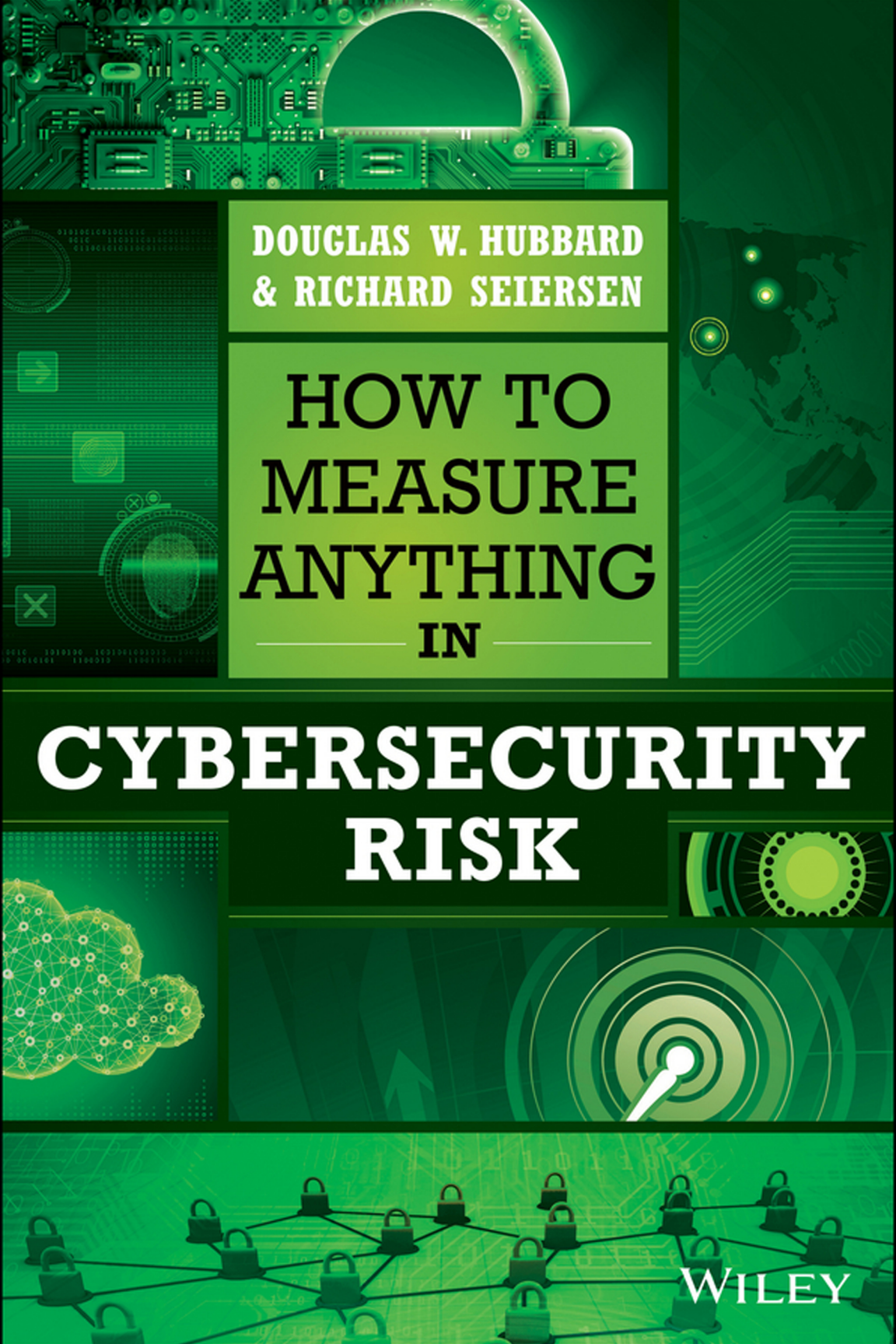
DOUGLAS W. HUBBARD
& RICHARD SEIERSEN
HOW TO MEASURE ANYTHING IN
CYBERSECURITY RISK
WILEY

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Douglas Hubbard's dedication: To my children, Evan, Madeleine, and Steven, as the continuing sources of inspiration in my life; and to my wife, Janet, for doing all the things that make it possible for me to have time to write a book, and for being the ultimate proofreader.

