



# TRILLIONS

THRIVING IN THE EMERGING  
INFORMATION ECOLOGY

PETER LUCAS   JOE BALLAY   MICKEY McMANUS



Praise for  
**TRILLIONS**

"MAYA Design's *Trillions* dangles a tantalizing and provocative notion: we can reach a promised land of prosperity by immersing ourselves in 'pervasive computing,' but we'll have to backpedal down the path of personal computing to get there. With sharp logic and vivid examples, *Trillions* builds the case for a truly networked future through an enjoyable series of forehead-slapping realizations. This is more than a book—it's a 200-page TED talk."

—**Daniel Altman**, Chief Economist of Big Think and author of *Outrageous Fortunes: The Twelve Surprising Trends That Will Reshape the Global Economy*

"Depending on your readiness to adapt to a hyper-connected world, there's tremendous opportunity—and tremendous threat—on the horizon. And therein lies the danger: companies that miss this paradigm shift may find themselves the road kill of their industries.

*Trillions* explains this complex transformation, and its implications, in an engaging and intelligible style that even non-geeks can appreciate. The book does what we can only hope our devices of the future will do as well: it remembers that a human is reading its pages, not a processor, and tames the complexity of the thesis so that the message never falls victim to the underpinnings of the argument. My remote should take a lesson from these authors."

—**Linda Tischler**, Senior Editor, *Fast Company*

"*Trillions* is bold, unabashed, ingenious, and absolutely fizzing with insights about the new-modern process of blending design, high-tech, and commerce. Always entertaining and mostly right on target."

—**David Brin**, author of *Earth*, *The Postman*, and *The Transparent Society*

"While it isn't written specifically with healthcare examples, *Trillions* is a wake-up call for our industry. It outlines a path that could lead to a rich and fertile future. It hints at the limitless potential of a world where computers become human-literate and are woven into a rich and healthy tapestry that could democratize and enrich medicine."

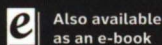
—**Eric Topol**, Director, Scripps Translational Science Institute, and author of *The Creative Destruction of Medicine*

"The authors of *Trillions* have laid out a framework for how to think about the future of big data and networked information systems, as well as the symbiotic relationship between the digital world, business, and humanity. This book will affect how we engage consumers, create experiences, and interact with products and services—it is a must read for any organization looking to be digitally fit for the future."

—**B. Bonin Bough**, Vice President, Global Media and Consumer Engagement, Kraft Foods

"If you're enchanted by Siri, have already placed an order for Google Glass, and think we've plucked only the low-hanging fruit from the tree of digital delights, this book is for you. With *Trillions*, authors [redacted] to the bar alongside futurists Alvin Toffler, Kevin Kelly, and Arthur C. Clarke. [redacted] argued you'll only be surprised if it doesn't happen."

—**John C. Abell**, journalist at Reuters, former New York Times  
Founding Editor of Reuters.com





LUCAS  
BALLAY  
McMANUS

# BRILLIANCE

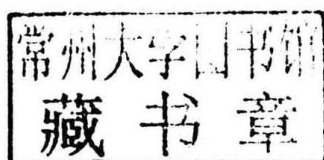
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# TRILLIONS

