Chapter 7

RoboTruckers: The Double Threat of AI for Low-Wage Work

So far, this book has focused on the trucking workplace as a site of intensifying surveillance, within which workers are much more closely monitored and managed than they were before. We have seen how monitoring technology challenges' truckers professional culture, autonomy, and manhood, as well as their ability to make the money they need to get by. Over the last fifteen years, as monitoring technologies have become ubiquitous, the specter of putting the manager (and the government) in the cab is gradually becoming an unwelcome reality for many truckers.

But recently, another narrative has emerged alongside this one. Economists and policymakers are becoming increasingly concerned about the effects of automation and artificial intelligence (AI) on employment—including whether some kinds of jobs will cease to exist at all. Trucking is often thought to be one of the first industries at substantial risk from the prospect of increasing automation, as self-driving trucks become a reality. This leads to a newfound concern about the relationship between trucking and technology: what will become of truckers if they are no longer needed behind the wheel? This chapter explores that threat.

Labor and automation

New technologies can profoundly affect how industries are organized and how work gets done within them. As AI technologies become cheaper and more sophisticated, policymakers have begun to express great concern about what they will mean for employment—including whether some forms of work will exist at all, and what will happen to the workers who do that work. The prospect of millions of workers finding themselves suddenly without employment brings with it the potential for tremendous social and economic disruption.

What's more, the jobs widely believed to be most threatened by the new wave of automation are those commonly held by less educated, poorer workers—what are often called "low-skill" jobs. "Low-skill" is an ambiguous (and somewhat misleading) term, as many jobs so categorized inarguably require significant expertise and ability. "Skill" is often used as a sort of shorthand for the amount of education or training a job requires. When economists refer to "low-skill" jobs, they often refer to blue-collar jobs that require no more than a high school or vocational education. "High-skill" jobs, by contrast, often require college or a more advanced degree.[1]

[1] Frey & Osbourne 2013; Acemoglu & Autor (2010) http://www.nber.org/papers/w16082.pdf, p. 33

Earlier waves of technological innovation—like computer-controlled machinery on the factory floor—have been *skill-biased*. That is, automated technologies generally replaced jobs held by low-skill workers. Workers with more education were both less likely to be threatened by technological replacement, and in some cases were in *greater* demand, as new technologies created new types of jobs for them. In this way, innovation has disproportionately negatively affected the labor of those at the bottom of the socioeconomic ladder.

What is it about a job that makes it more likely to be automated? Historically, one of the primary axes of distinction between automatable low-skill jobs and safer high-skill jobs was whether work consisted mostly of *manual* or *cognitive* tasks. Machines were comparatively better at manual (physical) tasks, while cognitive tasks—"knowledge work" involving processing, analyzing, or acting upon information, and more likely to be held by highly educated workers—were largely beyond machine capabilities and remained the ambit of the human.

But over time, computers became much more capable of analytic information-based work, making the distinction between manual and cognitive work tasks less salient. Instead, the more crucial distinction became whether a task could be easily boiled down into a standard, repeatable method. In 2003, the economists David Autor, Frank Levy, and Richard Murnane published an influential model that categorized work tasks not only as manual or cognitive, but also as *routine* or *nonroutine*.[2] A routine task is one that requires "methodical repetition of an unwavering procedure"[3]—the task involves doing the same thing over and over, like fixing the same part into place on an assembly line, or assisting a customer with an everyday request. Nonroutine tasks, on the other hand, have less clearly understood rules and procedures—and therefore, the economists predicted, are less susceptible to being programmed away. Autor and his co-authors argued that computers might *complement* workers in nonroutine tasks but are less likely to substitute for them. Nonroutine tasks—like selling a product or writing a legal brief—require skills like perception, problem-solving, and intuition that were then well beyond the purview of what a computer can do. Truck driving, in fact, was one of the jobs that Autor and his co-authors then believed would be safe from automation, because the nature of the work involves dealing with constant nonroutine scenarios.

But the latest wave of technological innovation is changing the game once again. As computers becomes more sophisticated and responsive to their environments, they can adapt to dynamic situations more adeptly—negotiating traffic, responding to conversational cues, developing novel solutions to problems. And this suggests the possibility of a new threat to workers whose tasks are primarily *non*routine. In light of robotic capabilities, computer vision, and machine learning, it's less important than it once was that a task be clearly definable and repeatable. Today's algorithmic systems are fed by tremendous amounts of data, can recognize and interpret speech, and can predict certain types of outcomes far better than a human can. They can complete myriad nonroutine

[2] Autor Levy Murnane, "The Skill Content of Recent Technological Change" p 1286
[3] Autor Levy Murnane, "The Skill Content of Recent Technological Change" p 1283

tasks, both manual and cognitive: they may offer personalized financial advice, diagnose medical conditions, navigate new environments, assist customers with complex needs. And though these systems certainly make errors, they learn constantly—integrating new information from the environment, from new data sources, and from past mistakes.

No one knows for certain just how this wave of technologies will impact workers, but some economists believe the situation will be dire. For example: in an influential 2013 paper called "The Future of Employment: How Susceptible Are Jobs to Computerization?"[4], economist Carl Frey and machine learning researcher Michael Osborne predicted that about 47 percent of total U.S. employment was at risk of being automated within the next 20 years—and that low-skill, low-wage jobs, in sectors like office administration and telemarketing, were likely to be hit hardest.[5]

Robot, take the wheel?

According to several economists' projections, trucking is a prime target for automation. A 2016 White House Report on Artificial Intelligence, Automation, and the Economy forecast that 80% to 100% of heavy and tractor-trailer truck driving jobs (between 1.3 and 1.7 million jobs) would be "threatened or substantially altered" by autonomous vehicle technologies.[6] The Frey and Osborne report concurs, estimating that truck driving is about 79 percent likely to become automated in the next two decades.[7] Other economists make similarly dire predictions, including Goldman Sachs (which estimates that trucking will lose about 300,000 jobs per year)[8] and the International Transport Forum (50 to 70 percent reduced driver demand in the U.S. and Europe by 2030).[9] The threat is commonly described in calamitous terms: as a "revolution,"[10] or as the "death of the American trucker."[11] As Doug Bloch, political director for the Teamsters, put it: "everywhere I go I

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[4] Cite. (they spell it "computerisation" in case we care)

[5] The Council of Economic Advisers projected that jobs with wages under $20 per hour were 83% likely to be automated using the Frey & Osborne data, while those with wages over $40 per hour were only four percent likely to be automated. CEA 2016 ch 5 https://obamawhitehouse.archives.gov/sites/default/files/docs/ERP_2016_Chapter_5.pdf

[6] White House report 15-17. This estimate does not, however, take into account new jobs that may be created in the wake of disruption. https://obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/Artificial-Intelligence-Automation-Economy.PDF

[7] Frey/Osborne p 66. Frey and Osborne's study points out that these jobs are put at risk in terms of *technological capabilities*, but that "several additional factors," including the cost of human labor, social resistance, and regulatory concerns—will influence how many jobs are *actually* replaced.

[8] https://www.nytimes.com/2017/11/13/business/self-driving-trucks.html

[9] https://www.itf-oecd.org/managing-transition-driverless-road-freight-transport

[10] http://www.latimes.com/politics/la-na-pol-self-driving-politics-20171121-story.html

[11] https://www.rollingstone.com/politics/politics-features/death-of-the-american-trucker-253712/

hear people talking about a robot apocalypse, about 4 million transportation workers losing their jobs in the next five to twenty years."[12]

And as we've seen, trucking may seem to be an industry ripe for disruption. The work itself is difficult, unsafe, and often deadly. Major cost drivers and human inefficiencies in the industry—especially the labor shortage—could be ameliorated if human drivers were just not needed at all; this creates a strong "push factor" in favor of an automated solution. And of course, the same concerns about driver fatigue and overwork that motivated electronic monitoring in the industry also serve as justification for making trucks drive themselves: machines can work long hours, they don't get sleepy, and they don't need to take breaks. The tension between the legal restrictions on drivers' work hours and the speed of business demanded by the industry could be significantly eased if machines could do more of the work.

There are cost considerations, too. Some industry forecasters claim the autonomous revolution will be the biggest economic disruption to trucking since deregulation in 1980. In a best-case scenario, fully automated trucks could save companies money in lots of ways. Automated trucks would use fuel more efficiently (largely because of the possibilities for *platooning*, in which trucks drive very close together to reduce wind drag); insurance rates might decline; and asset utilization—the amount of time trucks a company owns are actually on the road, driving, rather than sitting unused in a parking lot—would increase. And of course, most significantly, robots don't need to get paid. If autonomous trucks reduce demand for human labor (a big if, as we'll see), companies could save millions in paid wages to human drivers. Altogether, some estimates that these cost savings to companies could add up to more than a dollar per mile driven—about half of which would come from reduced labor costs.[13]

So trucking might be a perfect storm for automation. There aren't enough human truckers to meet demand, and the truckers who are on the road are faced with unsafe and unhealthy conditions. And trucking companies might see significant savings if they can operate their equipment more efficiently and without paying humans to do it.

Driven by these factors, driverless trucks have become a site of tremendous technical innovation and investment. Machine learning, sensing, and object recognition have improved an enormous amount over the last decade, leading to major investment in self-driving vehicle research and development. And these systems are currently best suited for trucking: autonomous vehicles do their best driving on highways—where the great majority of trucking miles are driven—rather than on city streets, where speeds are more variable, pedestrians more frequent, and obstacles less predictable.[14]

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[12] https://www.trucks.com/2018/05/09/trucking-industry-robot-apocalypse/
[13] https://www.overdriveonline.com/forecasters-truckings-autonomous-revolution-is-nigh-and-it-may-be-prickly/
[14] Stromberg, Joseph. 2014. "Why Trucks Will Drive Themselves before Cars Do." *Vox*. (http://www.vox.com/2014/6/3/5775482/why-trucks-will-drive-themselves-before-cars-do).