Richard Seiersen's dedication: To all the ladies in my life: Helena, Kaela, Anika, and Brenna. Thank you for your love and support through the book and life. You make it fun.

Doug and Richard would also like to dedicate this book to the military and law enforcement professionals who specialize in cybersecurity.

Contents

Foreword

Daniel E. Geer, Jr., ScD

Daniel Geer is a security researcher with a quantitative bent. His group at MIT produced Kerberos, and a number of startups later he is still at it—today as chief information security officer at In-Q-Tel. He writes a lot at every length, and sometimes it gets read. He's an electrical engineer, a statistician, and someone who thinks truth is best achieved by adversarial procedures.

It is my pleasure to recommend *How to Measure Anything in Cybersecurity Risk.* The topic is nothing if not pressing, and it is one that I have myself been dancing around for some time.[1] It is a hard problem, which allows me to quote Secretary of State John Foster Dulles: "The measure of success is not whether you have a tough problem to deal with, but whether it is the same problem you had last year." At its simplest, this book promises to help you put some old, hard problems behind you.

The practice of cybersecurity is part engineering and part inference. The central truth of engineering is that design pays if and only if the problem statement is itself well understood. The central truth of statistical inference is that all data has bias—the question being whether you can correct for it. Both engineering and inference depend on measurement. When measurement gets good enough, metrics become possible.

I say "metrics" because metrics are derivatives of measurement. A metric encapsulates measurements for the purpose of ongoing decision support. I and you, dear reader, are not in cybersecurity for reasons of science, though those who are in it for science (or philosophy) will also want measurement of some sort to backstop their theorizing. We need metrics derived from solid measurement because the scale of our task compared to the scale of our tools demands force multiplication. In any case, no game play improves without a way to keep score.

Early in the present author's career, a meeting was held inside a market-maker bank. The CISO, who was an unwilling promotion from Internal

We are fortunate to have two forewords from two leading thinkers in cybersecurity risk assessment—Daniel E. Geer, Jr., and Stuart McClure.

Audit, was caustic even by the standards of NYC finance. He began his comments mildly enough:

> Are you security people so stupid that you can't tell me:
> - How secure am I?
> - Am I better off than I was this time last year?
> - Am I spending the right amount of money?
> - How do I compare to my peers?
> - What risk transfer options do I have?

Twenty-five years later, those questions remain germane. Answering them, and others, comes only from measurement; that is the "Why?" of this book.

Yet even if we all agree on "Why?," the real value of this book is not "Why?" but "How?": *how* to measure and then choose among methods, *how* to do that both consistently and repeatedly, and *how* to move up from one method to a better one as your skill improves.

Some will say that cybersecurity is impossible if you face a sufficiently skilled opponent. That's true. It is also irrelevant. Our opponents by and large pick the targets that maximize their return on their investment, which is a polite way of saying that you may not be able to thwart the most singularly determined opponent for whom cost is no object, but you can sure as the world make other targets more attractive than you are. As I said, no game play improves without a way to keep score. That is what this book offers you—a way to improve your game.

This all requires numbers because numbers are the only input to both engineering and inference. Adjectives are not. Color codes are not. If you have any interest in taking care of yourself, of standing on your own two feet, of knowing where you are, then you owe it to yourself to exhaust this book. Its writing is clear, its pedagogy is straightforward, and its downloadable Excel spreadsheets leave no excuse for not trying.

Have I made the case? I hope so.

Note

1. Daniel Geer, Jr., Kevin Soo Hoo, and Andrew Jaquith, "Information Security: Why the Future Belongs to the Quants," *IEEE Security & Privacy* 1, no. 4 (July/August 2003): 32–40, geer.tinho.net/ieee/ieee.sp.geer.0307.pdf.

