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The Contradictory History of Accountability in Automated Aviation

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[1] The Intelligence and Autonomy (I&A) Initiative seeks to develop general principles applicable across sectors — on the legal, technical, societal, and economic level — to secure the public interest in intelligent systems. Our objective is to create coherent, common frameworks that will enable more effective policymaking and encourage an interdisciplinary approach that draws on valuable lessons across sectors. I&A is supported by the John D. and Catherine T. MacArthur Foundation and is based at Data & Society Research Institute in New York City.

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Abstract

What will happen to current regimes of liability when driverless cars become commercially available? What happens when there is no human actor—only a computational agent—responsible for an accident? This white paper addresses these questions by examining the historical emergence and response to technologies of autopilot and cruise control. Through an examination of technical, social and legal histories, **we observe a counter-intuitive focus on human responsibility even while human action is increasingly replaced by automation**. We argue that a potential legal crisis with respect to driverless cars and other autonomous vehicles is unlikely. Despite this, we propose that the debate around liability and autonomous systems be reframed more precisely to reflect the agentive role of designers and engineers as well as the new and unique kinds of human action attendant to autonomous systems. The advent of commercially available autonomous vehicles, like the driverless car, presents an opportunity to reconfigure regimes of liability that reflect realities of informational asymmetry between designers and consumers. Our paper concludes by offering a set of policy principles to guide future legislation.

I. Introduction

Across a range of disciplines, recent articles have pointed to a potential legal crisis with the advent of driverless cars and other autonomous vehicles. Who will be responsible if a driverless car hits a pedestrian? Who will be responsible if an unmanned drone flies through a window? At issue, the arguments claim, is that traditional paradigms for holding actors accountable have been disrupted to the point of obliteration. What happens when there is no human actor—only a computational agent—responsible?

The potential dilemmas described above hinge not only on technological capabilities but also cultural perceptions, norms and laws. This paper attempts to think about both technology and culture together in order to analyze the conditions and stakes of widespread autonomous systems.[2] Processes of automation we understand to be relevant to autonomous systems because automation is a low-level form of autonomy, when automation is considered as "a device or system that accomplishes (partially or fully) a function that was previously, or conceivably could be, carried out (partially or fully) by a human operator."[3]

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[2] In this paper we use the term "autonomous system" in its broad and colloquial meaning, a system of hardware and software that operates without human intervention. What constitutes "human intervention" is key to defining autonomy and varies within different domains. For a graduated definition of autonomy in the automotive context, see NHTSA Press Release. 2013. U.S. Department of Transportation Release Policy on Automated Vehicle Development. May 13. See also Robin Murphy and James Shields. 2012. *DOD DSB Task Force Report: The Role of Autonomy in DoD Systems*. Defense Science Board, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. Washington, DC.

[3] A framework for categorizing types of automation proposed by Parasuraman, Sheridan and Wickens is useful for specifically analyzing the types of perceptions and actions at stake in

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Specifically, this paper intervenes in discussions regarding predictions of autonomous technologies in the United States context in two ways. First, we contextualize the recent advances of driverless cars and other autonomous vehicles by presenting historical advances in automation, specifically aviation autopilots. Through an examination of the technical, social and legal histories of autopilot, we observe a counter-intuitive focus on human responsibility even as human action is increasingly replaced by automation. We argue that while autopilot technologies and associated high-level forms of automation had the potential to disrupt regimes of liability, government legislation and court rulings created a relatively seamless integration into existing product liability and tort law. Given this pattern, we argue that a potential legal crisis with respect to driverless cars and other autonomous vehicles is unlikely.

As our second intervention, we propose that the debate around liability and autonomous technologies be reframed more precisely to reflect the agentive role of designers and engineers as well as the new and unique kinds of human action attendant to autonomous systems. We argue that maintaining a focus on *human* accountability in complex human-machine systems is crucial as we enter a time of increasing technological innovation. This accountability must exist not only in the form of the operator or the physical manufacturer of a system, but also in the designers of the software and human-machine interface (HMI) that directs the system and creates the structures for potential human intervention. A computational agent is not, and must not, be seen as an individual agent but rather as an extension of the engineers and designers—the human agents—who developed it. We conclude by offering a set of policy principles based on our observations and analysis.

