1 INTRODUCTION

In 1966, Irv Gordon bought a new Volvo P1800 from a showroom in Huntington, New York. It cost him about $4,000. Just shy of fifty years later, outside of Girdwood, Alaska, Irv logged his three-millionth mile behind the wheel of that car. By the time he died at the age of seventy-seven in 2018, he'd racked up another quarter of a million miles on its odometer. Over the years, Irv's Volvo underwent some major repairs. The engine was rebuilt twice, and the car required extensive body work after an unfortunate incident with a car hauler. But Irv preferred to do most of the work himself – changing the oil, replacing the brakes, and other necessary repairs. Irv's approach was simple. He immediately replaced broken parts. In his words, "If it didn't start, I'd find out why . . . and fix it."[1]

As impressive as Irv's Volvo is, the world's oldest operating automobile was built in 1884 by Jules-Albert de Dion.[2] Dubbed "La Marquise," the steam-powered vehicle sacrificed various brass and copper fittings to scrap drives during World War I. It sat inoperable for decades until it was purchased by Tim Moore in 1987. Moore reverse engineered the missing parts, manufactured replacements, and had La Marquise running again within a year.[3] In 2011, the vehicle sold for $4.6 million at auction.

In terms of longevity, the clock at Salisbury Cathedral has La Marquise beat by about 500 years. Originally built in 1386, it was replaced by a newer model in 1884, the same year La Marquise was built – not a bad run by any estimation. After decades of rusting in obscurity, the original clock was rediscovered by horologist T.R. Robinson. In 1956, it was disassembled and shipped to clock makers, the Smith of Derby Group, who

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replaced various parts, fashioned others, and restored components to their original positions. Eventually, they got the clock back in working order, and it continues to keep time today.[4]

These examples may seem extreme. But if you want to get the most from the things you own, repair is essential. That's true not only of Irv's Volvo and the Salisbury Cathedral clock, but your smartphone and kitchen appliances as well. It's true for farmers who face software restrictions and legal threats when they try to repair their tractors to harvest their crops.[5] It's true for US military personnel, who are under orders not to repair vehicles, generators, and other equipment for fear of voiding product warranties – instead, shipping equipment thousands of miles for repair or awaiting unreliable service from private contractors.[6] And as the COVID-19 pandemic revealed, it's also true for hospitals confronting shortages of replacement parts, strict controls on repair manuals, and software locks that frustrate the repair of ventilators and other life-saving equipment.[7]

Without the freedom to repair, the things we own will fail sooner, work less effectively, and cost us more money. Imagine you drop your smartphone. Maybe you don't have to imagine. In the United States alone, tens of millions of us break our smartphone screens each year. You might choose to live with a busted screen, putting up with fractured images and risking the occasional sliced fingertip. If not, you are left with two choices – repair it or replace it.

A new screen for an iPhone will cost you as little as $50 from a third-party seller. Screens for some older models cost even less. But replacing your screen requires tools, skills, and confidence you might lack. If you take your phone to Apple, the company will charge you around $300 for this fairly simple repair. For that price, you might wonder, why not just buy a new phone? Apple agrees. The company will happily trade your broken phone for a discount on a new one, further closing the price gap between repairing and replacing. Apple's preference for replacement over repair, it should come as no surprise, is driven by the company's bottom line. The iPhone X cost Apple about $350 to make, but sold for $999. That's a profit margin of

roughly 64 percent. And Apple shareholders have come to expect blockbuster sales. The company sold 218 million phones in 2018 alone, generating over $140 billion in revenue. But when it comes to its repair services, Apple claims that it loses money.[8] In fact, CEO Tim Cook blamed the popularity of the company's own battery replacement program for declining iPhone sales in a letter to investors.[9]

So instead of repairing your old phone, you buy a new one. Apple keeps its shareholders happy, and you get a shiny new device that's a few millimeters thinner. What's so bad about that? Aside from spending several hundred dollars you could have otherwise saved, the decision to replace rather than repair has far-reaching environmental consequences. In 2018 alone, 1.5 billion mobile phones were manufactured worldwide, contributing to the more than 50 million metric tons of electronic waste produced that year. Electronics currently account for 70 percent of the toxic waste in US landfills, a figure that continues to rise. That electronic waste includes lithium, mercury, and lead – chemicals that endanger our water supplies and threaten human health. But it's not just the end of a product's life that should concern us. Extracting and refining raw materials produces pollution, as does manufacturing and shipping products across the globe. Those environmental harms are a classic example of what economists call negative externalities – costs that the parties to a transaction don't have to take into account. Instead, the consequences are passed on to our neighbors and future generations who will have to deal with the fallout.