Foreword

Stuart McClure

Stuart McClure is the CEO of Cylance, former global CTO of McAfee, and founding author of the *Hacking Exposed* series.

My university professors always sputtered the age-old maxim in class: "You can't manage what you cannot measure." And while my perky, barely-out-of-teenage-years ears absorbed the claim aurally, my brain never really could process what it meant. Sure, my numerous computer science classes kept me chasing an infinite pursuit of improving mathematical algorithms in software programs, but little did I know how to really apply these quantitative efforts to the management of anything, much less cyber.

So I bounded forward in my career in IT and software programming, looking for an application of my unique talents. I never found cyber measurement all that compelling until I found cybersecurity. What motivated me to look at a foundational way to measure what I did in cybersecurity was the timeless question that I and many of you get almost daily: "Are we secure from attack?"

The easy answer to such a trite yet completely understandable question is "No. Security is never 100%." But some of you have answered the same way I have done from time to time, being exhausted by the inane query, with "Yes. Yes we are." Why? Because we know a ridiculous question should be given an equally ridiculous answer. For how can we know? Well, you can't—without metrics.

As my cybersecurity career developed with InfoWorld and Ernst & Young, while founding the company Foundstone, taking senior executive roles in its acquiring company, McAfee, and now starting Cylance, I have developed a unique appreciation for the original professorial claim that you really cannot manage what you cannot measure. While an objective metric may be mythical, a subjective and localized measurement of your current risk posture and where you stand relative to your past and your peers is very possible.

Measuring the cyber risk present at an organization is nontrivial, and when you set the requirement of delivering on quantitative measurements rather than subjective and qualitative measurements, it becomes almost beyond daunting.

The real questions for all of us security practitioners are ultimately "Where do we start? How do we go about measuring cybersecurity's effectiveness and return?" The only way to begin to answer those questions is through quantitative metrics. And until now, the art of cybersecurity measurement has been elusive. I remember the first time someone asked me my opinion on a security-risk metrics program, I answered something to the effect of, "It's impossible to measure something you cannot quantify."

What the authors of this book have done is begin to define a framework and a set of algorithms and metrics to do exactly what the industry has long thought impossible, or at least futile: measure security risk. We may not be perfect in our measurement, but we can define a set of standard metrics that are defensible and quantifiable, and then use those same metrics day in and day out to ensure that things are improving. And that is the ultimate value of defining and executing on a set of security metrics. You don't need to be perfect; all you need to do is start somewhere and measure yourself relative to the day before.

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About the Authors

Douglas Hubbard is the creator of the Applied Information Economics method and the founder of Hubbard Decision Research. He is the author of one of the best-selling business statistics books of all time, *How to Measure Anything: Finding the Value of "Intangibles" in Business.* He is also the author of *The Failure of Risk Management: Why It's Broken and How to Fix It*, and *Pulse: The New Science of Harnessing Internet Buzz to Track Threats and Opportunities.* He has sold more than 100,000 copies of his books in eight different languages, and his books are used in courses at many major universities. His consulting experience in quantitative decision analysis and measurement problems totals over 27 years and spans many industries including pharmaceuticals, insurance, banking, utilities, cybersecurity, interventions in developing economies, mining, federal and state government, entertainment media, military logistics, and manufacturing. He is also published in several periodicals including *Nature*, *The IBM Journal of R&D*, *Analytics*, *OR/MS Today*, *InformationWeek*, and *CIO Magazine.*

Richard Seiersen is a technology executive with nearly 20 years of experience in information security, risk management, and product development. Currently he is the general manager of cybersecurity and privacy for GE Healthcare. Many years ago, prior to his life in technology, he was a classically trained musician—guitar, specifically. Richard now lives with his family of string players in the San Francisco Bay Area. In his limited spare time he is slowly working through his MS in predictive analytics at Northwestern. He should be done just in time to retire. He thinks that will be the perfect time to take up classical guitar again.

Introduction

Why This Book, Why Now?