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autonomous systems. Parasuraman et al. define automation specifically in the context of human-machine comparison and as "a device or system that accomplishes (partially or fully) a function that was previously, or conceivably could be, carried out (partially or fully) by a human operator." This broad definition positions automation, and autonomy by extension, as varying in degree not as an all or nothing state of affairs. They propose ten basic levels of automation, ranging from the lowest level of automation involving a computer that offers no assistance to a human to the highest level of automation in which the computer makes all the decisions without any input at all from the human. NHTSA (National Highway Transportation Safety Administration) has outlined a similar framework to describe levels of automation in cars. See Parasuraman et al. 2000. "A Model for Types and Levels of Human Interaction with Automation." *IEEE Transactions on Systems, Man and Cybernetics (*30)3, and NHTSA Press Release. 2013. U.S. Department of Transportation Release Policy on Automated Vehicle Development, May 13.

II. Contextualizing Aviation Technologies and Cultures

A. An Early History of Autopilot

Since the beginning of modern flight, the role of automating control of an aircraft has been a point of exploration. With the advent of new technologies—and new social norms—a complex dynamic of control has emerged between pilot, autopilot, and eventually flight management system.[4] This section traces the technical and social histories of autopilot technologies in order to bring to light how forms of agency and liability have emerged and how norms of accountability have been established.

Within a decade of the first successful heavier-than-air human flight by the Wright brothers in 1903,[5] [6] inventors like Lawrence Sperry were attempting to improve flight through automated controls.[7] Sperry's automatic pilot linked mechanisms (including a gyroscope, which had been invented by his father, Elmer Sperry) that measured the position of the aircraft with an electric servomotor that moved cables attached to the control surfaces of the aircraft. Sperry's autopilot was a two-axis autopilot, operating on only two of the three airplane's control axes.[8] Early media descriptions of the Sperry

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[4] See also David Mindell, 2005. "Beasts and Systems: Taming and Stability in the History of Control" in *Cultures of Control,* edited by Miriam Levin. Amsterdam: Harwood: 203-222.

[5] While the development of heavier-than-air flight can be traced to the mid 19th century, the first controlled and successful heavier-than-air human flight is generally credited to the Wright brothers in 1903. The Wright brothers had owned a successful bicycle shop, and they applied the principles of control and balance necessary for riding a bicycle to reconceiving the problem of successful human flight. The Wright Flyer was a fixed wing aircraft that allowed its operator to control the aircraft along three-axes (yaw, pitch and roll), and relied on a skilled pilot to operate it successfully; the stability of the aircraft was to come from a machine-man system, as opposed to a completely stable airframe in and of itself. See Charles Stark Draper. 1955. "Flight Control" 43rd Wilbur Wright Memorial Lecture. *Journal of the Royal Aeronautical Society* 59 July, 451-478:463. Charles Draper, a leading engineer on the Apollo lunar spacecraft control system, pointed the Wright brothers' decision to develop toward conditions of control, rather than inherent stability, as their primary contribution to aeronautics. Quoted in Tomayko 2000.

[6] James Tomayko. 2000. *Computers Take Flight: A History of NASA's Pioneering Digital Fly-By-Wire Project: The NASA History Series*. Washington, DC: National Aeronautics and Space Administration: 2.

[7] The first flight to successfully use Sperry's autopilot took place in New York in 1913.

