[THE]
MATHEMATICAL CORPORATION

Where Machine Intelligence
[+] Human Ingenuity
Achieve the Impossible

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To all the courageous, inspiring clients we've had the pleasure of knowing. Your work across the corporate, government, and nonprofit worlds is changing everything.

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INTRODUCTION

The Big Mind of the Mathematical Corporation

IMAGINE YOU ARE FLYING OVER A MAJOR CITY AT NIGHT—SAY, Chicago or Paris or Beijing—and it is completely dark below. All you see is a void of light akin to nighttime in the middle of the ocean. Then imagine that, as you're looking down, someone flips on the power grid, and you see today's web of human activity light up. Imagine further that someone flips the switch again, and you glimpse a future image of the city. Where you once thought there was nothing, you see a universe of action—both present and future. Enormous detail radiates from the darkness, and you perceive and envision features you never knew existed.

This ability to "flip the switch" to see formerly hidden detail and vital insights about the future expresses the potential of the mathematical corporation. Thanks to leaps in technology, we can get a new fine-grained, high-resolution picture of aspects we could never distinguish before. With machine intelligence, built on the bundle of technologies known as data science, we can see patterns, anomalies, and associations that were previously cloaked in obscurity.

But this ability stems not just from technology. It also results from a new form of leadership. This is the type of leadership that illuminates the darkness by shattering constraints on thinking you may have long accepted—above all, the rigid belief that the best

decisions always result from intuition and experience. As these constraints—those you recognize and those you do not—fall, every system and business process in your organization will reverberate with change. Every strategy in every industry will fundamentally shift.

Five years ago, we set out to discover how technology combined with new forms of leadership and faster innovation would affect business, government, and nonprofit organizations. After researching hundreds of organizations, we have distilled the elements that comprise the model of winning organizations of the future, organizations we call mathematical corporations.

We dub this new kind of organization the mathematical corporation because it is driven by data. The data feed ingenious algorithms. And when you lead this kind of organization, you practice a new kind of scientific management infused with inspirational leadership and purpose.

The mathematical corporation does not just look back at what successful companies have done. A backward look cannot hold the secrets to future results because new technology and thinking create breakthroughs that couldn't be conceived in the past. A forward look, revealed through examples of pioneers experimenting on the horizon, is the road map to success.

Indeed, a forward look reveals required skills, emerging strategies, innovative technology, and lessons learned about cultivating talent and organizational change. This forward look provides a guide to thinking and acting as a leader, in particular, developing what we call "future power." Future power is the ability to apply specific leadership techniques in league with machine intelligence technologies to see future possibilities and shape the future.

No organization today is a mature mathematical corporation. That's because becoming one is not as easy as "flipping the switch." But a number of leaders have put the critical pieces in place—combining new thinking, new applications of data, and advanced computation to take advantage of opportunities that emerge as a new era unfolds. These leaders understand that their innovations in

technology and strategy are overturning old approaches in the same way that the quality movement in the 1980s and the Internet in the late 1990s "changed everything."

This transformation, a shift to embracing complexity to reveal truths and predict future possibilities and outcomes, demonstrates the significance and power of the mathematical corporation. Once you break constraints you may not even know exist, you can tap machines to predict the course of events. You can conceive of advances you didn't think of before. And you can unleash your imagination to prescribe solutions to problems that weren't formerly apparent.

The leaders of mathematical corporations of course use analytics and "big data" as well as artificial intelligence and other advanced technology. But the capabilities of the mathematical corporation extend beyond mining big data sets, a decade-long endeavor that has focused organizations narrowly on answering known questions by querying specific, often proprietary, piles of data.

The mathematical corporation focuses also on answering unknown questions by querying a universe of data—more open and ubiquitous all the time. By searching for and answering questions outside the spotlight of conventional thought, it provides knowledge about the future, breaking through the darkness of past constraints. From an expanded grid of detail, to which you apply new thinking and new approaches to knowledge discovery, the mathematical corporation opens up choices and lines of decision making you never had before.