This book is the first of a series of spinoffs from Douglas Hubbard's successful first book, *How to Measure Anything: Finding the Value of "Intangibles" in Business*. For future books in this franchise, we were considering titles such as *How to Measure Anything in Project Management* or industry-specific books like *How to Measure Anything in Healthcare*. All we had to do was pick a good idea from a long list of possibilities.

Cybersecurity risk seemed like an ideal first book for this new series. It is extremely topical and filled with measurement challenges that may often seem impossible. We also believe it is an extremely important topic for personal reasons (as we are credit card users and have medical records, client data, intellectual property, and so on) as well as for the economy as a whole.

Another factor in choosing a topic was finding the right co-author. Because Doug Hubbard—a generalist in measurement methods—would not be a specialist in any of the particular potential spinoff topics, he planned to find a co-author who could write authoritatively on the topic. Hubbard was fortunate to find an enthusiastic volunteer in Richard Seiersen—someone with years of experience in the highest levels of cybersecurity management with some of the largest organizations.

So, with a topical but difficult measurement subject, a broad and growing audience, and a good co-author, cybersecurity seemed like an ideal fit.

What Is This Book About?

Even though this book focuses on cybersecurity risk, this book still has a lot in common with the original *How to Measure Anything* book, including:

1. Making better decisions when you are significantly uncertain about the present and future, and
2. Reducing that uncertainty even when data seems unavailable or the targets of measurement seem ambiguous and intangible.

This book in particular offers an alternative to a set of deeply rooted risk assessment methods now widely used in cybersecurity but that have no basis in the mathematics of risk or scientific method. We argue that these methods impede decisions about a subject of growing criticality. We also argue that methods based on real evidence of improving decisions are not only practical but already have been applied to a wide variety of equally difficult problems, including cybersecurity itself. We will show that we can start at a simple level and then evolve to whatever level is required while avoiding problems inherent to "risk matrices" and "risk scores." So there is no reason not to adopt better methods immediately.

What to Expect

You should expect a gentle introduction to measurably better decision making—specifically, improvement in high-stakes decisions that have a lot of uncertainty and where, if you are wrong, your decisions could lead to catastrophe. We think security embodies all of these concerns.

We don't expect our readers to be risk management experts or cybersecurity experts. The methods we apply to security can be applied to many other areas. Of course, we do hope it will make those who work in the field of cybersecurity better defenders and strategists. We also hope it will make the larger set of leaders more conscious of security risks in the process of becoming better decision makers.

Is This Book for Me?

If you really want to be sure this book is for you, here are the specific personas we are targeting:

- You are a decision maker looking to improve—that is, *measurably improve*—your high-stakes decision making.
- You are a security professional looking to become more strategic in your fight against the bad guy.
- You are neither of the above. Instead, you have an interest in understanding more about cybersecurity and/or risk management using readily accessible quantitative techniques.

- If you are a hard-core quant, consider skipping the purely quant parts. If you are a hard-core hacker, consider skipping the purely security parts. That said, we will often have a novel perspective, or "epiphanies of the obvious," on topics you already know well. Read as you see fit.

We Need More Than Technology

We need to lose less often in the fight against the bad guys. Or, at least, lose more gracefully and recover quickly. Many feel that this requires better technology. We clamor for more innovation from our vendors in the security space even though breach frequency has not been reduced. To effectively battle security threats, we think there is something equally important as innovative technology, if not more important. We believe that "something" must include a better way to think quantitatively about risk.

New Tools for Decision Makers

We need decision makers who consistently make better choices through better analysis. We also need decision makers who know how to deftly handle uncertainty in the face of looming catastrophe. Parts of this solution are sometimes referred to with current trendy terms like "predictive analytics," but more broadly this includes all of decision science or decision analysis and even properly applied statistics.

Our Path Forward

Part I of this book sets the stage for reasoning about uncertainty in security. We will come to terms on things like security, uncertainty, measurement, and risk management. We also argue against toxic misunderstandings of these terms and why we need a better approach to measuring cybersecurity risk and, for that matter, measuring the performance of cybersecurity risk analysis itself. We will also introduce a very simple quantitative method that could serve as a starting point for anyone, no matter how averse they may be to complexity.