Investors are making big bets on autonomous vehicles. Private investors spent more on AV companies in the second quarter of 2018—about $5 billion—than they had in the previous four years combined, driven in large part by SoftBank's $2.25 billion investment in General Motors' autonomous vehicle division.[15] One market research study predicted that the global AV market would increase *tenfold*—from $54 billion to $557 billion—between 2019 and 2026.[16] A 2017 Brookings report stated that autonomous vehicles were "the leading edge" for investment in AI systems, and projected continued market growth into the future.[17]

Alongside these investments, companies have begun publicly touting the accomplishments of their autonomous trucks. Perhaps the most poetic of these was the 120-mile test delivery, in Colorado, of 50,000 cans of Budweiser via autonomous truck. The test was successful (though the truck had a safety driver, was accompanied by a convoy of four state patrol cars, three company vehicles, and two tow trucks—a level of support clearly unsustainable for everyday beer deliveries).[18] Autonomous trucking startup Embark delivered refrigerators from El Paso to Palm Springs.[19] In Europe, a convoy of self-driving trucks platooned across the continent as a public demonstration of the technology's potential organized by the Dutch government.[20] Though these test runs and pilot projects are still accompanied by human backup drivers, their near-term goal is to remove the trucker from the cab altogether—at least for the majority of the time the truck is operating.

Systems like these contemplate the trucker as a *displaced* body. He is displaced both physically and economically: removed from the cab of the truck, and from his means of economic provision. The robot has replaced his imperfect, disobedient, tired, inefficient body, rendering him redundant, irrelevant, and jobless. And the result of this displacement, it is feared, could be sector-wide unemployment—the rapid dissolution of two million workers' livelihoods—resulting in massive demands for social services and economic disaster.

A slope, not a cliff

But the reality is more complicated. To be sure, unemployment is a real threat—but robotic trucks are unlikely to decimate the trucking profession in one sudden phase transition. Technical change is piecemeal. The path to fully autonomous trucking is likely to be a

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15 https://www.bloomberg.com/news/articles/2018-08-01/autonomous-car-tech-investment-skyrockets-on-softbank-deals

16 https://www.forbes.com/sites/edgarsten/2018/08/13/sharp-growth-in-autonomous-car-market-value-predicted-but-may-be-stalled-by-rise-in-consumer-fear/#4e1144b4617c (must pay for actual report)

17 https://www.brookings.edu/research/gauging-investment-in-self-driving-cars/

18 https://money.cnn.com/2016/10/25/technology/otto-budweiser-self-driving-truck/index.html

19 https://www.wired.com/story/embark-self-driving-truck-deliveries/

20 https://qz.com/656104/a-fleet-of-trucks-just-drove-themselves-across-europe/

gradual slope, not a steep cliff—a trajectory shaped not only by technical roadblocks (more on this in a moment), but by human, social, legal, and cultural factors, which economic forecasts about AI and job loss rarely consider.[21]

Truck drivers' daily work consists of much more than driving trucks. Truckers monitor their freight, keeping food at the right temperature in reefers and loads firmly secured to flatbeds. They conduct required safety inspections twice a day. They maintain the truck and make repairs to it—some of which are routine, and some less so. When truckers arrive at a terminal or delivery point, they don't just drop things off and leave: some load and unload their freight, they talk to customers, they deal with paperwork, they may spend hours making "yard moves" (waiting for an available delivery bay and moving to it, much as planes do at busy airports). Could some of these tasks be eliminated by intelligent systems? Surely some can and will—but these components of the job are much harder to automate, and will come much later, than highway driving.

And this is true of all work. Though we may boil jobs down to their component tasks for purposes of analyzing them, anyone who's held a job knows that work depends on deep-seated human knowledge that cannot always be boiled down to rule-sets and protocols. The philosopher Michael Polanyi called this the *tacit dimension* of human knowledge[22]—there are things humans know and do that evade easy categorization, and can barely be articulated, let alone automated. As Polanyi put it: "The skill of a driver cannot be replaced by a thorough schooling in the theory of the motorcar; the knowledge I have of my own body differs altogether from the knowledge of its physiology; and the rules of rhyming and prosody do not tell me what a poem told me, without any knowledge of its rules."[23] On Polanyi's reading, human activity is more art than science. Even if we can offload some tasks to machines, machines can never really replace people, precisely *because* they are machines.

And recall our discussion about imaginary rules. Machines are increasingly better at learning the rules, but have a hard time knowing when rules should *not* be followed. Just as ELDs make it more difficult for truckers to bend the timekeeping rules, autonomous vehicles may struggle with knowing when to bend the rules of the road. Indeed, some accidents have been caused by AVs hewing *too closely* to the rules (for instance, driving the posted speed limit). But driving requires fluidity, attention to local custom, and communication with surrounding drivers and pedestrians[24]—tacit knowledge that may be impossible for robots to fully grasp.

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[21] E.g. Brynjolffsson What Can Machines Learn? http://ide.mit.edu/sites/default/files/publications/pandp.20181019.pdf: "The rubric focuses on technical feasibility. It is silent on the economic, organizational, legal, cultural, and societal factors influencing ML adoption."

[22] Tacit dimension, 1966, polanyi

[23] Polanyi 1966, the tacit dimension, quoted in autor levy Murnane p 1283

[24] https://apnews.com/65e1c800ff0c4532abbdabc134e5f9b8

Social factors may slow adoption, too. The public fears autonomous vehicles. In a 2017 Harris poll,[25] sixty-nine percent of Americans thought riding in an autonomous car sounded very or somewhat risky; a Gartner poll the same year found that 55 percent of people would not ride in a fully autonomous car, and 29 percent would not ride in a car that was partially autonomous (allowing the driver to take over if necessary).[26] Drivers are nervous about hardware and software malfunctions, data security and hacking, and loss of control over the vehicle.[27] And though there have been relatively few crashes and fatalities of driverless vehicles to date (particularly in comparison to rates among non-autonomous vehicles), those that have occurred have attracted significant media attention and public response. An Uber AV struck and killed a pedestrian in Arizona in March 2018, prompting the state to ban the company from conducting further tests there. Jason Levine, executive director of the Center for Auto Safety, said that the crash "set consumer confidence in the technology back years if not decades."[28] (This crisis in confidence is encouraged by stakeholders with vested interests—like the international president of the Transport Workers Union, who called the Arizona accident "a stark reminder that our elected officials should think long and hard before they put dangerous humanless RoboBuses on the streets[.]"[29]) Later that same week, a Tesla in Autopilot mode struck a highway divider in California, killing its driver and sending Tesla's shares tumbling. Tesla's then-CEO Elon Musk responded by blaming human drivers for being overly "complacent" about autopilot mode and not paying sufficient attention while it was engaged.[30]

Given public fears around autonomous cars, autonomous trucks may face even more hesitation. The prospect of an imperfectly controlled 100,000-pound truck barreling unmanned down the highway is, for many, the stuff of nightmares or horror films. (Not for nothing, Stephen King's 1986 film *Maximum Overdrive* and Steven Spielberg's *Duel*, from 1971, each feature autonomous trucks with a life of their own and a taste for blood.) Certainly, public opinion will adjust as autonomous vehicles become safer and more commonplace, and as vehicles on the market gradually contain more automated features. But this process is likely to take time, and to temper the pace at which autonomous trucks might take over truckers' jobs.

Legal hurdles are also likely to slow adoption of fully autonomous vehicles. New types vehicles would require a host of new rules, from safety standards and traffic laws to insurance regulations and liability regimes. Standards for vehicle-to-vehicle

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[25] https://theharrispoll.com/breaking-down-the-barriers-of-self-driving-cars/
[26] https://www.cnbc.com/2017/08/24/consumers-still-anxious-about-autonomous-cars-says-gartner.html
[27] https://www.bloomberg.com/news/articles/2017-09-06/most-americans-wary-of-self-driving-tech-don-t-want-robo-cars
[28] https://www.bloomberg.com/news/articles/2018-03-19/uber-crash-is-nightmare-the-driverless-world-feared-but-expected
[29] http://www.pressreader.com/usa/the-columbus-dispatch/20180320/281513636687475
[30] https://www.bloomberg.com/news/articles/2018-06-07/tesla-model-x-in-california-crash-sped-up-seconds-before-impact

communication will need to be developed, so that autonomous cars can communicate with one another and with the infrastructure that surrounds them.[31] Steps will need to be taken to ensure that vehicle technologies are secure from hackers and other threats. Though rules of this sort have changed before and can change again, doing so takes time, invites competing interests, and is likely to delay the technical progress of autonomous vehicles for at least some time.[32]

The Federal Motor Carrier Safety Regulations[33] are the body of rules governing every aspect of commercial vehicles' operation on American highways, from safety requirements for drivers and equipment to what trucks may haul, from procedures for inspection to rules for noise and emissions. The regulations are extremely detailed; the "Green Book" (which compiles them in a single volume to be easily referenced by drivers) runs to about 600 pages of fine print. A comprehensive 2018 review[34] of the regulations assessed how compatible these rules might be with autonomous trucks. The review found that a number of rules and assumptions would need to be reassessed in light of autonomous trucks. Some of the rules seem fairly straightforward to revise or reinterpret. For example, current rules require requirement that a driver wear a seatbelt at all times; if a truck is operated autonomously or by a remote human, a seatbelt seems unnecessary. But others prove more difficult. For example, current rules require that a driver examine the cargo on his truck every three hours or 150 miles[35] to ensure it is well-secured; it is not immediately obvious how tasks like these are to be carried out without a human driver. Similarly, should current medical restrictions, licensing requirements, and hours-of-service rules apply to humans working in tandem with autonomous trucks, or remotely? It is not immediately clear.