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INFORMATION ECOLOGY

**PETER LUCAS**  
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**MICKEY McMANUS**



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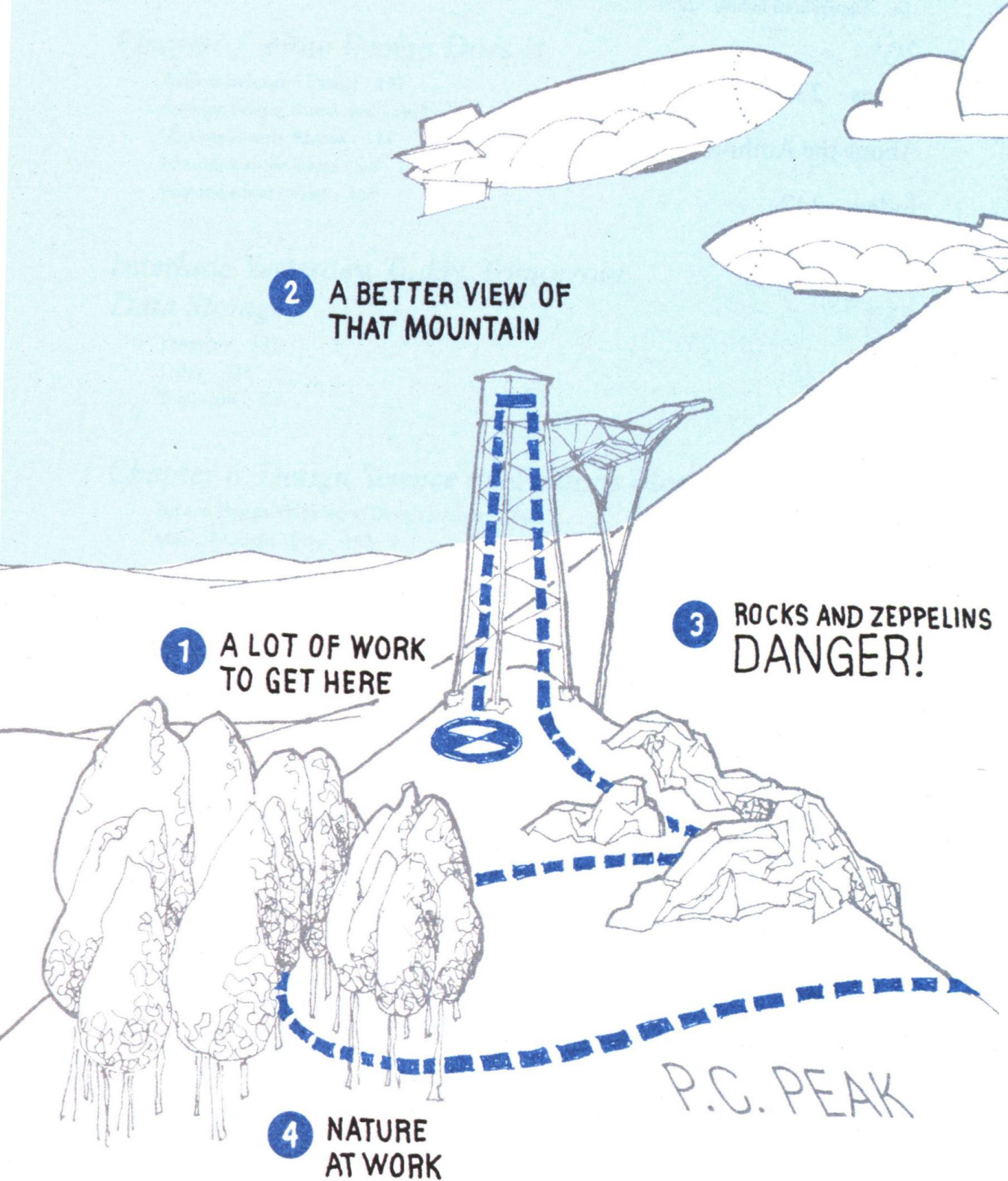
*To Diana, Sue, and Lynn*





