now we'll study how market oriented organizations work.

ENABLE MARKET-ORIENTED TEAMS ("OPTIMIZING FOR SPEED")

Broadly speaking, to achieve DevOps outcomes, we need to reduce the effects of functional orientation ("optimizing for cost") and enable market orientation ("optimizing for speed") so we can have many small teams working safely and independently, quickly delivering value to the customer.

Taken to the extreme, market-oriented teams are responsible not only for feature development, but also for testing, securing, deploying, and supporting their service in production, from idea conception to retirement. These teams are designed to be cross-functional and independent—able to design and run user experiments, build and deliver new features, deploy and run their service in production, and fix any defects without manual dependencies on other teams, thus enabling them to move faster. This model has been adopted by Amazon and Netflix and is touted by Amazon as one of the primary reasons behind their ability to move fast even as they grow.

To achieve market orientation, we won't do a large, top-down reorganization, which often creates large amounts of disruption, fear, and paralysis. Instead, we will embed the functional engineers and skills (e.g., Ops, QA, Infosec) into each service team, or provide their capabilities to teams through automated

† Adrian Cockcroft remarked, "For companies who are now coming off of five-year IT outsourcing contracts, it's like they've been frozen in time, during one of the most disruptive times in technology." In other words, IT outsourcing is a tactic used to control costs through contractually-enforced stasis, with firm fixed prices that schedule annual cost reductions. However, it often results in organizations being unable to respond to changing business and technology needs.

self-service platforms that provide production-like environments, initiate automated tests, or perform deployments.

This enables each service team to independently deliver value to the customer without having to open tickets with other groups, such as IT Operations, QA, or Infosec.[‡]

MAKING FUNCTIONAL ORIENTATION WORK

Having just recommended market-orientated teams, it is worth pointing out that it is possible to create effective, high-velocity organizations with functional orientation. Cross-functional and market-oriented teams are one way to achieve fast flow and reliability, but they are not the only path. We can also achieve our desired DevOps outcomes through functional orientation, as long as everyone in the value stream views customer and organizational outcomes as a shared goal, regardless of where they reside in the organization.

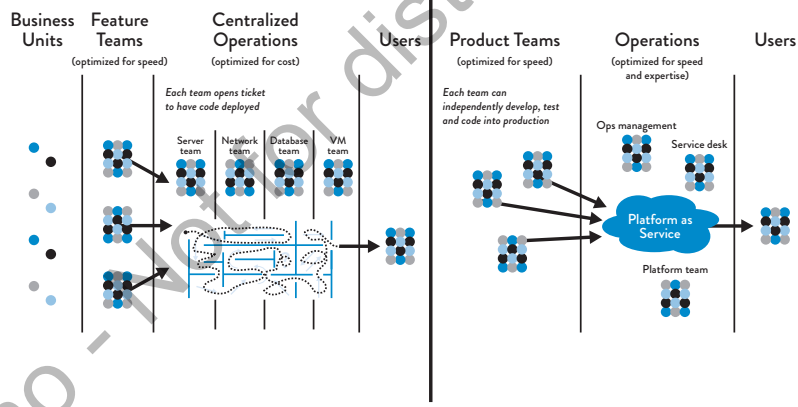


Figure 12: *Functional vs. market orientation*

Left: Functional orientation: all work flows through centralized IT Operations; Right: Market orientation: all product teams can deploy their loosely coupled components self-service into production. (Source: Humble, Molesky, and O'Reilly, Lean Enterprise, *Kindle edition, 4523 & 4592.)*

‡ For the remainder of this books, we will use *service teams* interchangeably with *feature teams*, *product teams*, *development teams*, and *delivery teams*. The intent is to specify the team primarily developing, testing, and securing the code so that value is delivered to the customer.

For example, high performance with a functional-oriented and centralized Operations group is possible, as long as service teams get what they need from Operations reliably and quickly (ideally on demand) and vice-versa. Many of the most admired DevOps organizations retain functional orientation of Operations, including Etsy, Google, and GitHub.

What these organizations have in common is a high-trust culture that enables all departments to work together effectively, where all work is transparently prioritized and there is sufficient slack in the system to allow high-priority work to be completed quickly. This is, in part, enabled by automated self-service platforms that build quality into the products everyone is building.

In the Lean manufacturing movement of the 1980s, many researchers were puzzled by Toyota's functional orientation, which was at odds with the best practice of having cross-functional, market-oriented teams. They were so puzzled it was called "the second Toyota paradox."

As Mike Rother wrote in *Toyota Kata*, "As tempting as it seems, one cannot reorganize your way to continuous improvement and adaptiveness. What is decisive is not the form of the organization, but how people act and react. The roots of Toyota's success lie not in its organizational structures, but in developing capability and habits in its people. It surprises many people, in fact, to find that Toyota is largely organized in a traditional, functional-department style." It is this development of habits and capabilities in people and the workforce that are the focus of our next sections.