If the past was about analytics and big data, the future is about the big mind of the mathematical corporation. Big mind comes from combining the mathematical smarts of machines with your own imaginative intellect. And this triggers the next leap in organizational performance.

Big mind may help you identify hacking in your financial system that was once too subtle to see. Or discover new energy sources that eliminate batteries and wires. Or find hiccups in your global

supply chain that propel warranty claims. Or identify flaws in company policies that spur employee healthcare costs. Or produce as yet unsynthesized materials that double the service life of products from tires to artificial hips. Or launch new businesses for which machine and human intelligence embedded in software—as in self-driving trucks—produces ten times the value of the base product itself.

Big mind may also help you determine how epidemics start and how to stop them. Or predict why crime waves sweep certain locales and show how to prevent them. Or analyze megacity traffic bottlenecks and devise how to eliminate them. Or address global conundrums like poverty, terrorism, and climate change.

In the pages ahead, we describe leaders who are addressing just these types of problems. At companies like Merck and InterContinental Hotels Group and Bloomberg LP. At government agencies like the US Census Bureau, Federal Aviation Administration, and US Army. At nonprofits like Polaris, the anti–human trafficking organization, and the Simon-Skjodt Center for the Prevention of Genocide. Leaders at these organizations have convinced us—and they will convince you—that developing the big mind of the mathematical corporation is inevitable—and imperative.

Because, as you see more, learn more, and infer more, you have the power to act more decisively to fulfill new missions. As computers manage the complexity of newly illuminated minutiae, you have more power to tackle the complexity of decision making—managing what has heretofore been thought of as unmanageable. The power of the mathematical corporation is as important to creating value for your customers and society as land, labor, and capital were in the past. This future power will drive you to ask bigger questions than you've ever asked before. It will allow you to generate the foresight to better see the future and to devise solutions that were once impossible to conceive.

This power to search for the secrets hidden in this once unknowable universe—secrets about the workings of human systems,

ecosystems, social systems, organizational systems, and urban systems like those in Chicago, Paris, and Beijing—gives you the ability to understand the workings of those systems like never before. It brings you to an epochal tipping point where the whole of individual technologies, put to work with human intellect, comes to equal more than the sum of the parts.

BIG MIND, BIG GAINS

The mathematical corporation is based on a timeless principle: the magic is in the details. (Okay, yes, sometimes the devil is, too.) Perhaps it's not surprising that this principle informs superior performers across human endeavor. The great jazz clarinetist and bandleader of the twentieth century Benny Goodman once said, "Sometimes when you start losing detail, whether it's in music or in life . . . you start to lose substance." Goodman was not talking about the work of organizations, but he could have been. Although most of us avoid as much complexity as we can, *we lose substance by doing so.*

In the past, we actually haven't had much choice, even if we knew better. Who could summon the energy to master all the details we would like to know to run our organizations optimally? Or even the details we *must* know? Especially these days. We have more data than ever about every street corner of knowledge in the universe. To get along in life, we just can't let too much of that light of knowledge shine in our eyes. It becomes overwhelming.

That's changing, though, big time. No matter the field in which you work, you can engage the mathematical corporation to process all the minute details of all manner of complex systems. And you can do so through new leadership, culture, and strategies based on machine intelligence—the multidisciplinary field of math, computer science, artificial intelligence, predictive modeling, and related disciplines. If you embrace the jazz of work and life, you will describe complexity you never could before. You will discover

secrets you didn't know. You will predict futures you couldn't imagine. And you will prescribe breakthrough ways to succeed.

The question, then, is how do you make this happen? If you are the leader writing the marching orders for your organization, what is your role? What do you need to do to "flip on the grid"?

Those are the questions we answer in this book, and we answer them in two steps. The first is how to change the way you think. The second is how to change the way you act.