# ROUTE MAP FOR THE ASCENT OF TRILLIONS MOUNTAIN

NOT TO SCALE



2 A BETTER VIEW OF  
THAT MOUNTAIN

1 A LOT OF WORK  
TO GET HERE

3 ROCKS AND ZEPPELINS  
DANGER!

4 NATURE  
AT WORK

P.C. PEAK



GRAND REPOSITORY IN THE SKY

**9** VAST BUSINESS OPPORTUNITIES

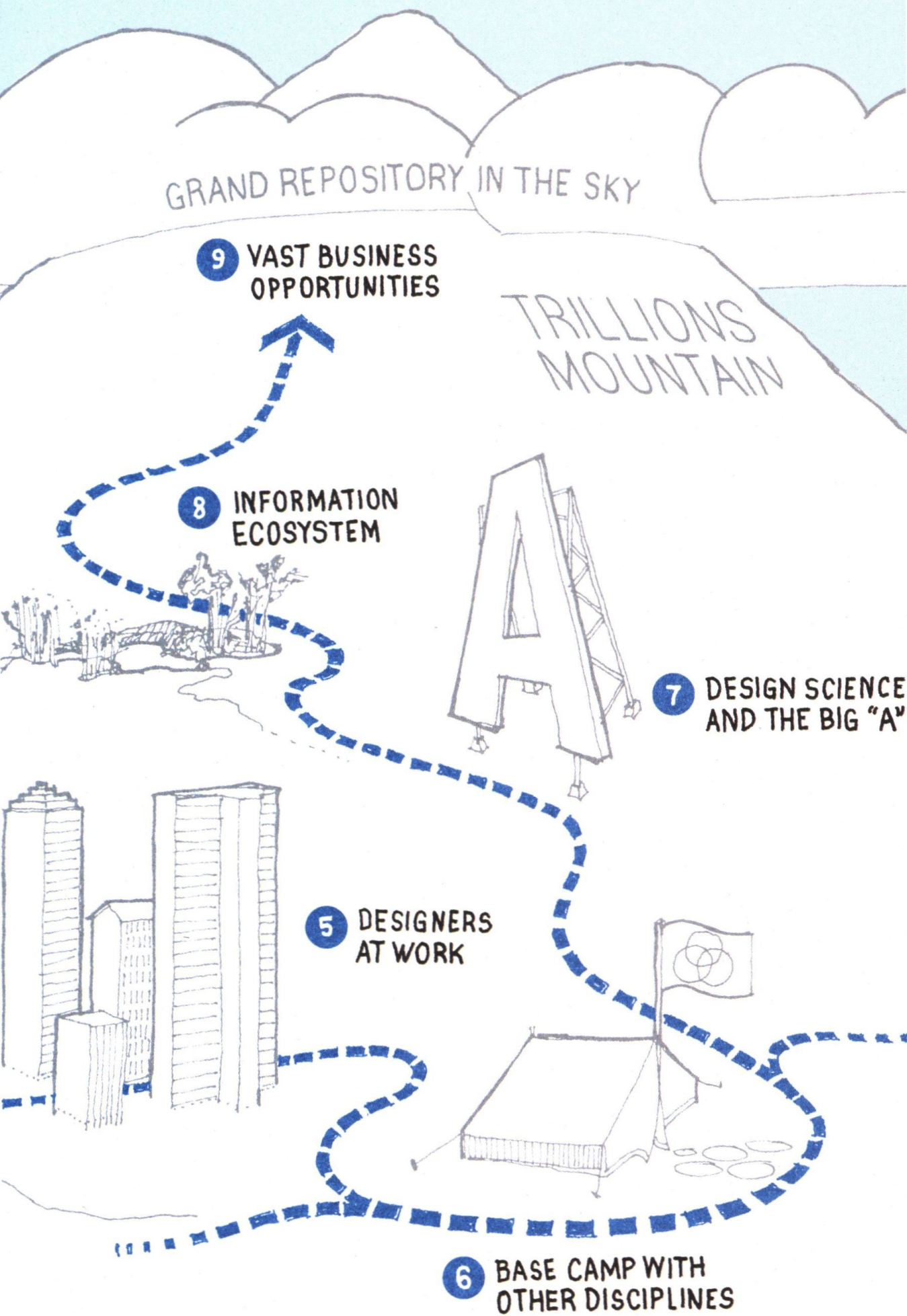
TRILLIONS MOUNTAIN

**8** INFORMATION ECOSYSTEM

**7** DESIGN SCIENCE AND THE BIG "A"

**5** DESIGNERS AT WORK

**6** BASE CAMP WITH OTHER DISCIPLINES







# Preface

## TWO MOUNTAINS

The ruling metaphor for technological change is that of successive waves of innovation. We envision each paradigm shift and its corresponding rearrangement of the way we live as a wave that comes crashing down on our beach just as the tumult of the previous one begins to recede. This book is about two such waves—the rise of mass-market computing and the age of pervasive computing that is about to supplant it. For reasons that will become clear, we have chosen a slightly different metaphor to describe this particular sequence: that of climbing two adjacent mountains.<sup>1</sup>