TESTING, OPERATIONS, AND SECURITY AS EVERYONE'S JOB, EVERY DAY

In high-performing organizations, everyone within the team shares a common goal—quality, availability, and security aren't the responsibility of individual departments, but are a part of everyone's job, every day.

This means that the most urgent problem of the day may be working on or deploying a customer feature or fixing a Severity 1 production incident. Alternatively, the day may require reviewing a fellow engineer's change, applying emergency security patches to production servers, or making improvements so that fellow engineers are more productive.

Reflecting on shared goals between Development and Operations, Jody Mulkey, CTO at Ticketmaster, said, "For almost 25 years, I used an American football

metaphor to describe Dev and Ops. You know, Ops is defense, who keeps the other team from scoring, and Dev is offense, trying to score goals. And one day, I realized how flawed this metaphor was, because they never all play on the field at the same time. They're not actually on the same team!"

He continued, "The analogy I use now is that Ops are the offensive linemen, and Dev are the 'skill' positions (like the quarterback and wide receivers) whose job it is to move the ball down the field—the job of Ops is to help make sure Dev has enough time to properly execute the plays."

A striking example of how shared pain can reinforce shared goals is when Facebook was undergoing enormous growth in 2009. They were experiencing significant problems related to code deployments—while not all issues caused customer-impacting issues, there was chronic firefighting and long hours. Pedro Canahuati, their director of production engineering, described a meeting full of Ops engineers where someone asked that all people not working on an incident close their laptops, and no one could.

One of the most significant things they did to help change the outcomes of deployments was to have all Facebook engineers, engineering managers, and architects rotate through on-call duty for the services they built. By doing this, everyone who worked on the service experienced visceral feedback on the upstream architectural and coding decisions they made, which made an enormous positive impact on the downstream outcomes.

ENABLE EVERY TEAM MEMBER TO BE A GENERALIST

In extreme cases of a functionally-oriented Operations organization, we have departments of specialists, such as network administrators, storage administrators, and so forth. When departments over-specialize, it causes *siloization*, which Dr. Spear describes as when departments "operate more like sovereign states." Any complex operational activity then requires multiple handoffs and queues between the different areas of the infrastructure, leading to longer lead times (e.g., because every network change must be made by someone in the networking department).

Because we rely upon an ever increasing number of technologies, we must have engineers who have specialized and achieved mastery in the technology areas we need. However, we don't want to create specialists who are "frozen in time," only understanding and able to contribute to that one area of the value stream.

One countermeasure is to enable and encourage every team member to be a generalist. We do this by providing opportunities for engineers to learn all the skills necessary to build and run the systems they are responsible for, and regularly rotating people through different roles. The term *full stack engineer* is now commonly used (sometimes as a rich source of parody) to describe generalists who are familiar—at least have a general level of understanding—with the entire application stack (e.g., application code, databases, operating systems, networking, cloud).

Table 2: *Specialists vs. Generalists vs. "E-shaped" Staff (experience, expertise, exploration, and execution)*

"I-shaped" (Specialists)	"T-shaped" (Generalists)	"E-shaped"
Deep expertise in one area	Deep expertise in one area	Deep expertise in a few areas
Very few skills or experience in other areas	Broad skills across many areas	Experience across many areas Proven execution skills Always innovating
Creates bottlenecks quickly	Can step up to remove bottlenecks	Almost limitless potential
Insensitive to downstream waste and impact	Sensitive to downstream waste and impact	
Prevents planning flexibility or absorption of variability	Helps make planning flexible and absorbs variability	

(Source: Scott Prugh, "Continuous Delivery," ScaledAgileFramework.com, February 14, 2013, http://scaledagileframework.com/continuous-delivery/.)

Scott Prugh writes that CSG International has undergone a transformation that brings most resources required to build and run the product onto one team, including analysis, architecture, development, test, and operations. "By cross-training and growing engineering skills, generalists can do orders of magnitude more work than their specialist counterparts, and it also improves our overall flow of work by removing queues and wait time." This approach is at odds with traditional hiring practices, but, as Prugh explains, it is well worth it. "Traditional managers will often object to hiring engineers with generalist skill sets, arguing that they are more expensive and that 'I can hire two server administrators for every multi-

skilled operations engineer.'" However, the business benefits of enabling faster flow are overwhelming. Furthermore, as Prugh notes, "[I]nvesting in cross training is the right thing for [employees'] career growth, and makes everyone's work more fun."

When we value people merely for their existing skills or performance in their current role rather than for their ability to acquire and deploy new skills, we (often inadvertently) reinforce what Dr. Carol Dweck describes as the *fixed mindset*, where people view their intelligence and abilities as static "givens" that can't be changed in meaningful ways.

