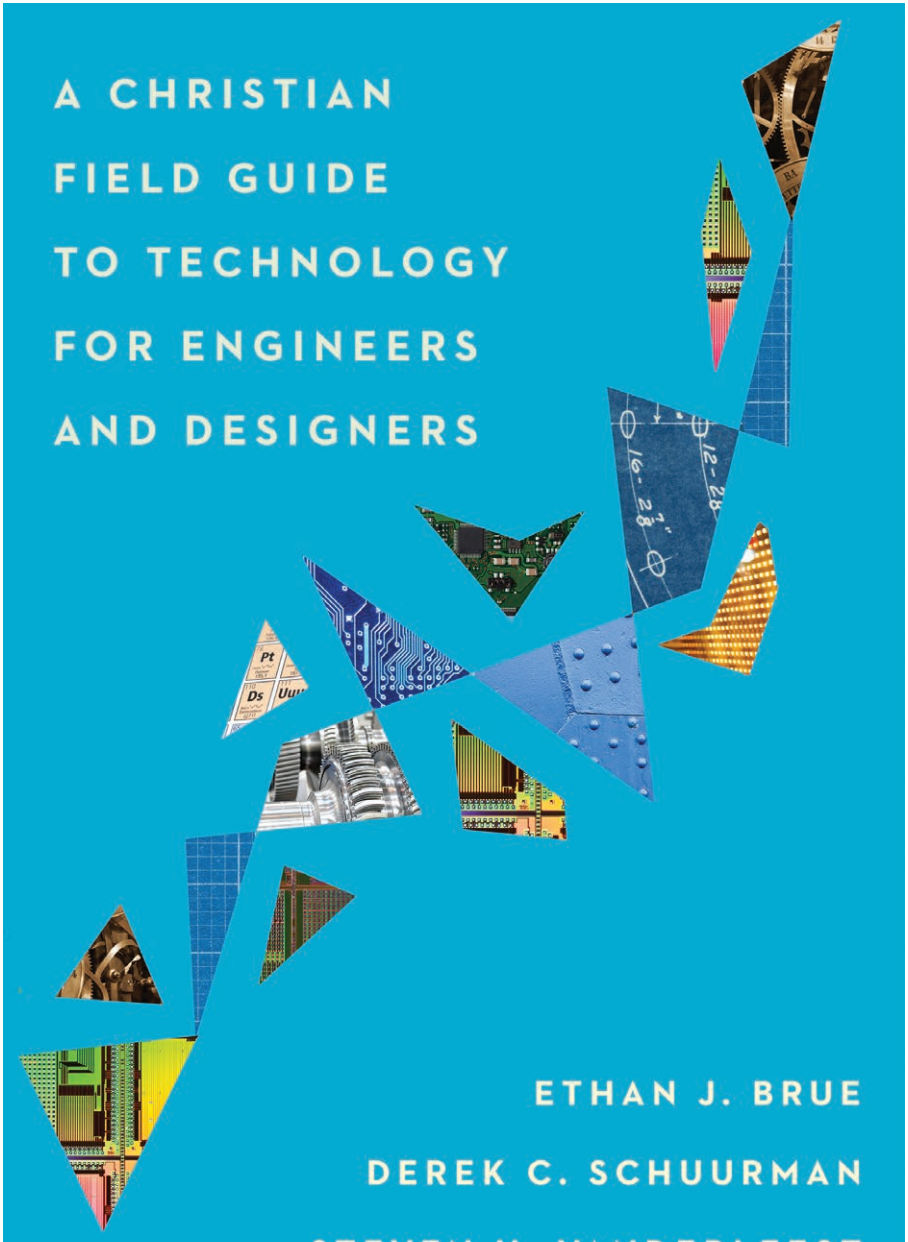
A CHRISTIAN FIELD GUIDE TO TECHNOLOGY FOR ENGINEERS AND DESIGNERS



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CHAPTER ONE

DREAMS TAKE FLIGHT

Not only cathedrals, but every great engineering work is an expression of motivation and of purpose which cannot be divorced from religious implications. . . . The age of cathedral building is long past. . . . But every manmade structure, no matter how mundane, has a little bit of cathedral in it.[1]

Samuel Florman

Before heading off into the technological landscape, we begin our field guide with an examination of the underlying yearning to design technology. What drives our dreams and longing to invent? This chapter was written collaboratively by all three authors, reflecting insights from their own journeys to become engineers. The purpose of this chapter is to connect our hopes and dreams exhibited in technology to our ultimate hope in our sovereign God who is making all things new in Christ.