Anyone who has climbed a real mountain (at least if they did so in the days before GPS) knows the experience of a long slog through the forest, during which one's exact position (and thus the status of the climb) can be known only vaguely. But then suddenly the timberline is reached and the accompanying long, clear sight lines produce an abrupt sense of orientation and perspective, after which one's relationship to the summit is correspondingly clear. When we started MAYA Design in 1989, we, and the industry we proposed to serve, had not yet reached the timberline of PC Peak. (This was an era in which the most complex technology to be found in the average home was a VCR, with its flashing "12:00" serving as a taunting harbinger of usability nightmares to come.) Our plan was to offer our services as a kind of mountain guide for the many industries that suddenly found themselves in the complexity business. Nobody quite knew what we were climbing toward or how long it would take to get there. But everybody knew that climb we must. It did not take long for the view to clarify. By the mid-1990s the Internet had gone mainstream, more or less everybody had a PC, and the agenda for the next decade or so was pretty much set. The path to the summit was suddenly obvious.

But, there was more to this newly clear view than most people noticed. While most eyes were (and remain today) firmly fixed on the summit, those who cast their gaze more widely discerned a surprise. PC Peak, which we have been climbing since the 1970s does not stand alone in the technological landscape. It has an adjacent companion—one with a much higher summit. This second peak is called Trillions Mountain, and it towers far over our current perch.

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<sup>1</sup>The metaphor isn't actually all that different, mountains merely being waves in an unusually viscous medium.

For many years, the only important computing device in a typical home or business was the personal computer (PC), first on the desktop and then on the laptop. In only the past few years, this has suddenly changed, with smartphones and tablet computers well on the way toward eclipsing the PC for most purposes. The term *pervasive computing*<sup>2</sup> refers to the assumption—now widely held by people who pay attention to such trends—that this transition, dramatic though it is, is just the first step in a far more fundamental change. Rather than moving computation out of one kind of box into other—smaller and more portable—boxes, by the end of this transition computing will for all practical purposes be confined to no box at all. Computation (and thus data) will all but literally have escaped into the ambient environment. We already put microprocessors into nearly every significant thing that we manufacture, and we are quickly figuring out how to make those processors usefully communicate with each other, and with us. Moreover, the cost of routine computing and storage is rapidly becoming negligible. We are, as we shall see, well on our way to a world with trillions of computers. Once these trends get past their initial chaotic stage, they will quickly coalesce into something new and disruptive: an *environment* of computation. Not computation that we *use*, but computation that we *live in*.

We are by no means the first to make this observation. As we have said, these trends are widely recognized. But most of what has been written on the topic comes in one of two forms. The first of these comprise world of tomorrow gee-whiz stories about the wonders to come—how houses will cater to our whims; power grids will become intelligent; and tractors will drive themselves through fields sown not just with seeds, but also with millions of “smart dust” moisture and nutrient sensors. The second form is written by and for computer scientists, dealing with tricky nuts-and-bolts issues such as distributed databases, self-configuring mesh networks, and “device discovery” protocols.

This book is neither of these. Although we do present examples, and at places verge on the technical, neither represents our main point. The book is really about *people*—how we might arrange for them to live well in this new kind of built environment, and how we might botch the job. In other words, it is about *design*. Exactly what that means, and what it takes to be an effective designer is a topic that needs a fresh look in each technological epoch. What it takes in the present era and the profound impact of this new mode of design on the business world are the major themes of this work.

The occasion for the book is the upcoming twenty-fifth anniversary of our company, MAYA Design. However, it is not intended as a self-congratulatory

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<sup>2</sup>Academics love to fight about names. The term *pervasive computing* has a major competitor in the literature: *ubiquitous computing*. As far as we can tell, the terms are synonymous. However, there seem to be sensitivities attached to the use of one or the other term, apparently having to do with concerns over whom history will recognize as the founders of the discipline. We have no dog in that fight. We use *pervasive computing* because we think it sounds better than the awkward *ubiquitous computing* and especially its common but hideous contraction *ubicomp*. Such things matter.