Instead, we want to encourage learning, help people overcome learning anxiety, help ensure that people have relevant skills and a defined career road map, and so forth. By doing this, we help foster a *growth mindset* in our engineers—after all, a learning organization requires people who are willing to learn. By encouraging everyone to learn, as well as providing training and support, we create the most sustainable and least expensive way to create greatness in our teams—by investing in the development of the people we already have.

As Jason Cox, Director of Systems Engineering at Disney, described, "Inside of Operations, we had to change our hiring practices. We looked for people who had 'curiosity, courage, and candor,' who were not only capable of being generalists but also renegades…We want to promote positive disruption so our business doesn't get stuck and can move into the future." As we'll see in the next section, how we fund our teams also affects our outcomes.

FUND NOT PROJECTS, BUT SERVICES AND PRODUCTS

Another way to enable high-performing outcomes is to create stable service teams with ongoing funding to execute their own strategy and road map of initiatives. These teams have the dedicated engineers needed to deliver on concrete commitments made to internal and external customers, such as features, stories, and tasks.

Contrast this to the more traditional model where Development and Test teams are assigned to a "project" and then reassigned to another project as soon as the project is completed and funding runs out. This leads to all sorts of undesired outcomes, including developers being unable to see the long-term consequences of decisions they make (a form of feedback) and a funding model that only values and pays for the earliest stages of the software life

cycle—which, tragically, is also the least expensive part for successful products or services.[†]

Our goal with a product-based funding model is to value the achievement of organizational and customer outcomes, such as revenue, customer lifetime value, or customer adoption rate, ideally with the minimum of output (e.g., amount of effort or time, lines of code). Contrast this to how projects are typically measured, such as whether it was completed within the promised budget, time, and scope.

DESIGN TEAM BOUNDARIES IN ACCORDANCE WITH CONWAY'S LAW

As organizations grow, one of the largest challenges is maintaining effective communication and coordination between people and teams. All too often, when people and teams reside on a different floor, in a different building, or in a different time zone, creating and maintaining a shared understanding and mutual trust becomes more difficult, impeding effective collaboration. Collaboration is also impeded when the primary communication mechanisms are work tickets and change requests, or worse, when teams are separated by contractual boundaries, such as when work is performed by an outsourced team.

As we saw in the Etsy Sprouter example at the beginning of this chapter, the way we organize teams can create poor outcomes, a side effect of Conway's Law. These include splitting teams by function (e.g., by putting developers and testers in different locations or by outsourcing testers entirely) or by architectural layer (e.g., application, database).

These configurations require significant communication and coordination between teams, but still results in a high amount of rework, disagreements over specifications, poor handoffs, and people sitting idle waiting for somebody else.

Ideally, our software architecture should enable small teams to be independently productive, sufficiently decoupled from each other so that work can be done without excessive or unnecessary communication and coordination.

† As John Lauderbach, currently VP of Information Technology at Roche Bros. Supermarkets, quipped, "Every new application is like a free puppy. It's not the upfront capital cost that kills you…It's the ongoing maintenance and support."

CREATE LOOSELY-COUPLED ARCHITECTURES TO ENABLE DEVELOPER PRODUCTIVITY AND SAFETY

When we have a tightly coupled architecture, small changes can result in large scale failures. As a result, anyone working in one part of the system must constantly coordinate with anyone else working in another part of the system they may affect, including navigating complex and bureaucratic change management processes.

Furthermore, to test that the entire system works together requires integrating changes with the changes from hundreds, or even thousands, of other developers, which may, in turn, have dependencies on tens, hundreds, or thousands of interconnected systems. Testing is done in scarce integration test environments, which often require weeks to obtain and configure. The result is not only long lead times for changes (typically measured in weeks or months) but also low developer productivity and poor deployment outcomes.

In contrast, when we have an architecture that enables small teams of developers to independently implement, test, and deploy code into production safely and quickly, we can increase and maintain developer productivity and improve deployment outcomes. These characteristics can be found in *service-oriented architectures* (SOAs) first described in the 1990s, in which services are independently testable and deployable. A key feature of SOAs is that they're composed of *loosely coupled* services with *bounded contexts*.[‡]

Having architecture that is loosely coupled means that services can update in production independently, without having to update other services. Services must be decoupled from other services and, just as important, from shared databases (although they can share a database *service*, provided they don't have any common schemas).

Bounded contexts are described in the book *Domain Driven Design* by Eric J. Evans. The idea is that developers should be able to understand and update the code of a service without knowing anything about the internals of its peer services. Services interact with their peers strictly through APIs and thus don't share data structures, database schemata, or other internal representations of objects. Bounded contexts ensure that services are compartmentalized and have well-defined interfaces, which also enables easier testing.

‡ These properties are also found in "microservices," which build upon the principles of SOA. One popular set of patterns for modern web architecture based on these principles is the "12-factor app."