Two dreams. Same goal. Same technology. Different endings. Samuel Langley dreamed of a flying machine. So did Orville and Wilbur Wright. In fact, so did many others, stretching back to the artist-inventor Leonardo da Vinci in the thirteenth century. Of all the dreamers, inventors, and innovators through the ages, the story that ultimately gets tied to the invention of human flight tells us as much about our own hopes and dreams as it does about the transcendent imagination fueling the technology itself.

In the mythology of flight, the Wright brothers most often play the protagonists. However, in the late 1800s, if you were betting on the

future of heavier-than-air powered flight, Samuel Langley would have had the best odds for being the inventor of the early aeroplane. He had the right education as a scientist, political capital, connections, and finances to make it happen. As a distinguished astronomer and head of the prestigious Smithsonian Institution, he had at his disposal seventy thousand dollars (nearly two million in today's dollars), of which the majority was taxpayer funded, to design, build, and test the first mechanically powered airplane. By contrast, with less than a thousand dollars of their own money, the Wright brothers were self-educated, self-funded, and self-motivated owners of a bicycle shop. This backdrop brings to mind our favorite storylines in which an unlikely underdog overcomes insurmountable odds to achieve success.

In the fall of 1903, Langley's scientifically engineered contraption, packing an impressive fifty-plus horsepower, made its long-awaited, well-publicized flight multiple times across the Potomac in Washington, DC, complete with a sizable entourage of reporters, scientists, and interested citizens. While the stage was impressive and the flight commendable, it was the dramatic landings that stole the show. The final and most spectacular landing occurred in December of 1903, morphing aeroplane into submarine and memorably landing a brave but fully chilled and drenched pilot, sputtering profanities, back on the riverbank. What crashed in the Potomac was more than just the flying mechanism. Equally damaged that day was the public's faith in institutional science, political power, and wealth. Meanwhile, a little over a week later, two bicycle mechanics who spent a mere four years of vacation time "playing with" technology were able to coax a mere twelve horsepower engine to lead them into history, witnessed by a handful of curious locals with surprisingly little drama.

Maybe we find the story of the airplane so intriguing because it embodies the rags-to-riches mythology that we want to be true. However, a closer reading of the Wright story reveals something deeper than the retelling of the American dream. The story reinforces the notion that in culture making, the visionary artist often eclipses the scientist. This

may explain why today we remember Kitty Hawk as the site of the first flight and why the Wright brothers achieved a chapter in history while Langley only secured a footnote.

What drove the brothers Wright to dream about flying? Momentous technological change often grows from a deep yearning or belief. The Wright brothers' imagination was sparked at an early age after Milton Wright gave a toy flying device to his young sons, Orville and Wilbur, in 1878. It was perhaps an odd gift coming from a man of the cloth, as Milton was a bishop in the Church of the United Brethren in Christ. Little did their father know that his gift might inspire the boys to dream of creating the first powered aircraft that could be reliably controlled by a human pilot. Not all beliefs are articulated in doctrinal statements, some take shape in wood and metal.

The boys grew up in Dayton, Ohio, pursuing diverse interests in sports, music, nature, and mechanical devices. As teenagers, their curiosity drove them to build their own printing press and to later start a bicycle shop. Reading news stories about early attempts to fly reinvigorated their childhood dreams, and they began researching and experimenting to create their own airplane. Possibly taking their cues from their bicycle world, they reconceptualized the "problem of flight" not as getting into the air, but as giving us control when we got there. Like the experience of learning to ride a bike, our earliest failures occur when trying to turn, slow down, or stop. Driven by this quest to solve the flight control problem, they built models and prototype gliders to test and refine their design. They meticulously examined each failure and improved the design before ever attempting powered flight—all the while refining their skill at riding the airplane. They identified the Outer Banks of North Carolina as an ideal location for their final field experiments because of its frequently windy conditions. They set up camp in Kitty Hawk, being drawn back to this wilderness landscape not simply for its aerodynamic advantages, but also for the contest of wit and skill played out against an unpredictable foe of wind and weather.