We show how to develop thinking skills to work in partnership with machines. How to break old perspectives about what's possible in the newest, biggest cities of data. How to muscle up your organization with new technology that takes you to a new level. How to devise strategies—once impossible strategies—to deliver superb performance, no matter your mission.

Mark Fields, the CEO of Ford Motor Company, has been taking steps to make Ford a mathematical corporation. By collecting and analyzing complex hidden data, he hopes to spur breakthroughs in Ford's products that were once the stuff of dreams. In 2015, Fields directed Ford to undertake twenty-five "experiments" to learn the secrets of all factors having to do with transportation.

In one experiment, two hundred Ford employee-volunteers began driving cars whose sensors collected up to twenty-five gigabytes of data an hour. As the data poured back to Ford, the company began searching for patterns that most customers, and competitors, couldn't see. The objective was to find new insights to help it improve its products and systems—and create new systems—to better serve customers.

Ford, like its competitors in the auto business, once surveyed customers for views about vehicles, customer satisfaction, and value for the money. The results enabled it to draw reasonable conclusions based on a *sampling* of reality. But, in the future, the company will analyze data about actual behavior of every customer that are so granular and high resolution that it will unravel mysteries about

how people move (what Fields calls "mobility"), how they like to feel ("the customer experience"), and what new things will appeal to them ("features and services of value"). And it will do this not via surveys of what people say but with data on what people do.

With the information Ford is collecting, the company will potentially discover every detail about the car and driver relationship: how drivers use their vehicles, where they're driving, what the road conditions are, even how great are the electromagnetic forces affecting the vehicle—in fact, hundreds of factors to improve the quality, safety, fuel economy, and emissions of the vehicle. Ultimately, insights will stem from collecting and analyzing all the data from the car's sensors, a job of scale and scope beyond anything possible with the tools and technology of the past.

Ford's move toward being a mathematical corporation illustrates a key point: our work and lives are evolving to a stage in which we will operate in two parallel worlds, the real and the digital. Each is a reflection of the other. We are already well along on this path. Eventually, the digital world will record once unfathomable subtlety, beauty, intricacy, and interconnectedness—molecular-level specifics beyond what humans can perceive. That detail will give us an alternative form of vision, the vision to ask once impossible questions.

In the business world, Fields ranks among a select number of CEOs outside technology businesses who have made a big, public commitment to profiting from this change, extracting from the digital world insights humans cannot perceive. In the high-tech world, Google, Tesla, and Amazon are leaders. This is a world where the digital infrastructure will not just sense and sample selected parts of life. It will, over time, measure and capture nearly all of human experience, as if every riff, note, and beat in the jazz of the big city were etched into a digital record. This is the resource—too big for a human alone to grapple with—that we will use to craft once impossible solutions, from self-driving cars to auto insurance tailored to every single driver.

A GENUINE LEAP

We have long had to constrain our thinking about the world because we didn't have the technology to either gather or analyze the volume, variety, and velocity of data now radiating from the world's devices. Even when we did have a lot of data, our approach—everyone's approach—was to grasp complex systems through a host of simple, often simplistic, rule-of-thumb mental models. These models only crudely approximated reality. We lacked the ability to make sense of the atomic-level nits and bits of the systems we work and live within.

But that ability is now at hand. As machines ingest and process ever more detail, computer models can do what people cannot, and consistently outstrip our crude, intuition-based mental performance. The ramifications of this development are bigger than many people think. You will make decisions based on deeper and broader inquiries. (What products or services can we create that will launch entirely new industries?) You will simulate and predict the future with genuine reliability. (How will drones and driverless trucks change our delivery model?)

This is not to suggest that you will give over the job of leadership to a machine. Quite the opposite. Machines are still a long way from being that good. The mathematical corporation provides new and exciting ways for people to employ unique human qualities at a higher level. The supercharged human ingenuity you will wield in the real world will stem from the thought-like operation of machines in the digital one.

Only leaders who learn to assemble the pieces and tap their potential will realize the benefits of this marriage, however. This requires personal growth and organizational change. Both are required if you are to make the mathematical corporation succeed.