Randy Shoup, former Engineering Director for Google App Engine, observed that "organizations with these types of service-oriented architectures, such as Google and Amazon, have incredible flexibility and scalability. These organizations have tens of thousands of developers where small teams can still be incredibly productive."

KEEP TEAM SIZES SMALL (THE "TWO-PIZZA TEAM" RULE)

Conway's Law helps us design our team boundaries in the context of desired communication patterns, but it also encourages us to keep our team sizes small, reducing the amount of inter-team communication and encouraging us to keep the scope of each team's domain small and bounded.

As part of its transformation initiative away from a monolithic code base in 2002, Amazon used the *two-pizza* rule to keep team sizes small—a team only as large as can be fed with two pizzas—usually about five to ten people.

This limit on size has four important effects:

1. It ensures the team has a clear, shared understanding of the system they are working on. As teams get larger, the amount of communication required for everybody to know what's going on scales in a combinatorial fashion.

2. It limits the growth rate of the product or service being worked on. By limiting the size of the team, we limit the rate at which their system can evolve. This also helps to ensure the team maintains a shared understanding of the system.

3. It decentralizes power and enables autonomy. Each two-pizza team (2PT) is as autonomous as possible. The team's lead, working with the executive team, decides on the key business metric that the team is responsible for, known as the fitness function, which becomes the overall evaluation criteria for the team's experiments. The team is then able to act autonomously to maximize that metric.[†]

4. Leading a 2PT is a way for employees to gain some leadership experience in an environment where failure does not have catastrophic consequences. An essential element of Amazon's strategy

† In the Netflix culture, one of the seven key values is "highly aligned, loosely coupled."

was the link between the organizational structure of a 2PT and the architectural approach of a service-oriented architecture.

Amazon CTO Werner Vogels explained the advantages of this structure to Larry Dignan of *Baseline* in 2005. Dignan writes:

> "Small teams are fast...and don't get bogged down in so-called administrivia....Each group assigned to a particular business is completely responsible for it....The team scopes the fix, designs it, builds it, implements it and monitors its ongoing use. This way, technology programmers and architects get direct feedback from the business people who use their code or applications—in regular meetings and informal conversations."

Another example of how architecture can profoundly improve productivity is the API Enablement program at Target, Inc.

Case Study
API Enablement at Target (2015)

Target is the sixth largest retailer in the US and spends over $1 billion on technology annually. Heather Mickman, a director of development for Target, described the beginnings of their DevOps journey: "In the bad old days, it used to take ten different teams to provision a server at Target, and when things broke, we tended to stop making changes to prevent further issues, which of course makes everything worse."

The hardships associated with getting environments and performing deployments created significant difficulties for development teams, as did getting access to data they needed. As Mickman described:

> The problem was that much of our core data, such as information on inventory, pricing, and stores, was locked up in legacy systems and mainframes. We often had multiple sources of truths of data, especially between e-commerce and our physical stores, which were owned by different teams, with different data structures and different priorities....The result was that if a new development team wanted to build something for our guests, it would take three to six months to build the integrations to get the data they needed. Worse, it would take another three to six months to do the manual

> testing to make sure they didn't break anything critical, because of how many custom point-to-point integrations we had in a very tightly coupled system. Having to manage the interactions with the twenty to thirty different teams, along with all their dependencies, required lots of project managers, because of all the coordination and handoffs. It meant that development was spending all their time waiting in queues, instead of delivering results and getting stuff done.

This long lead time for retrieving and creating data in their systems of record was jeopardizing important business goals, such as integrating the supply chain operations of Target's physical stores and their e-commerce site, which now required getting inventory to stores and customer homes. This pushed the Target supply chain well beyond what it was designed for, which was merely to facilitate the movement of goods from vendors to distribution centers and stores.

In an attempt to solve the data problem, in 2012 Mickman led the API Enablement team to enable development teams to "deliver new capabilities in days instead of months." They wanted any engineering team inside of Target to be able to get and store the data they needed, such as information on their products or their stores, including operating hours, location, whether there was as Starbucks on-site, and so forth.

Time constraints played a large role in team selection. Mickman explained that:

> Because our team also needed to deliver capabilities in days, not months, I needed a team who could do the work, not give it to contractors—we wanted people with kickass engineering skills, not people who knew how to manage contracts. And to make sure our work wasn't sitting in queue, we needed to own the entire stack, which meant that we took over the Ops requirements as well....We brought in many new tools to support continuous integration and continuous delivery. And because we knew that if we succeeded, we would have to scale with extremely high growth, we brought in new tools such as the Cassandra database and Kafka message broker. When we asked for permission, we were told no, but we did it anyway, because we knew we needed it.