Figure 1.1. Photo of the first powered, controlled, sustained airplane flight in history at Kitty Hawk, North Carolina, December 1903

Longing represented by dreams and imagination is an important factor in technology design. Today, most new technology originates in big companies, so we might mistakenly connect innovation to the economic motivations of corporate businesses and miss the role of play. One of the most striking features of the Wright brothers' story, though, is that their motivation arose not from some practical need but from a delight in tinkering and exploring. Their story demonstrates the power of play, imagination, and human creativity—driving them from the inauspicious printing press and bicycle shop in Dayton, Ohio, to flight tests in the boondocks of Kitty Hawk. Kitty Hawk was more akin to a rustic vacation camp than a science project, and the memoirs of their experiences on the Atlantic coast read more like poetry than a lab report. Orville and Wilbur were gymnasts, football fans, pond hockey players, bike riders, skate sharpeners, book lovers, naturalists, art connoisseurs, and musicians, as well as inventors. These diverse interests shaped their imaginations, and their curiosity drove them to design the world's first successful heavier-than-air engine-powered and pilot-controlled aircraft.

More important than the creation of the Wright Flyer itself, may be the creation of the Wright history. Langley and his institution of scientific predecessors may have, through their myriad of failures, done more for the ultimate future of aircraft design than the Wright brothers. Nevertheless, it is the Wright brothers that we more often choose to remember. Stepping back from the story, the reason may be bound up in our dreams. We also dream of the activity of creating: the adventure, the joy, the delight of exploration, free from the demands of our modern industrial machine. While only a few in the world are granted access to the well-educated and well-funded world of Langley, most of us can identify with the world of the Wright brothers. Their dreams of creating were as strong as their dreams of flying.

What drives humans to create technology? Some have suggested that invention is the result of Darwinian selection and that creating tools to survive is simply an evolutionary skill that developed over time, corroborating the old adage that necessity is the mother of invention. While some creative abilities that our ancestors employed to survive still endure, such as harnessing fire for energy, other creative endeavors are now directed toward crafting the arguably less essential jet skis and big screen televisions. Others have suggested that invention is a type of technological determinism, assuming that technological progress is inevitable, implying that engineers are compelled by some impersonal force. Still others have suggested that invention is driven primarily by consumerism and materialism, which creates the demand for what invention supplies.

Is invention only driven by the instinct for survival or the instinct of greed? Neither survival nor greed led us to the first flight at Kitty Hawk or the first majestic cathedral. They were driven by delight in creating something new and beautiful and noble. Technology always serves a purpose or seeks to achieve a goal by solving problems. The best technology delights us with intuitive melding of form and function, and in some ways this aesthetic makes it a product of not only science but also of art. Although calculation and logic are fundamental to

modern technology, the development of technology is a creative activity. We do not calculate a new technology, we *design* it. In the end, our best technology is derived not from our base instincts but from our noblest dreams.

Yearning for something better stokes our imaginations to explore new possibilities and to envision a different reality. Imagination is our conscious dreaming. Our ability to create technology allows us to ponder new and better ways to achieve our goals, and even to conceive of new goals that build on new tools. We can better our lives, improve our community, advance our society, and care for our world with the devices we dream up and build.

Science fiction has long inspired the imaginations of modern technology developers. Written in 1865, Jules Verne's classic tale *From the Earth to the Moon* imagined a voyage to the moon a century before the first moon landing. Another classic Verne story, *Twenty Thousand Leagues Under the Sea*, describes an electrically powered submarine a decade before the first one was constructed. Prolific science fiction author Arthur C. Clarke described artificial satellites for communication more than a decade before the USSR launched the Sputnik satellite in 1957. Today satellite technology is so common that we usually drop the qualifying adjective "artificial." Martin Cooper, an AT&T engineer widely recognized as the father of the cell phone, mused that *Dick Tracy* comics depicting futuristic wrist-watch radios may have inspired his vision for mobile phones. The *Star Trek* television series may have also inspired various technologies, ranging from spaceship propulsion to medical imaging. In one of the halls of the Smithsonian National Air and Space Museum one can view a model of the starship *Enterprise* from *Star Trek* near a model of the lunar landing module, placing the dream of space travel next to the reality of it. Indeed, imagination often precedes invention.