Another issue is coordination among the hodgepodge of state regulations that control new vehicle technologies on public roads. As legal scholar Bryant Walker Smith puts it, "[o]n the question of vehicles that don't quite look like a car (or quack like a truck), state and federal law are terrifically muddled."[36] States' conditions for AV testing are currently quite variable; some states have lenient requirements (in part to lure AV businesses to locate within them), while other states have stricter standards that impede AV testing. This isn't a

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[31] https://www.wired.com/2017/05/senseless-government-rules-cripple-robo-car-revolution/

[32] Brynjolfsson and Mitchell (http://science.sciencemag.org/content/358/6370/1530) (p 1534) note that legal constraints like these are "subtle and difficult to identify, and they can create considerable inertia" to the adoption and diffusion of new technologies.

[33] Code of Federal Regulations Title 49, Subtitle B, Chapter III, Subchapter B

[34] https://rosap.ntl.bts.gov/view/dot/35426

[35] Sec 392.9

[36] Bryant Walker Smith, "A Legal Perspective on Three Misconceptions in Vehicle Automation." https://poseidon01.ssrn.com/delivery.php?ID=506001013065022031089080087079006123025021068055070082025086091026071116090019004031057122111022009036109118001090013006085078017084012076061123004003069126091070091009075044009095078107069096030066091108069120076072125087004004004093108105090084008007&EXT=pdf

workable situation for autonomous trucks: if an autonomous truck can cruise through Illinois and Ohio but not Indiana, the whole route is effectively stifled.

Eventually, coordination will be necessary to ensure that autonomous trucks can travel easily across state boundaries. This coordination might come in the form of overriding federal laws that preempt the states' patchwork rules. It wouldn't be the first time the federal government has acted to avoid such problems: the Supreme Court has previously invalidated states' patchwork laws regulating truck safety because of the difficulty they posed for interstate commerce. For example, states have previously passed laws mandating that trucks traveling on their roads have curved mudflaps rather than straight ones, or have limited the length of trailers trucks may carry—but state-specific rules like these impede the ability for trucks to legally travel across the country.[37] In each case the Supreme Court has struck down these state laws for violating the Commerce Clause. Should autonomous vehicles become more common for interstate travel, the federal government would likely adopt a similar approach to ensure that they can travel across state boundaries unimpeded.

There's some indication that the federal government is already aiming to create consistent rules. [[a bit on new NHTSA standards]]

But lawmaking takes time, and any new rules are likely to face some opposition—not least from labor unions,[38] from highway safety interest groups, and from industries that might suffer in the face of autonomous vehicles, like railroads.[39] Though new regulatory regimes will be developed, they are likely to be introduced and refined over time—another reason that autonomous trucks will arrive on a slope, not a cliff.

Instead of thinking about a sudden wave of unemployment, then, we should think about how AI will *change what work looks like* over the long haul. Automation tends to threaten particular work *tasks*, but rarely replaces entire jobs.[40] One oft-used example is the bank teller. Despite widespread fears that ATMs would replace the job of the human teller in the 1990s and 2000s, teller jobs not only increased—but increased faster than the rate of the general labor force. Tellers' jobs changed—they now do more marketing and customer relations work than plain cash-handling—but they didn't disappear.[41] There are, of course, counterexamples: "pinboys" no longer reset the pins at bowling alleys, and there are far fewer elevator operators than there once were. But jobs that consist of many and complex tasks are unlikely to be automated away, as there will always be parts of the work that machines can't do.

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[37] Bibb v. Navajo Freight Lines; Raymond Motor Transportation v. Rice

[38] https://psmag.com/economics/trucking-teamsters-driverless-tech

[39] https://www.overdriveonline.com/autonomous-revolution-may-be-nigh-but-its-coming-for-brokers-faster-than-drivers/

[40] Erik Brynjolfsson, Tom Mitchell, and Daniel Rock, "What Can Machines Learn and What Does it Mean for Occupations and the Economy?" 2018 http://ide.mit.edu/sites/default/files/publications/pandp.20181019.pdf

[41] http://www.aei.org/publication/what-atms-bank-tellers-rise-robots-and-jobs/

All of this suggests that there will still be human truckers for a long time to come—but this doesn't mean that *what it is to be* a human trucker won't change substantially. Rather than whole-cloth replacement of human truckers, autonomous technologies might require *integration* between humans and machines over a long period of time, as truckers are required to coordinate their work—and themselves—with and alongside the technology.

There are many forms this integration might take. Here, I'll describe three possibilities that have emerged in the trucking context: the *handoff*, *network coordination*, and *hybridization*.

The handoff: passing the baton

One vision of the future imagines robots and humans as co-workers. In this model, people and machines "pass the baton" back and forth to one another: the worker completes the tasks to which she is best suited, and the robot does the same. For example, the robot might take responsibility for mundane or routine tasks, while the human handles decision-making in exceptional circumstances, or steps in when the robot's capacities are exceeded.[42]

Human-robot teams hold promise both because they try to seize on the relative advantages of each—and because humans get to keep their jobs. In fact, some believe that human jobs might become more interesting and fulfilling under such a model, if robots can take on more of the "grunt work" that humans currently are tasked with completing. Erik Brynjolfsson raises the possibility of a "digital Athens" in which humans have more time for leisure and creative work, having outsourced the dullest and dirtiest tasks to machines.[43]

In journalism, for example, AI is used to automatically generate millions of routinized articles about corporate earnings reports, weather forecasts, and sports scores.[44] So-called "robot journalists" pull statistics from predictable sources and use natural language processing techniques to turn them into bare-bones, formulaic articles, aimed at readers who just want the facts, and want them quickly (for instance, quarterly earnings reports contain important information for stock traders to act on). And rather than being seen as a threat, many journalists seem to welcome their robotic co-workers: when the Associated Press began using a service called Automated Insights to write these articles, TechCrunch business reporter Alex Wilhelm wrote that

> Earnings season makes most reporters want to poke their eyes out with sharp objects. ... If I could offload the most quotidian [reporting tasks], say, crafting a standard paragraph that compares results with forecasts, and save myself a few seconds, I'd be all for it. No one reads TechCrunch, or me I suppose, because our prose when comparing fiscal third quarter diluted earnings per

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[42] tk Deirdre helen handoff paper if it's out yet
[43] https://www.technologyreview.com/s/428429/when-machines-do-your-job/
[44] https://www.theverge.com/2015/1/29/7939067/ap-journalism-automation-robots-financial-reporting

> share on a non-GAAP basis to market expectations is especially riveting. But I think that people do seek out reporting and analysis that helps make those numbers mean something.[45]

By using AI for these routine tasks, the Associated Press was able to increase the number of its quarterly earnings articles from 300 to 4,400—while freeing up its journalists to "use [their] brains and time in more enterprising ways during earnings season."[46] In journalism, then, humans and machines work in tandem, to the strengths of each: robots write formulaic copy to get routine news out quickly, while humans are freed up to do the more creative and interesting analytic work.

The human/robot team is not an especially farfetched idea for trucking work. In fact, most of us encounter a version of this model every time we sit behind a steering wheel. Modern cars commonly offer some form of technological assistance to human drivers. Adaptive cruise control is an example: when a human driver activates it, the car automatically adjusts its own speed to maintain a given driving distance from the cars in front of it. Lane assistance operates similarly—some passenger vehicles can self-steer to avoid crossing lane dividers. Both adaptive cruise control and lane assistance are designed as safety features, under the well-founded assumption that human drivers with limited attention spans and perceptive capabilities will fail to brake in time when cars ahead of them slow down, or will let the car drift into an adjacent lane, perhaps because humans can get tired and distracted. Parking assistance follows the same logic: some passenger cars can steer themselves into parallel parking spaces, a skill which many humans find notably difficult. All of these are examples of human-machine "teamwork" in everyday driving. The human remains in charge—but passes the baton to the machine for work the machine is better equipped to handle.

These types of automation might seem very distant from the fully autonomous vehicles we've discussed—and they are, technologically. But conceptually, fully autonomous cars that drive themselves completely lie on a spectrum alongside assistive technologies like these—they all ascribe *some* degree of autonomy to the machine. To clarify what *autonomous* means in a given situation, technologists and regulators use a classification system developed by the Society of Automotive Engineers (SAE), an organization that develops professional standards for the automotive and aerospace industries. The SAE defines six "levels" of autonomy for vehicles. At Level 0, No Automation, the human is fully in control of driving the vehicle, though the car may provide notifications and warnings to help her do so. Level 1, Driver Assistance, means that the car can execute specific driving tasks based on information that the car senses about the environment—like the lane control, adaptive cruise control, and parking assistance examples we've discussed—and that the human does everything else.