In the following two years, the API Enablement team enabled fifty-three new business capabilities, including Ship to Store and Gift Registry, as well

as their integrations with Instacart and Pinterest. As Mickman described, "Working with Pinterest suddenly became very easy, because we just provided them our APIs."

In 2014, the API Enablement team served over 1.5 billion API calls per month. By 2015, this had grown to seventeen billion calls per month spanning ninety different APIs. To support this capability, they routinely performed eighty deployments per week.

These changes have created major business benefits for Target—digital sales increased 42% during the 2014 holiday season and increased another 32% in Q2. During the Black Friday weekend of 2015, over 280k in-store pickup orders were created. By 2015, their goal is to enable 450 of their 1,800 stores to be able to fulfill e-commerce orders, up from one hundred.

"The API Enablement team shows what a team of passionate change agents can do," Mickman says. "And it help set us up for the next stage, which is to expand DevOps across the entire technology organization."

CONCLUSION

Through the Etsy and Target case studies, we can see how architecture and organizational design can dramatically improve our outcomes. Done incorrectly, Conway's Law will ensure that the organization creates poor outcomes, preventing safety and agility. Done well, the organization enables developers to safely and independently develop, test, and deploy value to the customer.

8 How to Get Great Outcomes by Integrating Operations into the Daily Work of Development

Our goal is to enable market-oriented outcomes where many small teams can quickly and independently deliver value to the customer. This can be a challenge to achieve when Operations is centralized and functionally-oriented, having to serve the needs of many different development teams with potentially wildly different needs. The result can often be long lead times for needed Ops work, constant reprioritization and escalation, and poor deployment outcomes.

We can create more market-oriented outcomes by better integrating Ops capabilities into Dev teams, making both more efficient and productive. In this chapter, we'll explore many ways to achieve this, both at the organizational level and through daily rituals. By doing this, Ops can significantly improve the productivity of Dev teams throughout the entire organization, as well as enable better collaboration and organizational outcomes.

At Big Fish Games, which develops and supports hundreds of mobile and thousands of PC games and had more than $266 million in revenue in 2013, VP of IT Operations Paul Farrall was in charge of the centralized Operations organization. He was responsible for supporting many different business units that had a great deal of autonomy.

Each of these business units had dedicated development teams who often chose wildly different technologies. When these groups wanted to deploy new functionality, they would have to compete for a common pool of scarce Ops resources. Furthermore, everyone was struggling with unreliable Test and Integration environments, as well as extremely cumbersome release processes.

Farrall thought the best way to solve this problem was by embedding Ops expertise into Development teams. He observed, "When Dev teams had problems with testing or deployment, they needed more than just technology or environments. What they also needed was help and coaching. At first, we embedded Ops engineers and architects into each of the Dev teams, but there simply weren't enough Ops engineers to cover that many teams. We were able to help more teams with what we called an *Ops liaison* model and with fewer people."

Farrall defined two types of Ops liaisons: the business relationship manager and the dedicated release engineer. The business relationship managers worked with product management, line-of-business owners, project management, Dev management, and developers. They became intimately familiar with product group business drivers and product road maps, acted as advocates for product owners inside of Operations, and helped their product teams navigate the Operations landscape to prioritize and streamline work requests.

Similarly, the dedicated release engineer became intimately familiar with the product's Development and QA issues, and helped them get what they needed from the Ops organization to achieve their goals. They were familiar with the typical Dev and QA requests for Ops, and would often execute the needed work themselves. As needed, they would also pull in dedicated technical Ops engineers (e.g., DBAs, Infosec, storage engineers, network engineers), and help determine which self-service tools the entire Operations group should prioritize building.

By doing this, Farrall was able to help Dev teams across the organization become more productive and achieve their team goals. Furthermore, he helped the teams prioritize around his global Ops constraints, reducing the number of surprises discovered mid-project and ultimately increasing the overall project throughput.

Farrall notes that both working relationships with Operations and code release velocity were noticeably improved as a result of the changes. He concludes, "The Ops liaison model allowed us to embed IT Operations expertise into the Dev and Product teams without adding new headcount."

The DevOps transformation at Big Fish Games shows how a centralized Operations team was able to achieve the outcomes typically associated with market-oriented teams. We can employ the three following broad strategies:

- Create self-service capabilities to enable developers in the service teams to be productive.
- Embed Ops engineers into the service teams.
- Assign Ops liaisons to the service teams when embedding Ops is not possible.

Lastly, we describe how Ops engineers can integrate into the Dev team rituals used in their daily work, including daily standups, planning, and retrospectives.

CREATE SHARED SERVICES TO INCREASE DEVELOPER PRODUCTIVITY

One way to enable market-oriented outcomes is for Operations to create a set of centralized platforms and tooling services that any Dev team can use to become more productive, such as getting production-like environments, deployment pipelines, automated testing tools, production telemetry dashboards, and so forth.[†] By doing this, we enable Dev teams to spend more time building functionality for their customer, as opposed to obtaining all the infrastructure required to deliver and support that feature in production.