DREAMING OF SPACE

One of my indelible childhood memories is the sight of a television image of the launch of Apollo 17 and the subsequent fuzzy black and white video of men walking on the moon.[2] It was late 1972 when I watched footage of Walter Cronkite's report on the Apollo program's final mission to the moon. My father let me stay up late one evening to watch the spectacular images of people visiting another world. I didn't know it at the time, but these missions to the moon were the culmination of centuries of human dreaming about flight, outer space, and celestial bodies. What I did know was that it sparked my own imagination. It was one of the experiences that led me to dream about my own vocation: first imagining myself as an astronaut, but eventually focusing more on technology and deciding to become an engineer.

Figure 1.2. Apollo 17 launch

The entire Apollo program was the culmination of a dream. In 1961, US President John F. Kennedy laid out an ambitious, mind-boggling goal:

> I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important

> for the long-range exploration of space; and none will be so difficult or expensive to accomplish.

Tragically, Kennedy didn't live to see his challenge met. On July 21, 1969, astronaut Neil Armstrong stepped onto the surface of the moon. As he descended from the lunar landing module onto the surface of the moon, Armstrong said, "That's one small step for a man, one giant leap for mankind." People watching this historic moment could only imagine what leaps in space travel might lay ahead.

Like the explorers centuries ago that set out on uncharted waters to explore the unknown reaches of earth, many of those drawn to the original US space program were spurred by a dream of exploring the unknown reaches of space. Robert H. Goddard was the American scientist who built the first liquid-fueled rocket. He became fascinated by spaceflight after reading H. G. Wells's novel *The War of the Worlds* as a young man. The concept of interplanetary travel gripped his imagination, influencing his decision to study physics with a focus on developing rockets.

Wernher von Braun also dreamed of rockets and space travel. As a youth, he read a science fiction novel about two planets and grew up to become an aerospace engineer. However, his commitment to his dream of rockets eclipsed other concerns. His obsession led him to work on the V-2 rocket for Nazi Germany, even though his real interest was in space travel and not weapons of destruction. As the war came to a close, he arranged to surrender to American forces, hoping it would offer the best path for further rocket research. It did. He joined the US space program and is widely regarded as the inventor of the Saturn V rocket.

After retiring, Katherine Johnson would visit with aspiring students and recount her career at NASA, telling them to never give up on their dreams.[3] Johnson had joined NASA as a mathematician, calculating trajectories for spacecraft by hand, since this was in the 1950s, before the era of the electronic computer. She was the first woman to publish

a technical report at the space agency.[4] Her story of success as a Black woman in an organization dominated by White men became the subject of a 2016 feature film, *Hidden Figures*.

Figure 1.3. Katherine Johnson at her desk at the NASA Langley Research Center, 1966

DREAMING OF COMMUNICATION

Dreams can also be spurred by tragedy. Samuel Morse, inventor of the telegraph, originally worked as a portrait artist. While working on a commissioned piece that took him far from home, his wife became seriously ill and died. He learned of her sickness and death too late to return home before she had already been buried. Heartbroken, he began to dream about a way to communicate that would be faster than sending a message via horseback. A conversation with a scientist about electromagnetism a few years later gave him an idea for building a message-sending machine. Over the next decade he worked on a device that included a transmitter, a receiver, a relay to amplify the voltage over long distances, and a code to translate the messages. He patented his ideas in 1840, claiming an invention for "Improvement in the Mode of Communicating Information by Signals by the Application of Electro-Magnetism." Some of the intricate details of his invention are depicted in figure 1.4 as they appeared in his patent application for the device. In May of 1844, Morse sent his first message by telegraph: "What hath God wrought?" He chose the content of his first communication from the Bible (Numbers 23:23 KJV).

Centuries before Morse, Johannes Gutenberg invented the movable metal type printing press, choosing the Bible as his first publication.