Part II of this book will delve further into evolutionary steps we can take with a very simple quantitative model. We will describe how to add further complexity to a model and how to use even minimal amounts of data to improve those models.

Last, in Part III we will describe what is needed to implement these methods in the organization. We will also talk about the implications of this book for the entire cybersecurity "ecosystem," including standards organizations and vendors.

PART I

Why Cybersecurity Needs Better Measurements for Risk

CHAPTER 1

The One Patch Most Needed in Cybersecurity

There is nothing more deceptive than an obvious fact.

—Sherlock Holmes
The Bascombe Valley Mystery[1]

In the days after September 11, 2001, increased security meant overhauled screening at the airport, no-fly lists, air marshals, and attacking terrorist training camps. But just 12 years later, the FBI was emphasizing the emergence of a very different concern: the "cyber-based threat." In 2013, FBI director James B. Comey, testifying before the Senate Committee on Homeland Security and Governmental Affairs, stated the following:

> . . .we anticipate that in the future, resources devoted to cyber-based threats will equal or even eclipse the resources devoted to non-cyber based terrorist threats.
>
> —FBI director James B. Comey, November 14, 2013[2]

This is a shift in priorities we cannot overstate. How many organizations in 2001, preparing for what they perceived as the key threats at the time, would have even imagined that cyber threats would have not only equaled but exceeded more conventional terrorist threats? Yet as we write this book, it is accepted as our new "new normal."

Admittedly, those outside of the world of cybersecurity may think the FBI is sowing seeds of Fear, Uncertainty, and Doubt (FUD) to some political end. But it would seem that there are plenty of sources of FUD, so why pick cyber threats in particular? Of course, to cybersecurity experts this is a non-epiphany. We are under attack and it will certainly get worse before it gets better.

Yet resources are limited. Therefore, the cybersecurity professional must effectively determine a kind of "return on risk mitigation." Whether or not such a return is explicitly calculated, we must evaluate whether a given defense strategy is a better use of resources than another. In short, we have to measure and monetize risk and risk reduction. What we need is a "how to" book for professionals in charge of allocating limited resources to addressing ever-increasing cyber threats, and leveraging those resources for optimum risk reduction. This includes methods for:

- How to measure risk assessment methods themselves.
- How to measure reduction in risk from a given defense, control, mitigation, or strategy (using some of the better-performing methods as identified in the first bullet).
- How to continuously and measurably improve on the implemented methods, using more advanced methods that the reader may employ as he or she feels ready.

Let's be explicit about what this book isn't. This is not a technical security book—if you're looking for a book on "ethical hacking," then you have certainly come to the wrong place. There will be no discussions about how to execute stack overflows, defeat encryption algorithms, or execute SQL injections. If and when we do discuss such things, it's only in the context of understanding them as parameters in a risk model.

But don't be disappointed if you're a technical person. We will certainly be getting into some analytic nitty-gritty as it applies to security. This is from the perspective of an analyst or leader trying to make better bets in relation to possible future losses. For now, let's review the scale of the challenge we are dealing with and how we deal with it currently, then outline a direction for the improvements laid out in the rest of the book.

The Global Attack Surface

Nation-states, organized crime, hacktivist entities, and insider threats want our secrets, our money, and our intellectual property, and some want our complete demise. Sound dramatic? If we understand the FBI correctly, they expect to spend as much or more on protecting us from cyber threats than from those who would turn airplanes, cars, pressure cookers, and even people into bombs. And if you are reading this book, you probably already accept the gravity of the situation. But we should at least spend some time emphasizing this point if for no other reason than to help those who already agree with this point make the case to others.