Beyond environmental costs, the COVID-19 pandemic dramatically highlighted the immediate consequences of repair on human welfare. As hospitals across the globe faced shortages of life-saving ventilators, and manufacturers scrambled to ramp up production, the ability to maintain and repair existing equipment emerged as a pressing problem. Authorized repair, which often requires shipping devices back to the manufacturer, can leave hospitals without critical equipment for days or even weeks. In other instances, manufacturers withheld needed

repair manuals or failed to supply replacement parts, imperiling patients in a period of prolonged crisis.[10] When a hospital in Chiari, Italy, couldn't secure valves for its ventilators from the manufacturer, local volunteers designed and 3D-printed 100 replacements that cost $1 a piece. The volunteers managed this feat in just two days, with no help from the manufacturer, which refused to share design specifications.[11] Concerns over repair delays and expense are nothing new in the medical sector, but this crisis revealed just how fragile centralized repair systems can be.

As schools across the world shifted to remote instruction during the pandemic, demand for laptops and tablets outstripped supply.[12] In the United States alone, shortages and delays meant millions of students lacked the devices they needed to fully participate in online learning. Predictably, low-income families were hardest hit.[13] Four siblings sharing a single iPad are at a significant disadvantage in a Zoom-dependent curriculum, and setbacks in elementary education can have long lasting effects. In response to this educational crisis, repair shops, nonprofit organizations, and local volunteers tried to fill the gap with refurbished devices. And while those efforts had some impact, they were too often stymied by a lack of access to information, parts, and software. School districts and community organizations were forced to scrap older devices rather than fix them, adding to their spiraling costs and exacerbating the harm to students.[14]

If consumers were more aware of these environmental and human costs, some may be more likely to repair a damaged device, despite the inconvenience. But for some products, repair simply isn't an option. Take Apple's AirPod wireless headphones. They retail for $159 for the basic version and $249 for the Pro model. The company sold 35 million pairs in 2018, and nearly 60 million in 2019. Intended for commuters, the tiny, wireless devices are easily lost. The combination of their price, likelihood of being misplaced, and the unmistakable Apple design aesthetic have transformed the AirPod into a symbol of conspicuous, disposable consumption.[15] Even if you manage to

avoid losing them, the lifespan of AirPods is short by design. AirPods fail to live up to their advertised five-hour playback time after as little as eighteen months. At that point, your $249 headphones may work for only fifteen minutes on a full charge. All lithium-ion batteries degrade over time, but tiny batteries like those in the AirPods seem particularly prone to depletion.

For many products, replacing dead batteries is trivial. For our flashlights and remote controls, it's as simple as popping in a few fresh AAs. For many laptops and smartphones, it may require a few specialized tools or a trip to a local repair shop, but your battery can be swapped out in a matter of minutes. Not so for your AirPods. Their design makes battery replacement all but impossible. AirPods have no screws. They are held together by glue and solder. Accessing the battery, as the *Washington Post*'s Geoffrey Fowler discovered, requires a special vibrating knife to cut through the plastic shell. The procedure is more harrowing since the battery, about the thickness of a spaghetti noodle, is prone to combustion if punctured. But even assuming you can dislodge it safely, your AirPods will be irretrievably damaged in the process.[16]

Apple's designers and engineers are among the most talented in the world. They certainly could have designed headphones that incorporated replaceable batteries. And as a general rule, engineers want to build high-quality, lasting products as a matter of professional pride. Nonetheless, Apple chose to market headphones that were neither durable nor recyclable. The question is why?

It's worth noting that the booming market for wireless earbuds is driven by an earlier design decision by Apple – the removal of the standard headphone jack from the iPhone.[17] Like the entombed batteries in AirPods, that decision reflects certain philosophies. Apple's products are sleek, minimal, and impossibly thin, an aesthetic that has implications for repair regardless of its ultimate design justification. Rather than an abundance of choice and customization, Apple offers a limited, highly curated selection. The company's obsession with controlling the user experience, as sales

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figures make clear, has paid off time and again. But these design choices also embody Apple's attitude about repair. From the design of its products, to the price of its repair services, to its trade-in program, the message is clear: replace, don't repair.