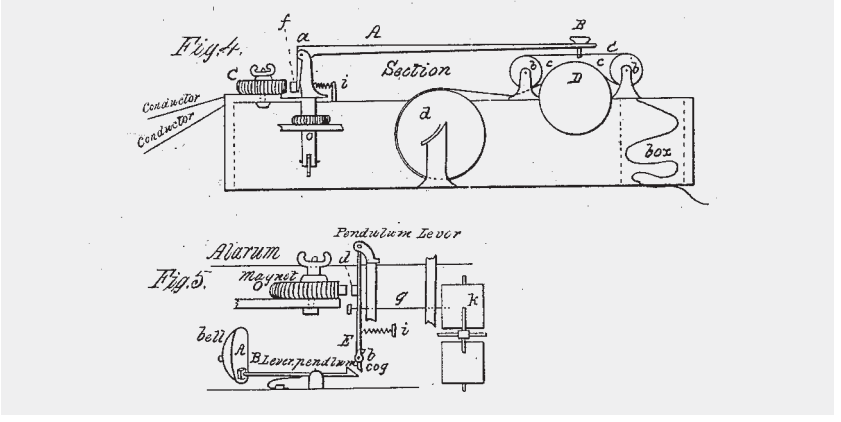

Figure 1.4. Two diagrams from the Morse Telegraph patent application

The Gutenberg Bible, as it came to be known, was the first mass-produced print book. Over 150 copies were printed around 1440, and the remaining forty-nine copies that have survived are considered some of the most valuable books in the world today. Later inventors were not as clever or biblical with their inaugural messages. A couple of decades after Morse, Alexander Graham Bell used the first telephone in 1876 to summon his assistant: "Mr. Watson, come here, I want to see you." A century later, Ray Tomlinson sent the first email message in 1971, seeking new ways to communicate with others over a distance.

What do these messages have in common? They marked the moment the inventor's dreams took flight and became reality. Each new communication technology allows people to connect with other people in a new way, forming new relationships at a distance not previously possible. Connecting might sound like a technical term, but it is a human term that describes the forming of a bridge between two people, linking them in relationship. It captures the ultimate and proper goal for technology—to help us be more fully human in relationship to each other and to God.

Imagination shapes technology, but technology can also shape our imaginations. At the turn of the previous century, theologian and statesman Abraham Kuyper reflected on radio communications in his devotional *Near Unto God*. He suggested that technology can "help us understand our God in ways that our imaginations couldn't as easily register before."[5] He observed that radio communication "helps us visualize how it is that the Lord, whose throne we say is in heaven, can pick up even a whispered prayer in the silence of our bedrooms." He continued, "The radio is thus even more of a gift of God—not only does it expand our world, it also helps us understand more about God's power."[6]

DREAMING OF LIGHT

Thomas Edison's creativity led to hundreds of inventions and thousands of patents. His dreams sometimes required weeks or even years of

experimentation and hard work before they became reality. His dream of creating a better light bulb by improving on the earliest versions of electric lighting was not realized easily—he made over one thousand attempts before discovering the right filament material. It took more than a year of further effort before he produced the first commercially viable incandescent bulb. When he finally came up with a working, reliable device, he patented the idea.

His dream was not just a better light bulb, but rather the transformation of the entire urban way of life with a complete direct current generation and distribution system. Edison envisioned the cultural transformation of homes and industries with electric power. His innovation extended well beyond a single technology. His creations encompassed all components of the system, from generators, to meters, to conductors. A new electrified community was perhaps Edison's grandest dream and greatest invention.

Edison, Morse, the Wright brothers, and many other inventors have turned dreams into reality. Although they may all have had an extraordinary creative genius, all humans are endowed with creativity.

USERS DREAM TOO

Inventors and science fiction writers are often the first to imagine a new technology, but users, inspired and enabled by the new inventions, begin to dream too. New technologies often make a big splash in society, causing excitement, wonder, fear, and amazement. Consider the scene on the street circa 1900 as people saw the first horseless carriage drive past, experiencing astonishment, delight, and perhaps fear. As a society, we exhibit a similar range of reactions to new inventions, such as our reaction to autonomous automobiles that are not only horseless but driverless. Whether our response is positive, negative, or mixed, it seems we inevitably incorporate new technologies into our daily lives. Right now, many of us are probably exploring new devices or tech tools, perhaps an app, that friends or relatives have not yet tried. Some may be skeptical, doubting its usefulness or concerned that it will change

their lives for the worse. Others might be favorably disposed toward the new device but cannot afford it. When new technology shows up, we are all forced to evaluate it and choose whether to adopt it. How can we make wise and faithful choices about the technology we adopt?