As the SAE's automation levels increase, the car gradually becomes responsible for more driving tasks. At Level 2—Partial Automation—the car can "self-drive" under certain

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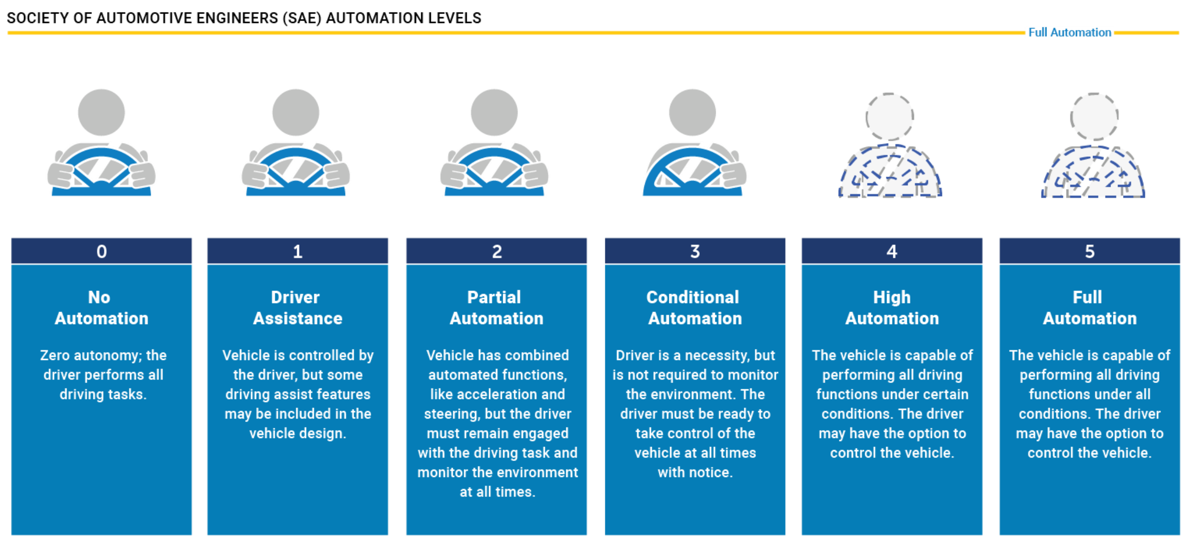
45 https://techcrunch.com/2014/07/01/bring-on-the-blogging-robots/

46 https://blog.ap.org/announcements/a-leap-forward-in-quarterly-earnings-stories

conditions—Tesla's autopilot mode, in which the car accelerates, brakes, and steers independently, is the best known commercial example—but the human is expected to monitor the environment and to take over if necessary. At Level 3, Conditional Automation, the car monitors the external environment and prompts the human to take control if necessary. As the SAE envisions Levels 4 and 5—High Automation and Full Automation, respectively—the human has even less role to play; at Level 4, the car is capable of driving itself under most conditions even if the human is prompted to intervene and fails to do so, and at Level 5, the human need play no role whatsoever in driving.

https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/styles/paragraphs_image_crop/public/nhtsa_sae_automation_levels.png?itok=0GsCp1em



http://cyberlaw.stanford.edu/files/blogimages/LevelsofDrivingAutomation.png

Summary of Levels of Driving Automation for On-Road Vehicles

This table summarizes SAE International's levels of *driving* automation for on-road vehicles. Information Report J3016 provides full definitions for these levels and for the italicized terms used therein. The levels are descriptive rather than normative and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. "System" refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*, as appropriate.

The table also shows how SAE's levels definitively correspond to those developed by the Germany Federal Highway Research Institute (BASt) and approximately correspond to those described by the US National Highway Traffic Safety Administration (NHTSA) in its "Preliminary Statement of Policy Concerning Automated Vehicles" of May 30, 2013.

Level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt level	NHTSA level
***Human driver* monitors the driving environment**								
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver only	0
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes	Partially automated	2
***Automated driving system* ("system") monitors the driving environment**								
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes	Highly automated	3
4	**High Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes	Fully automated	3/4
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**	-	

The most advanced AV technologies on the market today are just now approaching Level 3,[47] in which the car does most of the required monitoring of the environment—looking out for obstacles, keeping track of the locations and speeds of other cars, and the like—*but* the human is expected to "respond appropriately to a request to intervene." In other words, the machine has the baton most of the time, but the human has to be prepared to grab it immediately when the machine doesn't know what to do. A commonly used industry heuristic describes the progression of autonomy levels by the body part of the human driver that can be disengaged: "feet-off (Level 1), hands-off (Level 2), eyes-off (Level 3), and brain-off (Level 4)."[48]

What would the handoff model mean for truckers? In theory, the truck would handle the bulk of the driving in good conditions, and the human trucker would take over in situations where the machine has trouble—say, in a construction zone, or when visibility is poor.

[47] Audi claims it's at L3: https://www.forbes.com/sites/michaeltaylor/2017/09/10/tthe-level-3-audi-a8-will-almost-be-the-most-important-car-in-the-world/#2e9dfa21fb3d

[48] https://orfe.princeton.edu/~alaink/SmartDrivingCars/ITFVHA15/ITFVHA15_USA_Future_Truck_ADP_TF_WhitePaper_Draft_Final_TF_Approved_Sept_2015.pdf; https://www.just-auto.com/analysis/autonomous-vehicles-so-near-and-yet-so-far_id179343.aspx -- quote is from the latter

When the machine is in charge, the theory goes the trucker might be freed up for other tasks: as an American Trucking Association report forecasted, "[i]f drivers are unshackled from the wheel, they could do order processing, inventory management, customer services and sales[.]"[49] The former product manager of Otto—an AT startup acquired by Uber—had an even sunnier prediction: that when the truck drives itself, drivers could "nap and relax[,] ... chat with family and friends, learn a second trade, or run a business."[50]

This vision is similar to the transformation of the bank teller's role after the advent of the ATM: the machine does the boring routine work, freeing up the human for more interesting or skill-matched pursuits. But it leaves open big questions about whether or how truckers would be paid for time in the cab while the truck drives itself—after all, if trucking companies are still paying big labor costs, are autonomous trucks worth the investment?—and also wouldn't necessarily address problems around overwork and fatigue.

There's another problem that's even more fundamental. In theory, and given the right social and economic considerations, the baton-passing model sounds like an ideal arrangement. But in practice, baton-passing is incredibly difficult to execute smoothly in situations like driving. Recall that the machine passes off responsibility to the human in the situations it finds most difficult—when conditions are unusual, when there is something in the environment it isn't equipped to contend with, when there's a mechanical malfunction or emergency. Those situations are very likely to be safety-critical. One review of the scholarly literature found "a wealth of evidence" that automating some aspects of driving led to "an elevated rate of (near-) collisions in critical events as compared to manual driving. ... Essentially, if the automation fails unexpectedly with very little time for the human to respond, then almost all drivers crash[.]"[51]

And the time scale in which the baton is passed is miniscule: because of the nature of driving, a human is likely to have an extremely short window—perhaps only a fraction of a second[52]—in which to understand the machine's request to intervene, assess the environmental situation, and take control of the vehicle. This tiny time window is the reason why human drivers in semi-autonomous cars are warned that they must stay alert the entire time the car is driving. (Of course, in practice, humans ignore this warning—more on this later.) Despite the image of humans relaxing, napping, texting, eating, and being otherwise freed up from the requirements of driving, this image is patently unrealistic given the need for quick, safety-critical handoffs at current levels of automation. Audio and visual alarms can help humans know when a handoff is coming, but the

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49 https://www.sfchronicle.com/news/article/Robot-cars-may-kill-jobs-but-will-they-create-12410820.php

50 https://www.technologyreview.com/s/603493/10-breakthrough-technologies-2017-self-driving-trucks/

51 https://ac.els-cdn.com/S1369847814000904/1-s2.0-S1369847814000904-main.pdf?_tid=820b037e-401f-41a1-8b1a-11d0deeadeba&acdnat=1546871492_0b10519f2ad101fbf4259e4e98b91c08 p 208

52 http://delivery.acm.org/10.1145/2840000/2830565/p70-casner.pdf p 73

immediacy of the need to take control means that humans must still pay constant attention.[53]

This problem is made more severe because skills, if rarely used over time, tend to atrophy. The less often humans are called upon to drive a truck, pilot a plane, or otherwise do manually something which our robot co-workers have taken over day-to-day, the rustier we become at doing so. In 1983, engineering psychologist Lisanne Bainbridge wrote a prescient paper called "Ironies of Automation" that highlighted the paradox created when human workers become primarily "machine minders":

> [A human operator] may be expected to monitor that the automatic system is operating correctly, and if it is not he may be expected to call a more experienced operator or to take-over himself. ... Unfortunately, physical skills deteriorate when they are not used, particularly the refinements of gain and timing. This means that a formerly experienced operator who has been monitoring an automated process may now be an inexperienced one. ... When manual take-over is needed there is likely to be something wrong with the process, so that unusual actions will be needed to control it, and one can argue that the operator needs to be more rather than less skilled[.][54]

Skill atrophy leads to cognitive slowdown that can be crucial in a safety-critical situation; though the physical mechanics of how to do something may remain ingrained, humans do much worse with skills like performing mental calculations, recognizing abnormalities, navigating and visualizing how things relate to one another in space, and other cognitive tasks.[55] And subsequent generations of humans who never experience a fully manual system will have even smaller, weaker skillsets to fall back on.