The Global Information Security Workforce Study (GISWS)—a survey conducted in 2015 of more than 14,000 security professionals, including 1,800 federal employees—showed we are not just taking a beating, we are backpedaling:

> When we consider the amount of effort dedicated over the past two years to furthering the security readiness of federal systems and the nation's overall security posture, our hope was to see an obvious step forward. The data shows that, in fact, we have taken a step back.
>
> —(ISC)[2] on the announcement of the GISWS, 2015[3]

Indeed, other sources of data support this dire conclusion. The UK insurance market, Lloyd's of London, estimated that cyberattacks cost businesses $400 billion globally per year.[4] In 2014, one billion records were compromised. This caused *Forbes* magazine to refer to 2014 as "The Year of the Data Breach."[5,6] Unfortunately, identifying 2014 as the year of the data breach may still prove to be premature. It could easily get worse.

In fact, the founder and head of XL Catlin, the largest insurer in Lloyd's of London, said cybersecurity is the "biggest, most systemic risk" he has seen in his 42 years in insurance.[7] Potential weaknesses in widely used software; interdependent network access between companies, vendors, and clients; and the possibility of large coordinated attacks can affect much more than even one big company like Anthem, Target, or Sony. XL Catlin believes it is possible that there could be a simultaneous impact on multiple major organizations affecting the entire economy. They feel that if there are multiple major claims in a short period of time, this is a bigger burden than insurers can realistically cover.

What is causing such a dramatic rise in breach and the anticipation of even more breaches? It is called attack surface. "Attack surface" is usually defined as the kind of total of all exposures of an information system. It exposes value to untrusted sources. You don't need to be a security professional to get this. Your home, your bank account, your family, and your identity all have an attack surface. If you received identity theft protection as a federal employee, or a customer of Home Depot, Target, Anthem, or Neiman Marcus, then you received that courtesy of an attack surface. These companies put the digital you within reach of criminals. Directly or indirectly, the Internet facilitated this. This evolution happened quickly and without the knowledge or direct permission of all interested parties (organizations, employees, customers, or citizens).

Various definitions of the phrase consider the ways into and out of a system, the defenses of that system, and sometimes the value of data in that

system.[8,9] Some definitions of attack surface refer to the attack surface of a system and some refer to the attack surface of a network, but either might be too narrow even for a given firm. We might also define an "Enterprise Attack Surface" that not only consists of all systems and networks in that organization but also the exposure of third parties. This includes everyone in the enterprise "ecosystem" including major customers, vendors, and perhaps government agencies. (Recall that in the case of the Target breach, the exploit came from an HVAC vendor.)

Perhaps the total attack surface that concerns all citizens, consumers, and governments is a kind of "global attack surface": the total set of cybersecurity exposures—across all systems, networks, and organizations—we all face just by shopping with a credit card, browsing online, receiving medical benefits, or even just being employed. This global attack surface is a macro-level phenomenon driven by at least four macro-level causes of growth: increasing users worldwide, variety of users worldwide, growth in discovered and exploited vulnerabilities per person per use, and organizations more networked with each other resulting in "cascade failure" risks.

- *The increasing number of persons on the Internet.* Internet users worldwide grew by a factor of 6 from 2001 to 2014 (half a billion to 3 billion). It may not be obvious that the number of users is a dimension in some attack surfaces, but some measures of attack surface also include the value of a target, which would be partly a function of number of users (e.g., gaining access to more personal records)[10] Also, on a global scale, it acts as an important multiplier on the following dimensions.
- *The number of uses per person for online resources.* The varied uses of the Internet, total time spent on the Internet, use of credit cards, and various services that require the storage of personal data-automated transactions are growing. Per person. Worldwide. For example, since 2001 the number of websites alone has grown at a rate five times faster than the number of users—a billion total by 2014. Connected devices constitute another potential way for an individual to use the Internet even without their active involvement. One forecast regarding the "Internet of Things" (IoT) was made by Gartner, Inc: "4.9 billion connected things will be in use in 2015, up 30 percent from 2014, and will reach 25 billion by 2020."[11] A key concern here is the lack of consistent security in designs. The National Security Telecommunications Advisory Committee determined that "there is a small—and rapidly closing—window to ensure that the IoT is adopted in a way that maximizes security and minimizes risk. If the country fails to do so, it will be coping with the consequences for generations."[12]