Ford is investing in everything from apps that coach drivers on parking to software that records a driver's activity as proof for lower insurance rates to a system that directs ambulances to accident scenes. Fields calls it "a series of experiments and open-innovation challenges

around the world that will help us learn and shape our business for the future." He also says, "For us, it adds up to an opportunity."

You may pause here and rightfully ask: Have I heard this before? Is the opportunity being oversold? Does the detail in the parallel digital universe really promise that much payback? History shows that an awful lot of money is poured down the technology drain, never to improve performance. Can a commitment to mastering the world of ubiquitous data through the machinery and human intelligence of the mathematical corporation do that much? Aside from the stories of Uber and Airbnb, isn't this all simply a retooling of the current engines of commerce?

If you look closely, hints of the expanding potential emerge all around us. In late 2015, drug maker GlaxoSmithKline (GSK), in partnership with Boston-based Epidemico, a health information start-up at the Boston Children's Hospital, trawled Facebook and Twitter data for information about side effects of GSK's drugs. It found 21 million mentions. At final count, mentions of so-called adverse events on social media in one year not only prompted the recall of one GSK product but also exceeded all those in the Food and Drug Administration database since its inception in 1968.

What's significant is not just that this new world of data exists—in a sense it has always existed around the water cooler in the "real" world—it's that GSK can access this new world to capture this trove. Tapping formerly inaccessible data via the emergence of the new digital world can reveal insights we otherwise could not attain. Epidemico used its algorithms to discard irrelevant posts, standardize what remained, tally side effects, and compare ill effects to benefits. Long-buried facts—facts vital to human health—emerged to help people immediately.

The mathematical corporation will change not only how you think about strategy but also how you run the back office, how you recruit and retain talent, how you identify customers and clients, how you work with suppliers and partners, how you develop new products. For many, the mathematical corporation will disrupt business as

usual and offer opportunities to launch new organizations, enter or invent new industries, and change the nature of competition. You will combine the power of big mind with impossible questions, strategies, and technology to change the world (see figure).

OUR WAY OF THINKING

We start in Chapter 1 by describing the scale and scope of the new hidden digital world. How big, diverse, and interesting is this "big city"? What you will see when you examine the digital reflection of life is that we can now find untold new knowledge where there once was none. This new knowledge can emerge in systems of human behavior (for example, how people shop and buy), or global transportation (dynamic routing to save time and fuel), or population health (treatment and control options for stopping diabetes and asthma), and many more.

That we now have the ability to answer questions that, until recently, were unanswerable comes from our having crossed technological thresholds related to speed, complexity, and data capture. The upshot is simple, yet profound: we can now investigate

Figure I.1 The Mathematical Corporation

mountains of data for new insights not by pulling them apart into manageable chunks but by keeping them together.

The magic comes from examining these formerly unmanageable quantities and varieties for new predictive insights. We tell the story of how Merck worked to improve yield during vaccine production in its four-stage manufacturing line; each product run took about forty hours, and many batches risked being discarded. What wasn't obvious by examining each step of the process—growing yeast, agitating, fermenting, and so on—stood out when the data were examined as a whole.

What does it mean to think with machines? The mathematical corporation obliges you to reconsider what you're good at. How do you stack up compared to a computer in each of ten cognitive capabilities? If you've always excelled in comprehension, perception, math, memory, or organization, you are now up against a brainy new competitor. As we show in Chapter 2, you'll soon be able to give over a lot—roughly half—of your cognitive work to the machine. As a leader, you need to evolve your focus to excelling through imagination, creativity, reasoning, and problem structuring.

At Ditto Labs, a start-up inspired by work at MIT, entrepreneur David Rose and his team gauge the brand strength of companies by combing through 130 million social media images daily. Ditto's success rides on the central ability to ask the right questions—a skill computers cannot match. The machine performs the once uniquely human jobs of recognizing patterns in posted photos (is it, for example, GSK's logo or Merck's?) and comprehending the photos' context (taken at the beach, in a bar, at the pharmacy?). Rose and his people meanwhile ask the bigger questions, for instance, Can we quantify a brand's strength via images on social media?