Imaginative users not only adopt technologies, but they often have further thoughts about how to adapt or modify them for uses beyond what the inventor envisioned. For example, although monks may have invented the clock to artistically depict the God-ordained movement of the heavenly spheres, this mechanism was soon used to gather them for prayer with more precise regularity. As the precision of mechanical time extended beyond what an hourglass or sundial could provide, it ushered in an era where tools to measure time became common. Individual users imagined uses far beyond marking prayer times. Modern watch-wearers use clocks to monitor laborers, set mealtimes, synchronize meetings, and more. Gradually, time zones were established, and with the ability to more precisely measure time, deadlines could be specified to the minute. The clock changed society, illustrating the notion that we shape our technology, but our technology also shapes us.

FAITH UNDERLIES ALL TECHNOLOGY DREAMS

Technology surrounds us more than we realize. While we easily notice the latest device as high-tech, we often fail to recognize the pervasive presence of older technologies because they have faded into the background of our conscious observation. Computer scientist Alan Kay noticed this fading: "Technology is anything that wasn't around when you were born." For example, the worship director at one of our churches often mentions that she hopes the technology will run smoothly during the worship service. By "technology" she means the computer and projector displaying the song words on the screen, the audio system that allows the musicians to hear each other with good balance, the video shown part way through the service, and the wireless microphone for the preacher. She probably doesn't think about all the

other technologies that make up the service: the devices invented in previous ages that aid our formal worship like the piano, central heating, grape juice for Communion, architectural technology, carpeting, electric lights, printed Bibles, paved parking lots, and concrete steps at the entrance. All these technologies have faded into the background so that we hardly notice them unless they fail in some way. Similarly, you might recognize your smartphone as high-tech but fail to notice older technologies you are wearing right now, like your eyeglasses, stain-resistant pants, and even the zippers on your clothing. Noticeable or not, technology often changes the way we live, interact, work, play, and even worship.

The impulse to create technology is fueled by our dreams and our imagination. "In dreams begins responsibility," wrote the poet William Butler Yeats. He may not have been thinking of technology, but he understood that yearnings hint at responsibility and ultimate purposes. Technology has deeply religious roots. Our yearnings and imagination reflect personal values shaped by desires and longings within our hearts. They are glimpses of the ultimate dream: the longing to see the new creation and the new Jerusalem. Technology grows out of our human character endowed with the image of the Creator. It grows out of biblical callings to care for the creation, to love God, and to love our neighbor. Done well, our technological dreams become reality in building God's kingdom. Done poorly, our technological dreams become nightmares that pervert creation and harm our neighbor.

Most dreams fade away, but those shaped by the Spirit of God do not. This creative spirit is poured out on engineers who continue to see visions and dream dreams, prophetically pointing to a coming kingdom. The Christian faith does not restrain engineers from having extravagant ideas but encourages us to imagine what God desires. As Christians, our dreams must be animated by the biblical story, and our hearts must be tuned to a vision of God's coming kingdom. Christian engineers need to equip themselves with more than technical competency; they need to cultivate an imagination for how things ought to be. That

imagination must be shaped by faith in Jesus Christ, in whom and through whom and for whom all things exist.

There is more to the story of technology than simply dreaming. Our design and use of technology start with dreaming but are also influenced by a variety of other factors. Achieving dreams consistent with our Christian faith in the complex context of real life is the subject of the rest of this field guide. We begin in chapter two with the Scriptures by reviewing the biblical story and describing how it can inform our understanding of technology. Chapter three dispels the myth that technology is objectively neutral in order to make the case that we must exercise responsibility. As an aid to wise design, chapter four introduces one of the key concepts of the book: design norms for responsibly creating and evaluating technology. While the norms from this chapter provide a framework for guiding God-honoring designs, chapter five looks at how norms and virtues can inform and expand the topic of professional ethics. Chapter six examines the impact of sin on our technological work and products. Chapter seven provides a historical perspective, encouraging us to continually "zoom out" to see and imagine the big picture when immersed in the minutiae of a complex project. Leaping forward from the lessons of history, in chapter eight we hope that by pointing our design efforts to our broader eschatological hope, we can avoid undue utopianism or pessimism. In chapter nine we demonstrate technology design as a legitimate Christian calling, making the case that an engineer or scientist need not quit her job in order to serve Christ fully and faithfully. We end the book by addressing some concerns you might have about how one practically lives out their faith in the design of technology. Chapter ten takes the form of letters to a young engineer, giving practical real-world examples of how the ideas of this book become real—where the rubber meets the road.