All the platforms and services we provide should (ideally) be automated and available on demand, without requiring a developer to open up a ticket and wait for someone to manually perform work. This ensures that Operations doesn't become a bottleneck for their customers (e.g., "We received your work request, and it will take six weeks to manually configure those test environments.").[‡]

By doing this, we enable the product teams to get what they need, when they need it, as well as reduce the need for communications and coordination. As Damon Edwards observed, "Without these self-service Operations platforms, the cloud is just Expensive Hosting 2.0."

In almost all cases, we will not mandate that internal teams use these platforms and services—these platform teams will have to win over and satisfy their

† The terms *platform*, *shared service*, and *toolchain* will be used interchangeably in this book.

‡ Ernest Mueller observed, "At Bazaarvoice, the agreement was that these platform teams that make tools accept requirements, but not work from other teams."

internal customers, sometimes even competing with external vendors. By creating this effective internal marketplace of capabilities, we help ensure that the platforms and services we create are the easiest and most appealing choice available (the path of least resistance).

For instance, we may create a platform that provides a shared version control repository with pre-blessed security libraries, a deployment pipeline that automatically runs code quality and security scanning tools, which deploys our applications into *known, good environments* that already have production monitoring tools installed on them. Ideally, we make life so much easier for Dev teams that they will overwhelmingly decide that using our platform is the easiest, safest, and most secure means to get their applications into production.

We build into these platforms the cumulative and collective experience of everyone in the organization, including QA, Operations, and Infosec, which helps to create an ever safer system of work. This increases developer productivity and makes it easy for product teams to leverage common processes, such as performing automated testing and satisfying security and compliance requirements.

Creating and maintaining these platforms and tools is real product development—the customers of our platform aren't our external customer but our internal Dev teams. Like creating any great product, creating great platforms that everyone loves doesn't happen by accident. An internal platform team with poor customer focus will likely create tools that everyone will hate and quickly abandon for other alternatives, whether for another internal platform team or an external vendor.

Dianne Marsh, Director of Engineering Tools at Netflix, states that her team's charter is to "support our engineering teams' innovation and velocity. We don't build, bake, or deploy anything for these teams, nor do we manage their configurations. Instead, we build tools to enable self-service. It's okay for people to be dependent on our tools, but it's important that they don't become dependent on us."

Often, these platform teams provide other services to help their customers learn their technology, migrate off of other technologies, and even provide coaching and consulting to help elevate the state of the practice inside the organization. These shared services also facilitate standardization, which enable engineers to quickly become productive, even if they switch between teams. For instance, if every product team chooses a different toolchain, en-

gineers may have to learn an entirely new set of technologies to do their work, putting the team goals ahead of the global goals.

In organizations where teams can only use approved tools, we can start by removing this requirement for a few teams, such as the transformation team, so that we can experiment and discover what capabilities make those teams more productive.

Internal shared services teams should continually look for internal toolchains that are widely being adopted in the organization, deciding which ones make sense to be supported centrally and made available to everyone. In general, taking something that's already working somewhere and expanding its usage is far more likely to succeed than building these capabilities from scratch.[†]

EMBED OPS ENGINEERS INTO OUR SERVICE TEAMS

Another way we can enable more market-oriented outcomes is by enabling product teams to become more self-sufficient by embedding Operations engineers within them, thus reducing their reliance on centralized Operations. These product teams may also be completely responsible for service delivery and service support.

By embedding Operations engineers into the Dev teams, their priorities are driven almost entirely by the goals of the product teams they are embedded in—as opposed to Ops focusing inwardly on solving their own problems. As a result, Ops engineers become more closely connected to their internal and external customers. Furthermore, the product teams often have the budget to fund the hiring of these Ops engineers, although interviewing and hiring decisions will likely still be done from the centralized Operations group, to ensure consistency and quality of staff.

Jason Cox said, "In many parts of Disney we have embedded Ops (system engineers) inside the product teams in our business units, along with inside Development, Test, and even Information Security. It has totally changed the dynamics of how we work. As Operations Engineers, we create the tools and capabilities that transform the way people work, and even the way they think. In traditional Ops, we merely drove the train that someone else built. But in

† After all, designing a system upfront for re-use is a common and expensive failure mode of many enterprise architectures.

modern Operations Engineering, we not only help build the train, but also the bridges that the trains roll on."

For new large Development projects, we may initially embed Ops engineers into those teams. Their work may include helping decide what to build and how to build it, influencing the product architecture, helping influence internal and external technology choices, helping create new capabilities in our internal platforms, and maybe even generating new operational capabilities. After the product is released to production, embedded Ops engineers may help with the production responsibilities of the Dev team.