Rose's story leads us to examine how leaders of mathematical corporations handle their biases and limitations. As you make your mark in the era of the mathematical corporation, you have to break

through age-old constraints that have kept you, often unwittingly, from asking those "impossible questions." In Chapter 3, we show, among other techniques, how to reframe questions for this new era, reason more inductively, break free of reliance on proprietary data sets, and complement gut instinct with the more impartial judgment of machine models.

At Oregon State University's marine science center, director and fisheries oceanographer Bob Cowen broke through multiple constraints to better analyze ocean health. He ditched sampling the Pacific waters using nets and instead equipped his research ship to tow a high-speed camera (one made for identifying integrated circuit flaws in manufacturing). He then asked data scientists—technologists untrained in marine biology—to identify the plankton in sixty million photos. Sixty million! This was possible because data scientists could teach the machine to learn patterns they didn't know themselves.

All this would not be possible without the range of technologies we've been taking for granted. In Chapter 4, we describe the technologies in more detail—to be sure you grasp what's required for getting clean data for analysis, helping machines to learn and model, visualizing results to make breakthroughs, and investing in the infrastructure that supports it all. If you're going to find the treasure in complexity, you have to have the tools to see substance in the darkness.

We show what we mean with the example of Lawrence Berkeley National Laboratory, where scientists are demonstrating how computers can speed up the discovery of breakthrough materials for a variety of products. In the future, companies will calculate the crystal structure of molecules that have never been synthesized and in turn predict properties like elasticity and hardness—all with the help of computers.

Once, if you wanted to create a paint that was shiny, you had to experiment endlessly to find the right materials. You would have

consumed hours, days, months in the lab. Instead, by using computation, you can fast-track materials discovery by working on the machine alone. Some materials to be discovered will serve purposes much less mundane than paint. Higher-voltage electrodes for lithium-ion batteries is one. More efficient photovoltaics to better turn sunlight into electricity is another. Only in the last few years have computers been fast enough to do the necessary calculations.

That leads us to the next question for leaders. If the mathematical corporation can help you create such new, whiz-bang ways of doing things, what is its potential for enabling new strategies to fulfill new missions? In Chapter 5, we describe our process for coming up with breakthrough or "impossible" strategies by combining human ingenuity and the mathematical skills of machines. The secret is in using a version of rapid, iterative prototyping common in product development.

To describe what we mean, we develop further the story of Ford as well as that of JOOL Health, a start-up by University of Michigan professor Victor Strecher. Strecher, of the School of Public Health, has built a preventive care service that healthcare organizations and employers buy for their patients, subscribers, or employees. Individuals log in to their smartphones daily to rate five factors affecting their sense of life purpose—like sleep, creativity, and exercise. They then get advice from the "Aristotle Engine," an algorithm that extracts treatment suggestions from a variety of data sets.

The organizations, in turn, capture data on their populations' health, which they can use to intervene with new programs when they see red flags. Though early in development, Strecher's approach points to ways to upend the delivery of preventive health care.

Across organizations of all kinds, leaders are about to see that the mathematical corporation will allow them to slice through tangles of complexity to find answers that matter. The challenge is how to instigate change so people buy in to and drive the transformation.

So, in Chapter 6, we highlight elements of change management that apply specifically to establishing the mathematical corporation—building the team, shaping the culture, managing the talent, and managing biases.

At the US Census, chief operating officer Nancy Potok has attacked what is perhaps the most pervasive problem in government, culture change. Potok has spent recent years spurring innovation in part by championing a system in which people rank and publicize each of their project risks—and help each other work through them. One result will be an innovative new data science–driven mobile application for the 2020 census. "Enumerators," Census workers who go house to house, will follow algorithm-delivered advice on tablets. The system is expected to eliminate tens of thousands of miles of travel by the army of workers who visit households nationwide.