[8] Although autopilots did not become widespread in commercial aviation until after World War II, autopilots were in use and were incrementally developed in the interwar years in the United States and Europe. Today, autopilots are digital and operate on all three airplane axes, controlling multiple surfaces of an aircraft (rudder, aileron, elevator or on the of the trim tabs on those surfaces). Today autopilots generally have additional components including automatic navigation and automatic tracking capabilities. Since the 1970s, autopilots are generally only one automated system within the more expansive automatic flight control system (AFCS), which includes the electronic systems, equipment and devices which automate key aspects of the cockpit, including communication and navigation systems. In common parlance, the term autopilot is used interchangeably with the AFCS although strictly speaking they refer to different systems.

autopilot and similar technologies hailed the devices as revolutionizing flight safety. In 1914, one reporter proclaimed, "Long-sought aeroplane stabilizer invented at last!"[9] Another article describing a similar technology announced, "New device makes airships foolproof."[10] The emphasis on safety was understandable given that flying was tremendously dangerous at this time and generally was viewed as a hobby for daredevils or the rich and insane.

If the central engineering problem of early modern flight was achieving stability of the aircraft, then correspondingly, the central social problem was convincing the public that human flight was safe. For instance, in response to one of the first proposals to legislate aviation, a New York statesman summed up a predominant attitude by saying, "If a man wants to kill himself, let him do it."[11] Even in 1938, a judge described aviation as "ultra-hazardous" in a ruling involving liability for an airplane accident,

> Aviation in its present stage of development is ultra-hazardous because even the best constructed and maintained aeroplane is so incapable of complete control that flying creates a risk that the plane even though carefully constructed, maintained and operated, may crash to the injury of persons, structures and chattels on the land...[12]

It was the very impossibility of total human control that made flying seem so perilous. Flying was not only dangerous but also completely unregulated.[13] Technological advances achieved during World War I improved safety and exposed the public, through newspapers or first hand as soldiers, to the utility of flight. Still, even after World War I, flying was uncommon. The safety of flying did not impact the average citizen, and so the general attitude of legislatures and the public was that if an accident occurred, no one was to blame except the person who ventured into the air in the first place. It was the aviation

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[9] Harold Hoeber. 1914. "Long-sought aeroplane stabilizer invented at last." *New York Times*. 1 July:SM9.

[10] "New Device Makes Airships Foolproof." 1916. *New York Times*. 27 Nov:20.

[11] Nick A. Komons. 1978. *Bonfires to Beacons: Federal Civil Aviation Policy Under the Air Commerce Act, 1926-1938*. Washington, DC: U.S. Department of Transportation, Federal Administration. Available online: http://hdl.handle.net./2027/uc1.b4431995 (accessed 12/14 2014): 23.

[12] Quoted in Henry Grady Jr. Gatlin. 1951. "Tort Liability in Aircraft Accidents." *Vanderbilt Law Review* 4, 857-875: 61, footnote 24.

[13] As an FAA historian wrote, "Far from being viewed as a mode of transportation crucial to the nation's economic well-being, [flying] was regarded as late as 1924 as having limited commercial application. 'For the most part,' William P. MacCracken Jr., said, "people thought of flying as somewhere between a sport and a sideshow.'" Komons 1978: 11.

industry itself and associated special interest groups who advocated for federal certification and safety regulations.[14]

B. The Beginnings of Aviation Regulation

As technological advances increased the safety and quantity of commercial aircraft, laws and social norms shifted to meet the new technologies.[15] In 1926 President Calvin Coolidge signed the Air Commerce Act into law. This act established aviation as an object of federal regulation, including a mandate to foster the aviation industry, develop infrastructure, investigate accidents, license pilots and certify aircraft as airworthy. By the late 1940s a basic infrastructure for the American aviation industry was in place, a wealth of new technological advances had improved flight, and there was a growing trust in the utility and reliability of aviation. In 1938 passenger-miles flown were around 560 million. In 1946, passenger-miles flown were closer to 6 *billion*, more than ten times what it had been ten years earlier. By 1952, the number of passenger-miles flown more than doubled to 13 billion.[16]

Nonetheless, flying was a substantially risky mode of transportation. Consider, for instance, a series of accidents in the mid 1940s that brought flight safety to the forefront of the American media. In the summer of 1945, a B-25 bomber airplane crashed into the Empire State Building on its way to Newark while in thick morning fog. Fourteen people were killed.[17] In October and November 1946 there were four separate crashes in the United States, resulting in fifty-four deaths. Six months later, in the summer of 1947, 143

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[14] For a comprehensive history of early aviation from a regulatory standpoint see Komons 1978 especially Chapter 1, "The Chaos of Laissez Faire in the Air," for popular perspectives on aviation in the 1920s as derived from primary source documents.