Not only is it hard for humans to intervene when intervention is called for, it is cognitively unrealistic to expect humans to remain alert to the environment in case of emergencies—particularly as those emergencies become more rare, and as people begin to trust the technology more fully. Humans are notoriously bad at staying attentive to monotonous situations in which there is only rarely something important for them to notice and act upon. It's clear (particularly in the truckers' case) that work makes humans tired—but there's another kind of exhaustion, known as "passive fatigue,"[56] that comes from having *not enough* to do (what psychologist Stephen Casner and colleagues term "the tiring task of doing a little less"[57]). In fact, passive fatigue can be *more* harmful in the driving context

[53] http://delivery.acm.org/10.1145/2840000/2830565/p70-casner.pdf p 73
[54] Ironies of Automation, Bainbridge, p 775
[55] https://journals.sagepub.com/doi/pdf/10.1177/0018720814535628
[56] https://ac.els-cdn.com/S2351978915005004/1-s2.0-S2351978915005004-main.pdf?_tid=f5265605-f054-4406-bf4b-b8dddbeccc82&acdnat=1546961469_fd9bf21469b2e1270ade07b555fb17b3 Vigilance decrement and passive fatigue caused by monotony in automated driving, Krober et al 2015
[57] http://delivery.acm.org/10.1145/2840000/2830565/p70-casner.pdf p 74

than active fatigue (that is, fatigue that comes from being overloaded with work tasks), in terms of its effects on reaction times—and, ultimately, safety.[58]

Studies of so-called *vigilance decrement*—our tendency to let the mind wander from a boring task over time—were first conducted during World War II, when radar operators were charged with watching a display for hours to try to detect irregular blips. In 1948, psychologist Norman Mackworth developed a “clock test” in which study participants were given the mind-numbing task of monitoring the ticking hand of a blank-faced clock for two hours. When the clock hand jumped further than usual—the “signal”—participants were told to press a button. Mackworth’s test found that people became markedly less likely (10 to 15 percent) to detect the signal accurately after thirty minutes—and this ability declined even more as the task continued.[59] Subsequent studies have confirmed and extended Mackworth’s findings, finding that drivers in automated vehicles begin to show signs of tiredness and distraction after only ten minutes[60]—which got worse over longer drives.[61]

[possibly cut this paragraph] A further complication worth noting is where responsibility lies in such systems. Even when control over a task is distributed between human workers and machines, we tend to attribute legal and moral responsibility for failures to the human alone. MC Elish writes that the human in machine/human systems operates as a “moral crumple zone,”[62] absorbing blame when things go awry. Elish points to the Three Mile Island nuclear accident as an example: though the meltdown was a result of a variety of interconnected failures among cooling pipes, clogged filters, confusing control interfaces, and human operators, press accounts largely attributed the disaster to “human error,” ignoring the mechanical components that failed to operate as planned. Similar issues arise in aviation: even when autopilot systems malfunction or communicate incorrect or confusing information to human pilots, plane crashes are attributed primarily to pilots’ mistakes—including their failure to recognize when the *machine* has failed.

So it is difficult for humans to quickly understand and act on emergency situations—particularly as their skills degrade—and to monitor a machine with vigilance for long periods of time. This creates a fundamental irony about automation and human labor, argued Bainbridge; in contrast to its labor-saving intent, “[b]y taking away the easy parts of his task, automation can make the difficult parts of the human operator’s task more difficult.”[63]

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58 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4699167/

59 Mackworth, N.H. (1948). The breakdown of vigilance during prolonged visual search, Quarterly Journal of Experimental Psychology, 1, 6-21.

60 https://journals.sagepub.com/doi/pdf/10.1177/0018720818761711

61 https://reader.elsevier.com/reader/sd/pii/S0001457518301179?token=BDE6B8893A58AB499FD937564DDFD0E1B28DE9AF910A428735A983063D0E2BF52ECDF124ACE8C132A534CA89C3C9B526

62 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2757236

63 Bainbridge 777

This irony creates severe problems for human-robot handoffs in autonomous cars and trucks. So long as humans have *some* duty to monitor the driving environment—which they do at Levels 2 and 3, the current state-of-the-art—humans will almost inevitably do a poor job at accepting the baton from the machine. Does this mean there's no hope for safe autonomous vehicles? Not necessarily. If robots and humans make bad co-workers because of the weaknesses of the human, one solution might be to increase the level of automation even more, obviating the need for short-term handoffs to a human at all. This could create a second model of integration: *network coordination*.

Network coordination: divide and conquer

Our discussion of handoffs and baton-passing has focused on the nitty-gritty of specific driving tasks: who (or what) will take the wheel in what conditions, who (or what) is responsible for recognizing a pedestrian and looking out for the unexpected. But another way to think about the division of labor between humans and machines is as a matter of more systemic work-sharing. Rather than a focus on in-the-moment driving, we might think about humans and machines as sharing truck-driving work in a broader way: by dividing up responsibilities over the driving *route*. We've been thinking about the work of truck driving as a set of small, often simultaneous driving tasks: change lanes, hit the brakes, watch for road obstacles. We could instead think about it as a series of predictable *segments*: travel down the interstate, exit the highway and take local roads, steer around the receiver's docks. In this model, humans and robots still share the labor of trucking work, but take turns being wholly responsible for driving—much as you might take turns driving on a road trip with another person—with temporally and geographically predictable points of transition between the two of them. If we think of human/robot teams working together over these segments, a second model of integration emerges: *network coordination*. As we'll see, several trucking technology firms have set their sights on this sort of model.

But wait, you might think. The reason for autonomous cars to hand off control to humans is that they *aren't* fully capable of driving themselves—they can't negotiate unexpected obstacles well, they lack humans' tacit knowledge, they can fail catastrophically in new and complex situations. If this happens, how can we envision giving a machine total control over a portion of the route, without a human driver available to step in?

Part of the answer is that the difficulties autonomous vehicles encounter are "lumpy"—they're much more likely to occur in some route segments than others. Though they're far from perfect in any setting, autonomous vehicles perform much better on highways than on city streets: speeds are more constant, there are fewer intersections and unexpected obstacles, and contexts are generally more predictable and easier for a machine to negotiate. Things get much more complicated at the endpoints—when trucks leave the highways and venture into cities and towns to pick up or drop off loads. And when a truck arrives at a terminal, it doesn't just drop its stuff immediately and leave. A trucker might spend hours at a terminal making "yard moves"—queuing to be loaded or unloaded, backing the truck into the right bay, and following the directions of the customer. Some truckers load and unload freight themselves; others coordinate with the customer's unloading crew (or with "lumpers," third parties who unload the delivery on behalf of the customer). All of this requires irregular driving in response to immediate human direction, in large lots without lanes or traffic markings—and is nearly impossible for a machine to do on its own. (As a point of comparison, think of how planes taxi around at airports—despite the widespread use of autopilot in the air, there's little chance that taxiing will be automated anytime soon.) So, a natural division of labor in trucking might be that advanced autonomous trucks drive themselves over the long haul, and humans take the wheel for the endpoints—what's often called the "last mile" in transportation and logistics.

But still, you might think again: even over the long haul we've got problems. The state of the art in autonomous vehicles is still Level 3, which requires constant human monitoring, and brings with it all the intractable handoff problems we've discussed. So how is this a feasible model?

It isn't—yet. But some autonomous vehicle technology companies think the human/machine coordination challenges at Autonomy Levels 2 and 3 are so difficult that they are essentially attempting to "skip" those level, focusing their attention on developing Level 4 autonomy instead. They're doing this both for technical reasons and economic ones. In trucking, Level 3 offers little economic benefit: if a human trucker must stay in the driver's seat monitoring the road at all times (and growing more fatigued the longer he sits there), it's not obvious why the firm would invest substantially in the technology. But if Level 4 enables the truck to drive *without* the driver's constant attention (and for longer time periods—since robots don't get tired), the prospect is economically more attractive.

Is it possible to "skip" intermediate levels of automation and go straight to Level 4? Many carmakers are trying. Volvo plans do to so by 2021, claiming that it believes Level 3 driving to be inherently unsafe.[64] Ford also announced that it would "abandon[] a stepping-stone approach" and push straight to full autonomy.[65] Google's autonomous car division (now Waymo) raised eyebrows back in 2014 when it released a self-driving prototype with no steering wheel or brake pedal.[66] These experimental cars were so different from what people were used to that they were hard to stomach—but the company justified its vision based on what it had learned about difficulties with the handoff, and they seem to have been right to do so.

Uber, more popularly known for its ridesharing technologies, has tried to capitalize on this version of coordinated human/machine labor. In 2018, Uber announced that it envisions an autonomous truck network, connected by local (and presumably Uber-owned) "hubs" throughout the country. In this vision, customers would contract with Uber for the delivery of goods; autonomous trucks would run the long hauls between hubs, and human truckers

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[64] https://www.media.volvocars.com/global/en-gb/media/pressreleases/207164/volvo-cars-ceo-urges-governments-and-car-industry-to-share-safety-related-traffic-data

[65] https://www.linkedin.com/pulse/fords-road-full-autonomy-mark-fields/

[66] https://www.nytimes.com/2014/05/28/technology/googles-next-phase-in-driverless-cars-no-brakes-or-steering-wheel.html

would pick up and pilot the trucks from the hubs to delivery. Uber describes this model as "a future where truck drivers and self-driving trucks *work together*,"[67] handing off loads to one another at the transfer hubs.

This model exploits Uber's existing expertise with respect to distributing rides (or hauls) among drivers in a network. Alongside the network, the company has rolled out Uber Freight—an app that matches independent truckers with nearby available loads, replacing the load boards and brokers that typically orchestrate such matches—much like the driver/passenger matching that Uber specializes in for rideshare.

Uber described its network coordination model in sunny terms; it hoped that it "will lead to a more optimistic outcome"[68] than the mass job losses many fear to result from the new technology. Uber imagined instead that trucking jobs will shift from long-haul to local hauls—and that the increased efficiency of its model (self-driving trucks can drive all night and day) will boost the economy generally, increasing consumer demand for goods (and accordingly, more trucking jobs to move those goods).

Uber's assumption that the increased logistics efficiency wrought by automation will trickle down into consumer demand and more jobs is a big assumption—and not one shared by all economists. But, a model like this one *could* make human truckers' work better. Local drivers aren't on the road for weeks at a time, far from their families and communities—they go home every night. And importantly, local trucking would likely be safer and healthier for human truckers: by cutting out the long stretches of highway driving, the model could greatly reduce the driver fatigue that plagues the industry now.