That's especially true when it comes to AirPods. What do you do with your $249 headphones once they can't hold a charge? Throwing them out should be unthinkable. Their plastic shells will survive for at least a thousand years in a landfill. And their combustible batteries could start fires in trash compactors.[18] Alternatively, Apple offers "battery service" for AirPods. For $49 per earbud, and an additional $49 for their charging case, Apple will service your aging headphones. That's $147 to service a $159 product. As the price tag for AirPod "battery service" suggests, it isn't actually service at all. Since even Apple can't repair AirPods, it simply replaces your old headphones with new ones.[19] The depleted AirPods are then shipped to a handful of recycling centers that partner with Apple, where cobalt and other valuable materials are carefully extracted from the spent headphones. But given their tiny size, the laborious process of dissecting AirPods costs more than those materials are worth.[20] So Apple has been forced to sweeten the deal, paying recyclers extra to make processing AirPods economically viable. Understandably, the company offers consumers no financial incentive to trade in used AirPods. Since Apple doesn't disclose how many AirPods it has recycled, it is difficult to know how many have made their way into landfills.

AirPods are a textbook example of product design that is at best indifferent and, more likely, antagonistic to repair. But concerns about reparability are not limited to physical components. Today, an increasing number of consumer goods incorporate some measure of "smart" technology. These devices depend on a combination of embedded software code and network connectivity for their basic functionality. They range from smart speakers and home-security systems to comically mundane items like hairbrushes, saltshakers, dental floss, and trash cans. The proliferation of connected devices that make up the Internet of Things presents an assortment of risks for consumers, from privacy and

security to harassment and physical injury.[21] But smart devices also undermine repair by removing functionality from your device and outsourcing it to a remote server.

Take Jibo, the social robot. Released in 2017, Jibo was a foot-tall plastic robot with an emotive face and sensors that responded to physical interaction. It sold for $900 and could dance, talk, and play games with its owners. When the company that built Jibo failed, it powered down its servers. Since most of Jibo's functionality depended on those distant servers rather than the device's on-board computer, Jibo suffered from "digital dementia." The robot went limp, its dimly lit screen blank. And its head and torso "twist[ed] freely, like a lifeless body."[22] Cruelly, Jibo was forced to deliver a parting message to its owners: "While it's not great news, the servers out there that let me do what I do are going to be turned off soon. I want to say I've really enjoyed our time together. Thank you very, very much for having me around. Maybe someday, when robots are way more advanced than today, and everyone has them in their homes, you can tell yours that I said hello."

Jibo illustrates the risks to repair posed by the Internet of Things. The robot's physical components could be repaired. If its screen was on the fritz, it could be replaced. If a sensor wasn't working properly, it could be recalibrated. Even the embedded software in the device could be updated and patched. But most of Jibo's features were not housed in its plastic shell. Instead, they resided on a server that Jibo owners could not access, let alone repair. Jibo's basic operation, as purchasers eventually learned, depended on hardware and software over which they had no control. The tether connecting devices to remote servers in unknown locations is a core, if not defining, feature of smart devices. On a fundamental level, the Internet of Things as currently constructed is incompatible with repair.

In some cases, that incompatibility results in a loss of functionality. The starkest illustration is "bricking" – the post-sale, remote disabling of a device.[23] To take one example, in 2016 Google-owned Nest announced it would push an involuntary software update to its $300 Revolv home automation hubs,

rendering them entirely inoperable.[24] Despite selling the devices with the promise of a "lifetime subscription," the company announced that after May 15, "The Revolv app won't open and the hub won't work."[25] In others cases, sellers selectively eliminate functionality, like when Best Buy remotely killed the smart features of its Insignia line of refrigerators, electrical plugs, light switches, and security cameras in the homes of its customers.[26]

In the past, consumers could confidently draw a clear line between products and services. Once you purchased a television, for instance, the manufacturer had little say over how you used it. That's quite different from a service, like a cable subscription. There, the provider can add or subtract channels, change the price, or cancel the service altogether. Today the line between product and service is more of a blurry smudge. Our TVs, cars, and appliances are bundled with deeply intertwined software and data services that are central to their functionality. As a result, consumer expectations about repair are increasingly likely to conflict with the reality of the Internet of Things.