*festschrift*. We will keep our personal war stories to a minimum, and those we do tell are offered more in the spirit of a foot soldier's diary than a general's memoir. But they are, we think, worth the telling. For, they were culled from almost a quarter-century of intimate collaboration with engineers and marketing professionals from many of the world's most successful and advanced organizations.

As a business, MAYA is uniquely structured. In many ways, we reflect the tradition of the great industrial design consultancies of the 1940s and 1950s.<sup>3</sup> The majority of our work involves long-term consulting relationships with firms that develop and market technological products and services. But we also have many of the attributes of an industrial R&D lab, performing applied research in areas of relevance to our commercial work. In any given week, a designer at MAYA might spend time helping a new tech startup launch a tablet-based pervasive computing service; working on a project with one of our Fortune 500 clients developing a long-term product architecture; and exploring a DARPA-funded technology that will not be commercially viable for a decade. The hybrid nature of this project mix is virtuous in both directions: It lets us help our commercial clients see past the pressures of the next quarter and thus avoid the often-fatal pitfalls of local hill climbing, and it encourages us to focus our research efforts toward practical issues that are likely to really matter to the humans that are always at the center of our attention.

This is a book with three authors, a fact that would be blatantly obvious even absent the names on the cover. We have tried to even out the voices, at least in the main body of the text. But truth be known, we have not tried all that hard. The presence of three very different voices, and several others that show up from time to time, is an essential part of our story. They reflect a belief—at the very heart of MAYA's approach to design—that the problems we and our clients now face are beyond the ken of any one disciplinary tradition. From the day we opened our doors, we have brought together engineers, human scientists, and visual designers in the conviction that triangulating from all three of these disciplinary perspectives represents our best hope for getting the future right. We have never looked back.

We created MAYA at a time when the practice of interdisciplinary design was rare and the idea of human-centered design in computing and information systems was nascent. We maintain a belief that the hard problems that people, organizations, communities, and cultures will face in the coming years can only be solved at the intersection of how people think, how technology works, and what form and function the desired solution takes.

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<sup>3</sup> Our name, "MAYA"—an acronym standing for "Most Advanced Yet Acceptable"—is an homage to Raymond Loewy, one of several role models from among this group, who often spoke of his goal for a design to reach "the MAYA stage."



## A FIELD GUIDE TO TRILLIONS MOUNTAIN

And so, we find ourselves at the very apex of PC Peak. It was a long, tough climb, but we made it. We desperately want to go even higher, so we have taken to building fire towers, and extensions upon those. But the skills that got us to this eminence don't help much here at the top, so the towers are rickety and dangerous. Everybody sees Trillions Mountain out there across the valley, rising far above us into the clouds. But most people avert their eyes. We climb up, not down; and down appears to be the only way to get over there. Plus, we don't even know how to climb that kind of a mountain. So, it's back to the fire towers. Others busy themselves trying to cantilever a bridge out in the new mountain's direction. That isn't going too well, either.

But a few of us are ready to bite the bullet and start the trip, even if it means reversing some hard-won progress and then mapping a whole new territory. If you're up for the journey, we hope that this book will be of some assistance.

We begin with an overview of what we can see of Trillions Mountain from our present viewpoint. Most of the prerequisites to the emergence of pervasive computing are already in place, and many of the remaining developments are well underway. Although these claims are not really controversial, their implications are not well-known to many people, even within the industry, so Chapter 1 is intended as a kind of executive summary of progress to date. Chapter 2, while a bit more speculative, explores a set of possibilities that are certainly possible and in our judgment both likely and desirable.

Chapter 3 concerns itself with those rickety fire towers. As the industry climbed upward from the spacious foothills of the current mountain to the crowded heights, increased competition for a dwindling set of opportunities has led to some pretty risky behaviors. Here we will explore some of the less-than-healthy aspects of today's computing scene, with special emphasis on those that represent significant threats to the unfolding of a safe and sane technological future.