But there's one problem: recall that truckers are paid by the mile. The great majority of miles driven (and thus money earned) takes place on the highway—not on traffic-packed local roads, not while maneuvering around at a terminal at the end of a haul. The parts of the job that Uber proposes to automate are precisely the parts that make up the lion's share of a trucker's salary! They make close to nothing for the tasks to which they'd be exclusively relegated under Uber's model. Under the current pay scheme, Uber would be hard-pressed to convince human drivers to focus on the least profitable aspects of their work.

So the only way the network coordination model makes sense is if the pay structure of trucking adjusts with it. Truckers have argued for pay reform in the industry for decades, but have lacked the political capital to make change. Uber, on the other hand, is an immensely powerful company that would be much more likely to have the power to transform the industry—just as it did to the taxi industry. What's more, Uber began publicizing its plans in 2017, shortly after it came under an unwelcome public spotlight for its questionable corporate culture and labor practices—a time when it might have welcomed a worker-friendly "win." So Uber's proposal initially seemed as though it might

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[67] https://medium.com/@UberATG/the-future-of-trucking-292202cb42a2 -- italics are mine.

[68] https://medium.com/@UberATG/the-future-of-trucking-b3d2ea0d2db9

be an unholy alliance that could actually *help* improve truckers' lots, and create a viable way forward for humans and machines to work together.[69]

In July 2018—only months after Uber announced its hub-and-spoke model to much fanfare—the company abruptly shuttered its autonomous truck division, saying it had decided to focus its energies exclusively on self-driving passenger cars. It's not entirely clear what precipitated this shift, though many in the industry chalked it up to legal troubles between Uber and Waymo (Google's self-driving vehicle group), from which Uber had allegedly poached trade secrets in a much-publicized lawsuit that cost Uber about $250 million in settlement.[70]

With Uber's shift away from autonomous trucks went any serious hope of achieving the network coordination model anytime soon. The project would have been tremendously ambitious, even for Uber—it necessarily involves substantial regulatory and organizational change, as well as colossal infrastructure and logistics costs to build transfer hubs all over the country and to distribute loads efficiently at the hubs. Uber was one of the only companies that might have pulled it off in the near term.

A variation on network coordination is allowing truck drivers to take the wheel remotely. Some companies like Starsky Robotics are working on this.[71] Starsky Robotics is developing a drone-operator-like system in which trucks drive themselves to a certain point, and human drivers sub in remotely from the highway exit to the terminal[72]—as if they are playing a video game. In theory, such a system could allow a single driver to pilot dozens of vehicles a day, for short periods of time, all over the country—and still return home each night. Some refer to this as a "call-center" model in which the robot calls into a human phone bank for guidance.[73] But it isn't obvious that this model is sustainable. For one, the handoff problems seem likely to be only exacerbated by distance and by the fact that the human may be monitoring several vehicles at a time. And there are other problems unique to the model: Ford shut down its system testing this idea after the vehicles repeatedly lost their cell signal so that human operators couldn't see the video feed.[74]

Hybridization: The rise of the RoboTrucker

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[69] https://www.theatlantic.com/technology/archive/2018/02/uber-says-its-self-driving-trucks-will-be-good-for-truckers/551879/

[70] https://www.technologyreview.com/the-download/610236/waymo-and-uber-have-reached-a-settlement-in-their-trade-secrets-trial/

[71] http://m.fleetowner.com/driver-management-resource-center/will-truckers-become-drone-operators

[72] http://fortune.com/2017/02/28/starsky-self-driving-truck-startup/

[73] https://www.wsj.com/articles/who-does-a-driverless-car-call-when-it-needs-help-a-human-1528191000

[74] https://www.wsj.com/articles/who-does-a-driverless-car-call-when-it-needs-help-a-human-1528191000

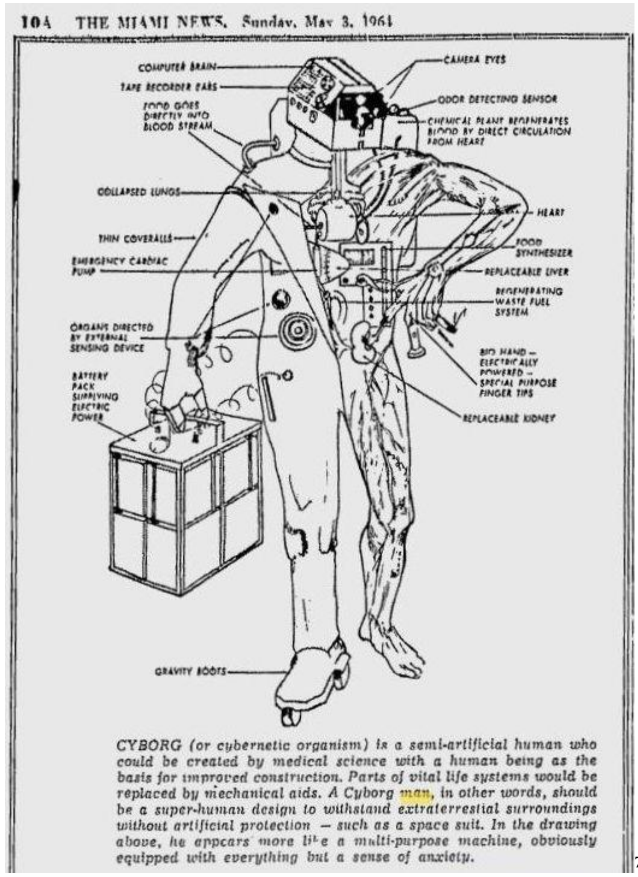
The future of trucking might someday look like these baton-passing or network-coordination models of shared labor. But right now, human/machine interaction in trucking looks very different. What we see happening in trucking now involves a much less discrete parceling-out of functions between humans and machines. Instead, truckers' physical bodies and intelligent systems are being *integrated into one another*.

The idea of direct integration between human bodies and computers has historical roots. The idea of the *cyborg*—a human/robot hybrid, or *cy*bernetic *or*ganism —was first proposed by scientists Manfred Clynes and Nathan Kline in 1960.[75] Clynes and Kline were interested in adapting human bodies for living in space for long periods of time. They thought there were essentially two ways to do this: humans could bring equipment to space that allowed their bodies to function more or less as they would in a "normal" (Earth-bound) environment—or they could *adapt* their bodies to more naturally function in the environment of space. Clynes and Kline were far more excited by the second option—the cyborg—in which the human body is modified to better fit the environs in which it operates.

A key aspect of the cyborg ideal is that it is seen as an *enhancement* of the normal human body. Becoming part-human, part-machine is a way of becoming *super*human: machines extend a person's natural capabilities and leave the person "free to explore, to create, to think, and to feel."[76] Clynes and Kline wrote that "adapting man to his environment, rather than vice versa, will not only mark a significant step forward in man's scientific progress, but may well provide a new and larger dimension for man's spirit as well."[77]

Take a look at the image below, from a 1964 article in the *Miami News*[78] discussing the prospect of sending cyborgs into space. The "machine-man" pictured here sports "tape recorder ears," "camera eyes," and, intriguingly, "special purpose finger tips." He is "equipped with everything but a sense of anxiety" as he traverses the new environment in which he finds himself, and is made more capable than ever by the technology that seamlessly integrates with his body.

[75] http://www.guicolandia.net/files/expansao/Cyborgs_Space.pdf
[76] Id. p 27
[77] Id. p 76
[78] [image of article is here: http://img.gawkerassets.com/post/8/2012/06/article.jpg]



10A THE MIAMI NEWS, Sunday, May 3, 1964

CYBORG (or cybernetic organism) is a semi-artificial human who could be created by medical science with a human being as the basis for improved construction. Parts of vital life systems would be replaced by mechanical aids. A Cyborg man, in other words, should be a super-human design to withstand extraterrestial surroundings without artificial protection — such as a space suit. In the drawing above, he appears more like a multi-purpose machine, obviously equipped with everything but a sense of anxiety.[79]

But the idea of the human/machine hybrid doesn't always connote freedom and potential. In the workplace, the integration of technology and human bodies and technology can instead be seen as a way for managers to keep ever-closer tabs on their employees. At the most extreme, a few companies have begun offering workers microchip implants—just like the chips we commonly implant into our pets. These chips, usually implanted into the hand, use near-field communication technology to be "read" by sensors throughout the workplace: they give workers access to restricted areas, let them use copiers and printers, and can let them be scanned to purchase food in the cafeteria.[80]

Though implants are still an exceptional case, a huge number of employers use wearable technologies to monitor workers. Neck-worn "smart" ID badges give employers insight into precisely where workers are in the office, for how long, and with whom they interact, and lets managers measure and incentivize behaviors that the firm considers productive.[81] Amazon has patented location- and motion-tracking wristbands for use in its warehouses,

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[79] The Miami News – May 3, 1964: https://www.newspapers.com/newspage/302056795/ illustration MIGHT be from World Book encyclopedia initially but we are not sure (see resolved comment)

[80] https://www.sfgate.com/business/article/Cyborgs-at-work-Employees-get-microchipped-11047084.php

[81] https://www.humanyze.com/

which can track how long it takes for a worker to pull an item from the shelf and whether the worker takes a too-lengthy bathroom break, and which vibrate when the worker makes an error.[82]

These sorts of wearables are generally found *on* rather than *in* the body, but often draw on data about bodily systems and behaviors. Workplace wellness programs may collect biometric data from wearable devices like Fitbits to incentivize healthy behaviors (like physical activity) through insurance discounts. Face recognition technologies and other biometrics are used for clocking in and out of hourly jobs, and for measuring workers' moods.[83] Another Amazon patent application for an "augmented reality user interface facilitating fulfillment"[84] describes a pair of goggles to be worn by warehouse workers that projects instructions within the worker's field of view, like directions to a particular location within a warehouse, and information about items to be packed. The goggles double as a tool for fine-grained monitoring of what the worker is doing, the speed at which she moves, the direction she is looking, and the like.