They will take part in all of the Dev team rituals, such as planning meetings, daily standups, and demonstrations where the team shows off new features and decides which ones to ship. As the need for Ops knowledge and capabilities decreases, Ops engineers may transition to different projects or engagements, following the general pattern that the composition within product teams changes throughout its life cycle.

This paradigm has another important advantage: pairing Dev and Ops engineers together is an extremely efficient way to cross-train operations knowledge and expertise into a service team. It can also have the powerful benefit of transforming operations knowledge into automated code that can be far more reliable and widely reused.

ASSIGN AN OPS LIAISON TO EACH SERVICE TEAM

For a variety of reasons, such as cost and scarcity, we may be unable to embed Ops engineers into every product team. However, we can get many of the same benefits by assigning a designated liaison for each product team.

At Etsy, this model is called "designated Ops." Their centralized Operations group continues to manage all the environments—not just production environments but also pre-production environments—to help ensure they remain consistent. The designated Ops engineer is responsible for understanding:

- What the new product functionality is and why we're building it
- How it works as it pertains to operability, scalability, and observability (diagramming is strongly encouraged)
- How to monitor and collect metrics to ensure the progress, success, or failure of the functionality

- Any departures from previous architectures and patterns, and the justifications for them
- Any extra needs for infrastructure and how usage will affect infrastructure capacity
- Feature launch plans

Furthermore, just like in the embedded Ops model, this liaison attends the team standups, integrating their needs into the Operations road map and performing any needed tasks. We rely on these liaisons to escalate any resource contention or prioritization issue. By doing this, we identify any resource or time conflicts that should be evaluated and prioritized in the context of wider organizational goals.

Assigning Ops liaisons allows us to support more product teams than the embedded Ops model. Our goal is to ensure that Ops is not a constraint for the product teams. If we find that Ops liaisons are stretched too thin, preventing the product teams from achieving their goals, then we will likely need to either reduce the number of teams each liaison supports or temporarily embed an Ops engineer into specific teams.

INTEGRATE OPS INTO DEV RITUALS

When Ops engineers are embedded or assigned as liaisons into our product teams, we can integrate them into our Dev team rituals. In this section, our goal is to help Ops engineers and other non-developers better understand the existing Development culture and proactively integrate them into all aspects of planning and daily work. As a result, Operations is better able to plan and radiate any needed knowledge into the product teams, influencing work long before it gets into production. The following sections describe some of the standard rituals used by Development teams using agile methods and how we would integrate Ops engineers into them. By no means are agile practices a prerequisite for this step—as Ops engineers, our goal is to discover what rituals the product teams follow, integrate into them, and add value to them.[†]

† However, if we discover that the entire Development organization merely sits at their desks all day without ever talking to each other, we may have to find a different way to engage them, such as buying them lunch, starting a book club, taking turns doing "lunch and learn" presentations, or having conversations to discover what everyone's biggest problems are, so that we can figure out how we can make their lives better.

As Ernest Mueller observed, "I believe DevOps works a lot better if Operations teams adopt the same agile rituals that Dev teams have used—we've had fantastic successes solving many problems associated with Ops pain points, as well as integrating better with Dev teams."

INVITE OPS TO OUR DEV STANDUPS

One of the Dev rituals popularized by Scrum is the daily standup, a quick meeting where everyone on the team gets together and presents to each other three things: what was done yesterday, what is going to be done today, and what is preventing you from getting your work done.[†]

The purpose of this ceremony is to radiate information throughout the team and to understand the work that is being done and is going to be done. By having team members present this information to each other, we learn about any tasks that are experiencing roadblocks and discover ways to help each other move our work toward completion. Furthermore, by having managers present, we can quickly resolve prioritization and resource conflicts.

A common problem is that this information is compartmentalized within the Development team. By having Ops engineers attend, Operations can gain an awareness of the Development team's activities, enabling better planning and preparation—for instance, if we discover that the product team is planning a big feature rollout in two weeks, we can ensure that the right people and resources are available to support the rollout. Alternatively, we may highlight areas where closer interaction or more preparation is needed (e.g., creating more monitoring checks or automation scripts). By doing this, we create the conditions where Operations can help solve our current team problems (e.g., improving performance by tuning the database, instead of optimizing code) or future problems before they turn into a crisis (e.g., creating more integration test environments to enable performance testing).

INVITE OPS TO OUR DEV RETROSPECTIVES

Another widespread agile ritual is the retrospective. At the end of each development interval, the team discusses what was successful, what could be improved, and how to incorporate the successes and improvements in future iterations or projects. The team comes up with ideas to make things better

† Scrum is an agile development methodology, described as "a flexible, holistic product development strategy where a development team works as a unit to reach a common goal." It was first fully described by Ken Schwaber and Mike Beedle in the book *Agile Software Development with Scrum*. In this book, we use the term "agile development" or "iterative development" to encompass the various techniques used by special methodologies such as Agile and Scrum.

and reviews experiments from the previous iteration. This is one of the primary mechanisms where organizational learning and the development of countermeasures occurs, with resulting work implemented immediately or added to the team's backlog.