[15] This statement should not be taken as an implicit form of technological determinism. Our method in this paper derives from the social shaping of technology approach articulated by Donald MacKenzie and Judith Wajcman in their introduction to the collection, *The Social Shaping of Technology* (1999). A social shaping of technology approach positions technology and culture within the same sphere, as co-dependent and mutually constitutive. See Donald Mackenzie and Judith Wajcman, eds. 1999. *The Social Shaping of Technology*. Philadelphia, PA: Open University Press, 2nd edition. For social science approaches to studying the mutual constitution of technology and culture see also: Wiebe Bijker, Thomas Hughes, and Trevor Pinch eds. 1987. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Cambridge, MA: MIT Press.

[16] John R. M. Wilson. 1979. *Turbulence Aloft: The Civil Aeronautics Administration Amid Wars and Rumors of Wars 1938-1953*. Washington, DC: U.S. Department of Transportation, Federal Administration. Available online: http://hdl.handle.net./2027/mpd.39015006384344 (accessed 12/14 2014): 264.

[17] "Warning to pilot bared in Empire State Crash." 1945. *Chicago Daily Tribune*. Jul 29. ProQuest Historical Newspapers: Chicago Tribune.

people were killed in plane crashes in a two-week period. In the fall of 1947 even more crashes occurred, resulting in the worst year of aviation fatalities to that date.[18]

The conception and acceptance of aviation as a form of mass transportation did not develop until the 1950s.[19] This leap in adoption can be attributed to many social and technological factors, including advances in aviation technology. Technologies that were refined or created in the context of the military began to be used in civil aviation. Some of these advances included improved aircraft size to payload ratios, use of specialized instruments to fly and electronic autopilots.[20] Moreover, the aviation industry had grown exponentially during the war, with the US government as its primary customer.[21] In addition, public perceptions were shifting from the idea of flying as a dangerous stunt to an important and safe mode of transportation. American air power was understood to be the key to the Allies victory and became central to military doctrine, so much so that President Truman and the US Senate created a new branch of the armed services, the United States Air Force.[22] In addition, airlines began to focus their marketing campaigns on the safety of flying and particularly the responsible and skilled image of the airplane pilot. Airlines required their crews to adopt military style uniforms and switched to the nautical nomenclature of captain, first officer and second officer. The pilots' union responded to the existing reputation of pilots as cowboys of the sky by publishing a code of ethics that explicitly reflected an ethos of maturity, caution and professionalism.[23]

Meanwhile, media descriptions of autopilots and the automatic capabilities of aircraft at the time emphasized the technologies not so much as tools for the pilots, but as replacements. For instance, in a 1946 article a reporter explained the value of a new version of an autopilot by writing,

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[18] Steven Alan Leveen. 1982. "Cockpit Controversy: The Social Context of Automation in Modern Airlines." Ph.D. Dissertation, Department of Science and Technology Studies, Cornell University. See also Wilson 1979, Chapter 10.

[19] For an excellent history of aviation in the United States see Peter W. Brooks. 1961. *The Modern Airliner: Its Origins and Development*. London: Putnam. For a comprehensive history of aviation in the 1950s and 1960s, see Stuart I. Rochester. 1976. *Takeoff at Mid-Century: Federal Aviation Policy in the Eisenhower Years 1953-1961*. Washington, DC: Department of Transportation, Federal Administration.