- *Vulnerabilities increase.* A natural consequence of the previous two factors is the number of ways such uses can be exploited increases. This is due to the increase in systems and devices with potential vulnerabilities, even if vulnerabilities per system or device do not increase. At least the number of *discovered* vulnerabilities will increase partly because the number of people actively seeking and exploiting vulnerabilities increases. And more of those will be from well-organized and well-funded teams of individuals working for national sponsors.
- *The possibility of a major breach "cascade."* More large organizations are finding efficiencies from being more connected. The fact that Target was breached through a vendor raises the possibility of the same attack affecting multiple organizations. Organizations like Target have many vendors, several of which in turn have multiple large corporate and government clients. Mapping this cyber-ecosystem of connections would be almost impossible, since it would certainly require all these organizations to divulge sensitive information. So the kind of publicly available metrics we have for the previous three factors in this list do not exist for this one. But we suspect most large organizations could just be one or two degrees of separation from each other.

It seems reasonable that of these four trends the earlier trends magnify the latter trends. If so, the risk of the major breach "cascade" event could grow faster than the growth rate of the first couple of trends.

Our naïve, and obvious, hypothesis? Attack surface and breach are correlated. If this holds true, then we haven't seen anything yet. We are heading into a historic growth in attack surface, and hence breach, which will eclipse what has been seen to date. Given all this, the FBI director's comments and the statements of Lloyd's of London insurers cannot be dismissed as alarmist. Even with the giant breaches like Target, Anthem, and Sony behind us, we believe we haven't seen "The Big One" yet.

The Cyber Threat Response

It's a bit of a catch-22 in that success in business is highly correlated with exposure. Banking, buying, getting medical attention, and even being employed is predicated on exposure. You need to expose data to transact business, and if you want to do more business, that means more attack surface. When you are exposed, you can be seen and affected in unexpected and malicious ways. In defense, cybersecurity professionals try to "harden" systems—that is, removing all nonessentials, including programs, users,

data, privileges, and vulnerabilities. Hardening shrinks, but does not eliminate, attack surface. Yet even this partial reduction in attack surface requires significant resources, and the trends show that the resource requirements will grow.

Generally, executive-level attention on cybersecurity risks has increased, and attention is followed by resources. The boardroom is beginning to ask questions like "Will we be breached?" or "Are we better than Sony?" or "Did we spend enough on the right risks?" Asking these questions eventually brings some to hire a chief information security officer (CISO). The first Fortune 100 CISO role emerged more than 20 years ago, but for most of that time growth in CISOs was slow. *CFO Magazine* acknowledged that hiring a CISO as recently as 2008 would have been considered "superfluous."[13] In fact, large companies are still in the process of hiring their first CISOs, many just after they suffer major breaches. By the time this book was written, Target finally hired their first CISO,[14] and JPMorgan did likewise after their breach.[15]

In addition to merely asking these questions and creating a management-level role for information security, corporations have been showing a willingness, perhaps more slowly than cybersecurity professionals would like, to allocate serious resources to this problem:

- Just after the 9/11 attacks the annual cybersecurity market in the United States was $4.1 billion.[16] By 2015 the information technology budget of the United States Defense Department had grown to $36.7 billion.[17]
- This does not include $1.4 billion in startup investments for new cybersecurity-related firms.[18]
- Cybersecurity budgets have grown at about twice the rate of IT budgets overall.[19]

So what do organizations do with this new executive visibility and inflow of money to cybersecurity? Mostly, they seek out vulnerabilities, detect attacks, and eliminate compromises. Of course, the size of the attack surface and the sheer volume of vulnerabilities, attacks, and compromises means organizations must make tough choices; not everything gets fixed, stopped, recovered, and so forth. There will need to be some form of acceptable (tolerable) losses. What risks are acceptable is often not documented, and when they are, they are stated in soft, unquantified terms that cannot be used clearly in a calculation to determine if a given expenditure is justified or not.

On the vulnerability side of the equation, this has led to what is called "vulnerability management." An extension on the attack side is "security event management," which can generalize to "security management." More recently there is "threat intelligence" and the emerging phrase "threat management."