Having Ops engineers attend our project team retrospectives means they can also benefit from any new learnings. Furthermore, when there is a deployment or release in that interval, Operations should present the outcomes and any resulting learnings, creating feedback into the product team. By doing this, we can improve how future work is planned and performed, improving our outcomes. Examples of feedback that Operations can bring to a retrospective include:

- "Two weeks ago, we found a monitoring blind-spot and agreed on how to fix it. It worked. We had an incident last Tuesday, and we were able to quickly detect and correct it before any customers were impacted."
- "Last week's deployment was one of the most difficult and lengthy we've had in over a year. Here are some ideas on how it can be improved."
- "The promotion campaign we did last week was far more difficult than we thought it would be, and we should probably not make an offer like that again. Here are some ideas on other offers we can make to achieve our goals."
- "During the last deployment, the biggest problem we had was our firewall rules are now thousands of lines long, making it extremely difficult and risky to change. We need to re-architect how we prevent unauthorized network traffic."

Feedback from Operations helps our product teams better see and understand the downstream impact of decisions they make. When there are negative outcomes, we can make the changes necessary to prevent them in the future. Operations feedback will also likely identify more problems and defects that should be fixed—it may even uncover larger architectural issues that need to be addressed.

The additional work identified during project team retrospectives falls into the broad category of improvement work, such as fixing defects, refactoring, and automating manual work. Product managers and project managers may

want to defer or deprioritize improvement work in favor of customer features.

However, we must remind everyone that improvement of daily work is more important than daily work itself, and that all teams must have dedicated capacity for this (e.g., reserving 20% of all cycles for improvement work, scheduling one day per week or one week per month, etc.). Without doing this, the productivity of the team will almost certainly grind to a halt under the weight of its own technical and process debt.

MAKE RELEVANT OPS WORK VISIBLE ON SHARED KANBAN BOARDS

Often, Development teams will make their work visible on a project board or kanban board. It's far less common, however, for work boards to show the relevant Operations work that must be performed in order for the application to run successfully in production, where customer value is actually created. As a result, we are not aware of necessary Operations work until it becomes an urgent crisis, jeopardizing deadlines or creating a production outage.

Because Operations is part of the product value stream, we should put the Operations work that is relevant to product delivery on the shared kanban board. This enables us to more clearly see all the work required to move our code into production, as well as keep track of all Operations work required to support the product. Furthermore, it enables us to see where Ops work is blocked and where work needs escalation, highlighting areas where we may need improvement.

Kanban boards are an ideal tool to create visibility, and visibility is a key component in properly recognizing and integrating Ops work into all the relevant value streams. When we do this well, we achieve market-oriented outcomes, regardless of how we've drawn our organization charts.

CONCLUSION

Throughout this chapter, we explored ways to integrate Operations into the daily work of Development, and looked at how to make our work more visible to Operations. To accomplish this, we explored three broad strategies, including creating self-service capabilities to enable developers in service teams to be productive, embedding Ops engineers into the service teams, and assigning Ops liaisons to the service teams when embedding Ops engineers was not possible. Lastly, we described how Ops engineers can integrate with the Dev

team through inclusion in their daily work, including daily standups, planning, and retrospectives.

PART II CONCLUSION

In Part II: *Where to Start*, we explored a variety of ways to think about DevOps transformations, including how to choose where to start, relevant aspects of architecture and organizational design, and how to organize our teams. We also explored how to integrate Ops into all aspects of Dev planning and daily work.

In Part III: The First Way, *The Technical Practices of Flow*, we will now start to explore how to implement the specific technical practices to realize the principles of flow, which enable the fast flow of work from Development to Operations without causing chaos and disruption downstream.

Author Biographies

GENE KIM

Gene Kim is a multiple award-winning CTO, researcher, and author of *The Phoenix Project: A Novel About IT, DevOps, and Helping Your Business Win* and *The Visible Ops Handbook*. He is founder of IT Revolution and hosts the DevOps Enteprise Summit conferences.

JEZ HUMBLE

Jez Humble is co-author of the Jolt Award–winning *Continuous Delivery* and the groundbreaking *Lean Enterprise*. His focus is on helping organizations deliver valuable, high-quality software frequently and reliably through implementing effective engineering practices.

PATRICK DEBOIS

Patrick Debois is an independent IT consultant who is bridging the gap between projects and operations by using Agile techniques, in development, project management, and system administration.

JOHN WILLIS

John Willis has worked in the IT management industry for more than thirty-five years. He has authored six IBM Redbooks and was the founder and chief architect at Chain Bridge Systems. Currently he is an Evangelist at Docker, Inc.