The human/machine hybrid imagined in these contemporary scenarios of labor seem a far cry from the enhanced, worry-free cyborg Clynes and Kline imagined. In her 2008 book *The Culture of Soft Work*, Heather Hicks describes the cyborg as a cultural icon of modern work: when "work activities coded in machine parts suffuse the human body," she writes, "the results are humans not liberated, but under control."[85] Microchips and augmented-reality goggles marry a worker's unique bodily and cognitive capabilities with those of the machine, turning her into a "super-worker" of sorts—but also operate as tools through which she can be more closely supervised and managed.

Compare the cyborg man from the *Miami News* illustration to the below cartoon, which appeared in a 2017 blog post published by *Land Line*, a truckers' trade magazine.[86]

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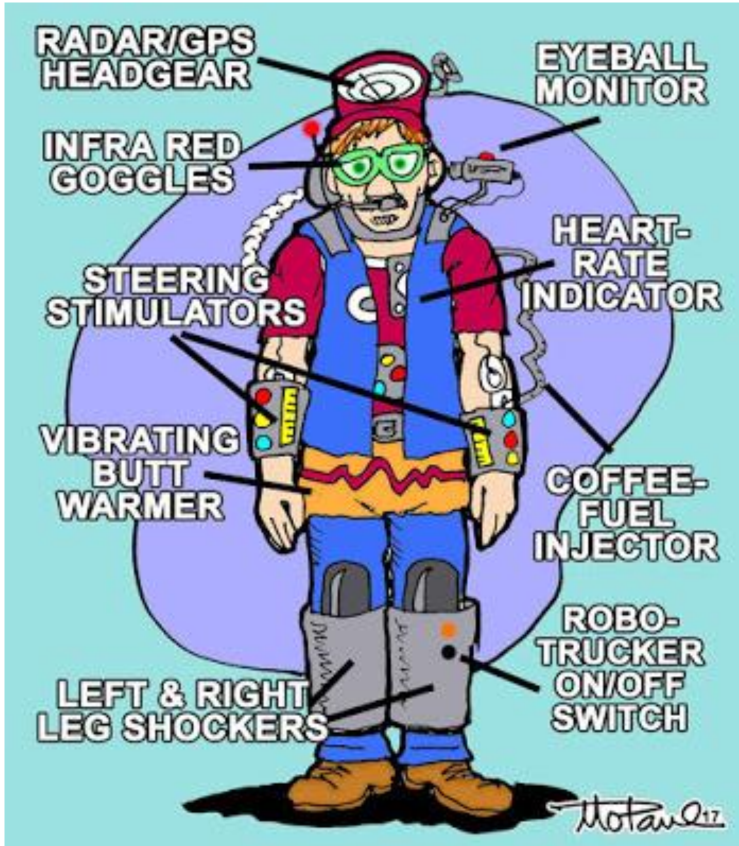
[82] https://money.cnn.com/2018/02/02/technology/amazon-employee-tracker/index.html

[83] https://www.dqindia.com/tech-mahindras-moodometer-gauges-employees-mood-uplift-work-environment/

[84] https://gizmodo.com/amazon-imagines-future-employee-surveillance-with-paten-1828051062 Patent application: US 2018/0218218 A1, published 8/2/18, here

[85] P 136 of Culture of Soft Work, Hicks

[86] http://landlinemedia.blogspot.com/2017/01/new-gadgets-move-us-closer-to-world-of.html



The article accompanying the illustration laments the rise of the "RoboTrucker": the driver burdened by a proliferation of gadgets that aim to keep him awake and alert. The technologies shown in the illustration are exaggerated for effect, but only just: a number of products on the market do more or less what the cartoon depicts. These tools generally are marketed as *fatigue detection* systems or *lone worker monitoring* devices, aimed at giving managers remote insight into how tired a trucker's body is, and how fit he is to drive at that moment.

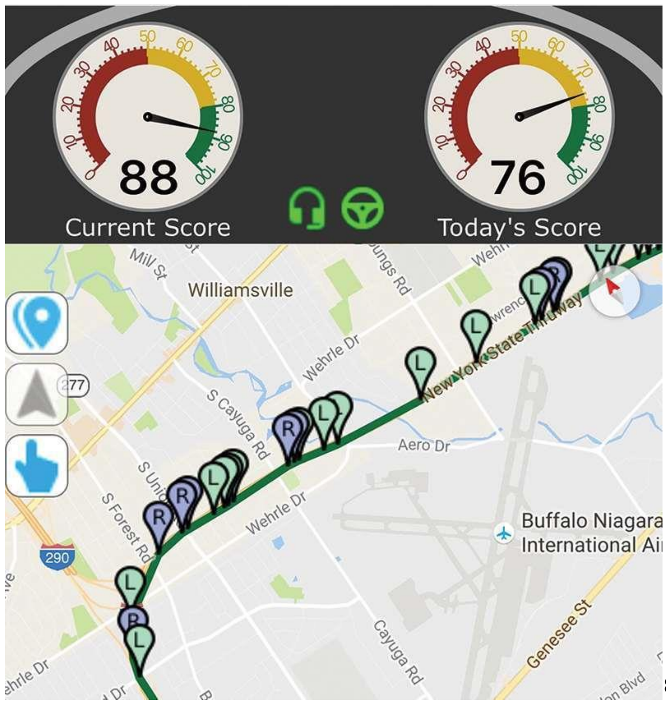
Generally speaking, there are two kinds of technologies that turn truckers into robotruckers. The first are wearables, which monitor elements of the trucker's internal bodily state and use them as metrics for management. For example:

- Mercedes is working on a vest that monitors a trucker's heart rate that can stop the truck if it senses the trucker is having a heart attack.

- The SmartCap is a baseball cap (also available as a headband) that detects fatigue by monitoring a driver's brainwaves (essentially doing a constant EEG). Rear View Safety markets a similar system; if the wearer gets tired, it sounds an alarm (and some models flash lights in the wearer's eyes) It can be configured to send an alert to a fleet manager or a family member. Similar devices are used by high-speed train conductors in China to monitor workers' stress levels and emotional spikes.[87]

- Optalert, an Australian company, manufactures a pair of glasses that monitor the speed and duration of a trucker's blinks in order to give him a realtime fatigue score.

- Maven Machines' Co-Pilot Headset detects head movement that suggests the driver is distracted (for example, looking down at a phone) or tired (for example, failing to check his side-view mirrors regularly).[88] Back-office map of when left and right mirror checks are performed:



[89]

- Wrist-worn Actigraph systems monitor *and predict* fatigue rates over time. The technology, initially developed by an Army research lab, blends biometric data about a trucker's alertness with other data (like start time) to forecast how long he can drive before becoming too tired.[90]

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[87] https://www.scmp.com/news/china/society/article/2143899/forget-facebook-leak-china-mining-data-directly-workers-brains

[88] https://www.overdriveonline.com/fatigues-fast-track-body-language-wearable-monitor-makers-see-inroads-in-trucking-industry-detecting-fatigue/

[89] https://www.overdriveonline.com/fatigues-fast-track-body-language-wearable-monitor-makers-see-inroads-in-trucking-industry-detecting-fatigue/

[9090] https://www.overdriveonline.com/fatigues-fast-track-body-language-wearable-monitor-makers-see-inroads-in-trucking-industry-detecting-fatigue/

The second set of technologies are **cameras** pointed at the driver designed to detect his level of fatigue, often by monitoring his eyelids to track his gaze and look for signs of "microsleep." Seeing Machines is one of several companies that market driver-facing cameras that use computer vision to monitor a driver's eyelids and head position for signs of fatigue or inattention. If the driver's eyes close or look away from the road for too long, it sounds an alarm and sends a video to his boss[91]—and can also causes the driver's seat to vibrate in order to "goose" him back into attention.[92] Another driver-facing camera vendor, Netradyne, uses deep learning and data from driver- and road-facing cameras to generate scores for drivers based on their safe and unsafe driving behaviors.

Some industry insiders believe that it's only a matter of time before trucker wearables and driver-facing camera systems become standard and even legally required, following the path of the ELD before it. Firms will value these systems not only for fatigue detection, but as a source of evidence in accident investigations,[93] and even as a means of tying drivers' performance to compensation (for example, by giving drivers bonuses for not triggering fatigue alarms).[94] If this sounds familiar, it should; the same managerial dynamics that supported the adoption of the ELD seem very likely to be similarly tied to biometric and camera systems in the near future. And just as previous managerial tools were baked into the ELD's hardware, fatigue detection tools seem destined to become part and parcel of the very same systems. For example, Blue Tree Systems' ELD offers managers the ability to score drivers on a number of driving behaviors, and but also tracks the time between a driver taking his foot off the accelerator and pushing it onto the brake—a measure called "anticipation"—which can operate as a proxy for fatigue (as tired drivers tend to make these moves more suddenly).[95] Driver-i's machine vision capabilities not only monitor drowsiness, but checks to ensure the driver's seatbelt is buckled.[96] There are also early indications that such systems might be of interest for insurance purposes;[97] one carrier's

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[91] https://www.thetruckersreport.com/smile-facial-recognition-software-coming-truck-near/

[92] http://www.landlinemag.com/Magazine/2016/June/story/alertness-cams.aspx

[93] https://www.overdriveonline.com/one-year-in-lytx-activevision-camera-system/ (noting "exonerations"… but not the reverse)

[94] https://www.overdriveonline.com/tomorrows-trucker-camera-systems-taking-a-lead-in-data-harvest/; https://www.overdriveonline.com/dashcam-video-monitoring-platform-with-artificial-intelligence-bonus-aims-at-driver-rewards-focus/