Because so many data today are personal—names, credit card numbers, locations, health records—you can't avoid tough choices about how to collect and use people's information. These choices are often not about what's legal but about what's "right" and "wrong." Making the right choice can make or break a new product, service, or mission. In Chapter 7, we outline the ethical reasoning you can apply to tough decisions and detail those issues you will most likely have to wrestle.

The issues boil down to how transparently you should treat your data use, handle privacy rights, safeguard data ownership, and manage security. The leaders of mathematical corporations have to get ahead of the curve of public opinion to avoid ethical questions that trigger an outcry from angry people, politicians, or both.

We drive this point home with the story of Euclid Analytics, where founding CEO Will Smith spent eighteen months alternately developing and defending his data-handling policies. Euclid gathers cell phone–emitted location data from shoppers in retail stores. These data feed an analysis of shopping behavior to customers like Nordstrom and Home Depot. Smith was called on the carpet: US

Senator Al Franken, a privacy crusader, urged Smith to answer probing questions about alleged practices he called troubling. But Smith, in a cross-industry policy development effort, ultimately won over the Federal Trade Commission and Franken's colleague and fellow privacy crusader US Senator Chuck Schumer.

The issue of ethics leads us to our final, and tough, leadership challenge. That's the degree to which you address societal problems beyond the ken of your organization. In our interconnected world, you can't ignore global, cross-sector problems like immigration, climate change, and world hunger. The impact of each of these issues sends ripples, if not stormy waves, onto the shores of all organizations. Given the power of machine intelligence to find new ways to ease these problems, we show in Chapter 8 three approaches to contributing to solutions: opening your data to help with societal improvement, aligning your organization's strategy with strategies for social good, and, if you're a corporate leader, using philanthropy to contribute money and skills to the larger good.

Bloomberg L.P., run by founder Michael Bloomberg—for twelve years mayor of New York City—has embraced the task on all levels. The company has charged data science chief Gideon Mann with running the annual Data for Good Exchange in New York, a forum to put corporate techies in touch with organizations that need help using machine intelligence for societal benefit. Bloomberg also sponsors a data scientist at UNICEF, which is using Bloomberg financial data to investigate the effect of one company's adoption of child labor policies on the policies of all other companies in its supply chain—Apple's effect on Foxconn, for example. UNICEF hopes to use the global business, financial information, and media giant's data sets to catalyze a reduction of child labor common in global sourcing.

This final chapter on social good makes an impressive case for the potential impact of the mathematical corporation. If you're like us, you will realize something else: leading in this era requires a dose

of humility. The parallel digital world, though a work in progress, is rapidly illuminating every detail in your field of mastery. The machine is processing big-city complexity with such alacrity that you might feel like your skills are being overtaken.

Imagine you are a physics student studying the principles of light as a wave. All of a sudden, someone tells you that, according to new research, light travels with the characteristics of not just waves but also particles. You think, uh oh, there's a whole other thing going on, and I don't know anything about it. The good news is that, with machine intelligence, this gap actually reveals an opportunity—if you choose to bridge it. You can combine your strongest competencies with the machine's evolving capabilities to master the detail, to create new substance.

Now is the time to grab opportunities to reap big rewards by embracing the full jazz of complexity in the big city of work and life. As the poet and management consultant David Whyte said, "Stop trying to change reality by attempting to eliminate complexity . . . apprentice yourself to the complex poetry of human endeavor."

Leading in the era of the mathematical corporation means learning to treasure the detail in systems you never quite knew before. It means breaking tired thinking patterns to transform yourself and your organization. It means working with the machine to wield ingenuity and new ways of leadership to create impossible strategies and execute incredible solutions. You will stand out, lighting up the hidden power grids of work and life, exploring new substance to orchestrate fresh music. You will flip the switch to realize the promise of the mathematical corporation.