We then begin to plan our climb up Trillions Mountain. There are many novel challenges ahead, but most of them share a common basis. That basis is *complexity*. More than anything else, what will distinguish computing in the future from computing in the past are sheer scale and the complexity that comes with it. Devices will exist in unprecedented numbers, as will occasions for human-machine interactions. The design techniques that have served us well on PC Peak will be wholly inadequate for the problems of scale that we will soon face.

These are unfamiliar issues to the computing world, but they are not without precedent. The next section of the book examines some of these precedents and what we might learn from them. Chapter 4 examines the ultimate master of distributed complexity: Nature herself. We explore the basic self-organizational patterns of natural systems and how they inform steps toward



the creation of an ecology of information devices. Chapter 5 looks at the design process itself, both from an historical and contemporary perspective. Finally, Chapters 6 and 7 bring science into the story, examining the thesis that the notions of *design* and *science* are not, as is often assumed, disjoint activities. We pay special attention to the generalization of the concept of architecture as the basis for a scientific approach to the design process.

The last two chapters, Chapters 8 and 9, attempt to pull this material together into a coherent, if fuzzy, image of life in the foothills of Trillions Mountain. We know better than to be too specific here, but it is possible to discern the broad strokes of how the story of pervasive computing is likely to unfold, and in these chapters we lay them out in as much specificity as we dare.

Finally, scattered throughout is a fair amount of supplementary material, which we hope will support and reinforce the main thread of the text. Each of us indulges in a bit of first-person storytelling, as do a few of our MAYA colleagues. Included here are a number of case studies describing both examples of our research activities and commercial work done in collaboration with our clients. You will also encounter references to various audio, video, and interactive material, which can be found at the book's website: [TRILLIONS.MAYA.COM](http://TRILLIONS.MAYA.COM).

There are also two “interludes” — minichapters whose purpose is to place examples of these trends into their historical context. We end the book with an epilogue containing material specifically aimed toward members of the business community as they face the challenges raised by the advent of pervasive technologies.

Some topics that are discussed in *Trillions* really deserve dedicated books in their own right. Much of the research work that has been done by our small band and by others is still very much in progress as this book goes to print. However, where possible, we have included pointers in the end pages to where you can drill deeper into the topics we have touched.





# Acknowledgments

It is customary for authors of works of nonfiction to whine to their readers about the impossibility of thanking everyone that they should. We certainly have no cause to break with this tradition. Indeed, our situation is worse than most. The contents of this book are not the results of a bounded research project. Rather, they are the collective product of a quarter-century collaboration, not only among the authors, or even among the hundreds of design professionals who have worked at MAYA over the years. Rather, the circle of credit extends in a most fundamental way to include the many extraordinary clients with whom we have been privileged to work. The countless intimate collaborations with our clients' engineers, designers, marketers, and managers are the wellspring of whatever insights we may have to offer. To mention even a few would be a disservice to many others of equal importance, so we can only acknowledge the depth and breadth of our debt here. And, of course, the collective contribution of everyone in the MAYA family—past and present—is vast beyond calculation.

In thanking those with a direct hand in the creation of the book itself, we must begin with Ralph Lombreglia. Whatever success we have had in making unfamiliar and complex topics accessible to the general reader has benefited greatly from his fine rhetorical sensibilities and his unfailing good advice throughout the project. A number of longtime MAYAns have also been direct contributors to the text: Jeff Senn—a genuine polymath who has been a core member of the MAYA family since the day we opened our doors—has made countless contributions both to the ideas and to the words themselves. Bill Lucas (no relation to Pete) and David Bishop have each taken the time to write essays that we have gratefully included in the text.

Nearly everyone in the MAYA companies has read early drafts of the manuscript, and many have provided valuable feedback. Special recognition must go to Dutch MacDonald, who has regularly provided detailed feedback on all aspects of the project while also managing to keep the business on an even keel during our frequent bouts of book-driven inattention. Lori Paul, our treasured executive assistant (a title that vastly understates her value), has been characteristically masterful at keeping the process moving forward amidst the background chaos of a busy consultancy. Thanks are also due to Chris DeMarco for technical support and Christen Adels for attending to legal matters.