Putting aside product design, there are other powerful tools companies use to limit repair. We've already seen how economics can dissuade consumers through unreasonably high repair fees and trade-in programs that incentivize replacement. Less appreciated is the role law – in particular, intellectual property (IP) law – plays in restricting repair. Device makers use patents and trademarks to limit the availability of replacement parts. They claim schematics and other repair information as trade secrets. And they leverage copyright to lock down the software tools necessary to diagnose and repair today's devices.

The outsized influence of intellectual property law on repair reflects the ubiquity of IP in the modern marketplace. The rounded corners of the iPhone are patented, as are its app icons.[27] Internal components you will likely never see, like cables and batteries, are emblazoned with Apple's trademarked logo.[28] And of course, the software that makes the iPhone work is protected by copyright. The same is true for your car, from the

patented design of your headlight to the software code that controls the transmission. The devices we rely on every day are suffused with overlapping intellectual property rights.

If anyone could escape the reality of IP-protected smart devices, you might think it would be farmers. We imagine farmers living off the land in rural communities, less dependent on modern technology and more rooted in traditions and practices that pre-date the digital era. But this image of farm life is out of step with reality. Farming today relies on a range of technologies, from moisture sensors and drones to genetically modified crops and patented biological pest controls. Even that classic symbol of rural America, the John Deere tractor, has been transformed into a complex, software-dependent piece of digital technology.

Modern John Deere tractors can cost as much as $800,000. No longer purely mechanical devices, they depend on multiple electronic control units (ECUs) to operate everything from the engine to the power seat. These embedded computers run software code essential to the operation and repair of the tractor. By controlling access to that code, John Deere can prevent independent diagnosis and repair. Without enlisting a John Deere technician, the tractor's software won't even recognize replacement parts.[29] That level of control forces farmers to rely on authorized John Deere dealers for service, rather than doing it themselves or turning to local Mom and Pop repair shops.

Copyright law has been central to Deere's strategy to shut competitors out of the lucrative market for farm-equipment repair. Since the software code on ECUs is protected by copyright, Deere believes it can legally prevent farmers and repair shops from accessing that code. The Digital Millennium Copyright Act (DMCA) makes it unlawful to remove or bypass digital locks that restrict access to copyrighted materials. The law was meant to help protect movies, video games, and other works from online copyright infringement. But under Deere's theory, it applies with equal force to its tractors.

After a years-long battle, farmers convinced the US Copyright Office to grant them a temporary, three-year exemption from

the DMCA in 2015.[30] It insulated farmers from liability for accessing software in order to diagnose, repair, or modify their tractors. The exemption was renewed for another three years in 2018, and the Copyright Office will consider it again in 2021.[31] Nonetheless, the practical hurdles to unlocking Deere's code and remaining sources of legal risk limit the impact of the exemption. As a result, many farmers rely on unlicensed copies of Deere software downloaded from Ukrainian hackers just to keep their tractors running.[32] And demand for decades-old, pre-digital Deere tractors has exploded. At a recent auction, a 1989 model sold for over $40,000.[33]

As these examples illustrate, companies like Apple and John Deere have devised strategies that leverage product design, economics, and law in order to discourage or capture repair markets. Those efforts – combined with persistent marketing messages that convince us we need newer, thinner, and supposedly better products – have contributed to a brand of disposable digital consumerism. Rather than prizing products that are reliable and durable, we are trained to replace our devices for the latest model even when our existing phones, laptops, and cars work perfectly fine. Once we adopt that mindset, repair looks more like a quaint anachronism, or even a hindrance to innovation, than a socially responsible choice.

But beyond staving off economic and environmental harms, repair serves other crucial values. Repair is a social practice that builds valuable skills. It demands analytic reasoning, strategic thinking, and creativity. And repair helps us develop a more complete understanding of how a device operates, enriching our awareness of the world around us. In that sense, it makes us freer, more autonomous, more in control of the world we occupy. Repair empowers us.