[95] https://www.overdriveonline.com/fatigues-fast-track-regulations-are-fatigue-monitoring-systems-destined-to-upend-hours-based-regulations/

[96] https://www.overdriveonline.com/fatigues-fast-track-dashcam-monitoring-private-eyes-watching-you/

[97] https://www.overdriveonline.com/fatigues-fast-track-body-language-wearable-monitor-makers-see-inroads-in-trucking-industry-detecting-fatigue/

safety director said he expects a mandate for use of fatigue monitoring "not from the feds[,] but from the underwriters."[98]

Others raise the possibility that fatigue-detection systems might upend the hours-of-service regulations altogether[99]—after all, why not know *precisely* how tired a driver is, rather than making a blanket rule that assumes everyone has the same capabilities? This prospect raises a number of interesting issues. Might the trade-off for clumsy hours restrictions be an intrusive invasion of truckers' bodily privacy? To what extent do the potential benefits of a more personally-tailored regulation—not to mention the public safety benefits of less tired truckers—warrant requiring truckers' intimate bodily data to be collected by their employers, much less the government? It will likely be a while before we do away with the hours-of-service regulations altogether—but the government is beginning to dip its toe into using AI-driven technologies for enforcement purposes. As far back as 2013, the FMCSA's Medical Review Board urged the regulator to consider requiring cameras for monitoring driver performance;[100] AAA has also recommended requiring driver-facing cameras as a safety measure.[101] As another example, a pilot program at the U.S.-Canada border is using facial recognition software to scan drivers' faces as a "fast track" through customs enforcement; by scanning the driver's face, Customs will know instantaneously whether the trucker "is up-to-date on his paperwork and border fees[.]"[102]

The *Land Line* article acknowledges that these sorts of technologies can help truckers in some contexts—giving him needed directions, helping him stay safer and better connected. But it raises concerns about the slippery slope such technologies create, arguing sarcastically:

> "Why can't we produce boots for the right foot that "shock" the driver if he or she applies too much or too little pressure on the gas pedal? And how about some gloves that create a small "burn" if the driver's hands don't remain in the correct position on the steering wheel? While we're at it, can we get a helmet that tracks a driver's thoughts, and produces a "stinging" sensation if he or she begins thinking about anything other than driving?"

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[98] https://www.overdriveonline.com/fatigues-fast-track-regulations-are-fatigue-monitoring-systems-destined-to-upend-hours-based-regulations/

[99] https://www.overdriveonline.com/fatigue-monitoring-eventual-replacement-for-hours-of-service/

[100] https://www.overdriveonline.com/tomorrows-trucker-potential-for-fatigue-detection-points-to-intensive-enforcement/

[101] https://www.thetruckersreport.com/aaa-calls-driver-facing-cameras-tech-trucks/

[102] https://www.thetruckersreport.com/truckers-targeted-facial-recognition-artificial-intelligence/

As this passage makes clear, there's something viscerally offensive about the micromanagement enabled by these technologies; the privacy intrusions brought about by the introduction of the ELD pale in comparison.

This is the felt reality of AI in trucking labor now: using AI to address human "weakness" through constant, intimate, visceral monitoring. There's an enormous distance between the narrative of displacement that characterizes most public discussion of AI's effects on truckers and how these effects are actually being felt through these technologies. The threat of displacement is a real one, particularly to truckers' economic livelihood—but driverless trucks are not yet borne out by common experience, and drivers are also not yet handing off a baton to or splitting routes with a robot co-worker. Truckers' encounters with automation and artificial intelligence have not yet supplanted them or made their skills redundant.

Instead, technologies like the ones described above represent a distinct and simultaneous threat: a threat of *compelled hybridization*, an intimate invasion into their work and bodies. AI in trucking today doesn't kick you out of the cab; it texts your boss and your wife, flashes lights in your eyes, and gooses your backside. Though truckers are, so far, still in the cab, intelligent systems are beginning to occupy these spaces as well—in the process, turning worker and machine into an uneasy, confrontational whole.

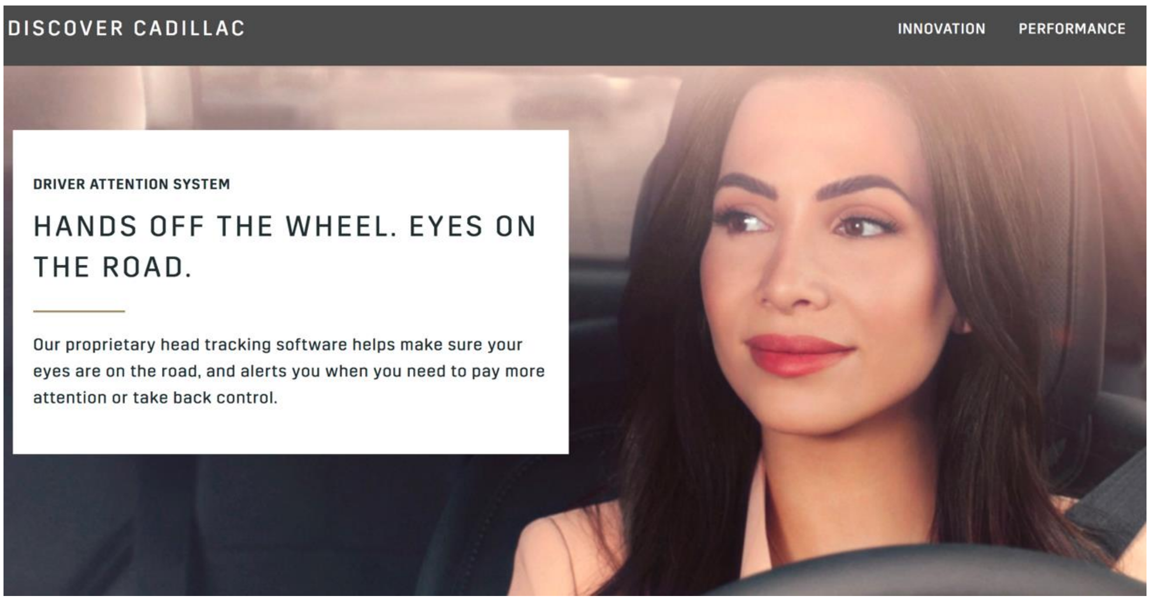
Automation and surveillance as complements

Telling the story of how AI is finding its way into trucking helps us to understand workplace *automation* and workplace *surveillance* as complementary phenomena. The risk of worker displacement is one component of the story, and an important one. But we shouldn't focus so exclusively on the risk of lost jobs that we fail to pay attention to the nature, quality, and dignity of the work that remains. Trucks will be "driven" by humans for a long time to come, though what "driving" means is likely to change—and we must consider what these changes mean for the humans tasked with doing the job. They may mean that the job is less risky, less boring, and better for all involved—or they may mean that the worker is monitored more intimately and more intrusively by the technology he works alongside.

A skeptical reader might chalk all this up to growing pains. There are always winners and losers in technological change; some people's jobs disappear, some improve, and others get worse. Such is the price of progress. And perhaps all these intrusive technologies prove is how much we *need* fully autonomous systems in the first place. Humans are faulty in ways that robots are not: humans get tired, they get distracted, they have heart attacks and strokes. The faster we get humans and their imperfections out of the loop, the better off everyone will be.

It's true that humans are faulty—but automating them away isn't a solution. There will always be a role for humans in (so-called) autonomous systems—in their design, operation, maintenance, use, and oversight. Those roles may look different than they did before, to be sure—but the notion that humans *can* be eliminated from systems is fundamentally false.

This tells us something about the relationship between automation and surveillance. A naïve reading of the situation might suggest that automation obviates the need for surveillance. But recall that even the most autonomous vehicle systems on the market today require humans to maintain attention and be at the ready to step in. And recall that humans are *extremely bad* at maintaining such attention—and will look for creative ways around doing so.



So how do we impel the human to fulfill her role? By monitoring her, and nagging her, and imposing legal liability on her if she fails. Despite marketing rhetoric of humans kicking back and napping while their cars autonomously zip them around town, the consumer market for autonomous vehicles is rife with surveillance—in fact, the same sorts of technologies to which the robotrucker is subjected. GM's Driver Attention System engages when its hands-free "Super Cruise" mode is enabled; the system's camera monitors the driver's head and eyes, and uses flashing lights, voice alerts, and seat vibrations if it detects that the driver is inattentive. (It will eventually stop the car and contact emergency services if the driver fails to take control.) Toyota and Tesla have similar driver-monitoring systems. My goal is not to suggest that some degree of monitoring is not acceptable or necessary for these systems to operate safely; rather, it is to recognize that surveillance is part and parcel of autonomous systems because *people are still integral to those systems*, and are likely to remain so.

* * *

Back to the truckers. Technology isn't deterministic, and its impact on work and workers depends on the details. Are technologies introduced as a "shock" to the system, or gradually integrated with work practices over time? What policies are put into place to govern the use of new tools, to allocate their risks, and to insulate workers from their effects? Are workers retrained in new skills if their old skills become obsolete, and what social safety net—unemployment insurance, welfare benefits, health care provision—do we have in place to help them during periods of disruption? How can technologies be integrated into the identity and culture of an occupation, its workers' traditions and goals *beyond* making money? And how do we account for workers working *with* systems, not just being replaced by them?

[TK: In a way, the introduction of a new technologies becomes an inflection point for evaluating the direction of an institution, and reconfiguring the social and legal scaffolding around it. How could autonomous technologies be *good* for truckers? Not sure how to round this out but there is something to be said about assistive technology and about the potential for labor law and wage reform occasioned by the new tech.]