The impulse to repair is deeply ingrained in us, dating back to humanity's origins. So, it is not surprising that, in the face of legal and technological restrictions on this ancient tradition, some have rebelled. Recent years have witnessed the emergence of a global right-to-repair movement. It brings together tinkerers, hobbyists, repair professionals, policy advocates, sustainability

experts, and everyday people. This coalition operates both locally and globally to share parts, tools, information, and techniques. Since the first repair café, a community space dedicated to empowering everyday people to fix their stuff, opened its doors a decade ago in Amsterdam, thousands have sprung up across the globe – not to mention Fixit Clinics, Restart Parties, and other in-person events that foster repair locally. At the same time, the internet is fertile ground for repair information. Whatever problem ails your smartphone, washing machine, or garage-door opener, there's a good chance you can find a detailed explanation of the repair procedure on YouTube. And iFixit – a company that sells tools and replacement parts – has built an online community that provides free, community-edited repair instructions to millions of readers.

The goal of repair stands in obvious tension with the strategies increasingly employed by device makers. But for more than a decade, dedicated consumers and repair providers have waged a largely unnoticed battle against the largest, best-capitalized corporations in history. Their resistance takes many forms: tearing down new products to identify and overcome impediments to repair, bypassing technological locks on diagnostic software, sourcing hard-to-find replacement parts, and sharing information over a chorus of corporate legal threats. More recently, the battle has moved to courtrooms, administrative agencies, and legislatures as the repair community attempts to fix the most powerful tool blocking repair – the law.

This book tells the story of repair – its history, the strategies developed to undermine it, and the path towards a more reparable future. That story begins with the economic, environmental, and social benefits of repair. The ability to fix the technology we rely on can save us billions of dollars. It can help us reduce the staggering harms to the planet that flow from the extraction of raw materials, their conversion into consumer devices, and their eventual disposal. And repair helps us develop knowledge and skills that foster autonomy and build community. As we will see, repair is an ancient practice that has evolved alongside human technology from its earliest beginnings. It has grown

more specialized, but thanks in part to the internet, repair is on the verge of democratization.

In response, firms are cracking down. Accessible, affordable repair presents a threat to the business models of companies that manufacture and sell consumer goods by the billions. Short product lifespans are central to their profitability. Predictably, they employ a combination of technological, economic, and marketing techniques to steer consumers away from repair. Device makers design components that are difficult to replace; charge unreasonably high prices for authorized repairs; squeeze independent repair providers out of the market; and construct digital locks meant to keep us out of the products we own.

Increasingly, legal rules play a central role in regulating access to repair. Three interrelated bodies of law in particular – intellectual property, antitrust, and consumer law – are essential to understanding the legal landscape around repair. Device makers assert IP rights, with varying degrees of success, to prevent unwanted repairs. They claim their copyrights, patents, trademarks, and trade secrets are infringed by the sale of replacement parts, the sharing of repair documentation, and the use of diagnostic tools and software. But those claims are often at odds with established legal precedent and sound public policy. Like IP, antitrust law is a tool for regulating competition in the marketplace. But while exclusive IP rights are meant to insulate firms from the usual competitive forces of the market, antitrust law is designed to limit the market power firms can wield against both competitors and the public. That makes it well-suited for pushing back on device makers seeking to control repair markets. Although they target different sorts of behavior, both antitrust and consumer law share a concern with safeguarding fair competition and reducing harms to individual consumers. By targeting specific unfair and deceptive practices, consumer law supplements the structural rules imposed by antitrust law.

Although they have potential to better promote repair, as they currently exist, none of these bodies of law offers a framework

that can effectively push back on manufacturers' overreaching tactics. If we want to enable repair, legal reform is necessary across doctrinal lines. Although distinct, these areas of law interact in ways that complicate the policy response to repair. IP and antitrust law stand in uneasy tension at times. Antitrust and consumer-protection law share some core goals but pursue them using different means. But in the end, all three of these areas of law shape the competitive landscape in ways that implicate repair. Given that fact, responsibility for creating an environment hospitable to repair can't fall on any single body of law or institutional actor. Nor can the solutions be limited to legal reform. Protecting and restoring repair will require us to rethink product design, recalibrate market incentives, and shift the social norms of our consumer culture to better reflect the value of repair. These are no small tasks. But considering the fundamental necessity of repair to our way of life, the sooner we get started, the better.

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