[20] Instrument flight, as opposed to visual flight, refers to a mode of operating the aircraft based solely on information from the flight instruments and other avionics, and not on visual cues. Instrument flying, once called 'blind flying' is used for instance when flying at night or in bad weather with low visibility. For a fascinating early discussion of instrument flight see Herbert W. Anderson. 1937. "Instrument—Not blind flying." *Journal of Air Law* 8, 191-203.

[21] The aviation industry had been only the 46th largest industry in the United States in 1939. During the war it was the largest industry in the country. By 1948 as war expenditure expired, the industry fell to the 12th largest position, still well above its position less than a decade earlier. Wilson 1979: 203

[22] National Security Act of 1947, 50 U.S.C § 401.

[23] Leveen 1982: 71.

> Since [the airplane] is fully automatic and does not depend upon the pilot reading and interpreting a lot of instruments the human element is almost removed. The pilot now has only to monitor the operation of the automatic equipment from the moment of takeoff until the airplane comes to rest on the landing strip at its final destination….[24]

The following year, in 1947, a US military aircraft, the C4, accomplished the first entirely automatic flight across the Atlantic Ocean, flying from Newfoundland to England entirely under the control of a flight programed on punched cards. A reporter for *Time* magazine narrated the event,

> The plane behaved as if an invisible crew were working her controls. … The commanding robot was a snarl of electronic equipment affectionately known as "the Brain." Everything it did on the long flight was "preset" before the start. It received radio signals from a U.S. Coast Guard cutter. Later it picked up a beam from Droitwich, England, and followed that for a while. When the plane neared Brize Norton, the wide-awake Brain concentrated on a special landing beam from an R.A.F. radio and made a conventional automatic landing. On the way over, the crew checked the course and watched the instruments. Most of them had little to do. They played cards and read books.[25]

As the capabilities of autopilots and other automated aviation systems became more sophisticated and widely used, automation came to be seen as central to aviation safety and success. The driving logic of aviation innovation was that more automation means safer flight.[26] Engineers sought to factor out the possibility for human error by removing as much human action or intervention as possible. Nonetheless, as the responsibility to carry out safe flight has shifted to autopilots and other automated systems, the responsibility for accidents has remained focused on pilots.

III. Locating Accountability in the Automated Cockpit

A. Litigation

Considering this description of the C4 flight, as well as the media accounts of autopilots mentioned above, we see an emphasis on the implicit responsibility assigned to automation. "The Brain" is described as controlling itself, obviating the crew. Autopilots "do not depend upon the pilot;" they are independent, and yet also improve the pilot. Who is in control? While technologically these mid-20th century aircraft were far from a 21st century idea of autonomous, it is important to keep in mind how technologies were

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[24] Wayne Thomis. 1946. "Rain, Fog, Snow! Future Airliner to Go Right Thru: Automatic Devices Will Handle It." *Chicago Daily Tribune*. Jun 6. ProQuest Historical Newspapers: Chicago Tribune.
[25] "No Hands." 1947. *Time* 50(14): 63.
[26] Leveen 1982.

positioned and received when they were new.[27] From media accounts, as well as regulatory debates within the industry around job responsibilities,[28] we observe that autopilots and other automated systems were perceived as significant agents of action. In practice, the responsibility of flying an aircraft was distributed between crew and automation, with automation in many ways positioned as more central and significant. In this light, we would assume that this distribution would disrupt established regimes of accountability and legal liability, with the designers of automated flight systems taking on greater responsibility for failure in flight.

However, this was not the case. The first cases focused on litigation around autopilot systems appeared in the 1950s, when autopilots became standard and when commercial travel began to be commonplace. These cases were part of an area of law called product liability law, involving both tort law and contract law. While it is not within the scope of this paper to review aspects of products liability law more thoroughly, it is relevant to point to the continuously evolving nature of this area of law, especially with respect to strict liability.[29]

Typically, the early cases involving autopilot systems featured airline carriers as defendants, even when the problem that caused the crash was suspected to be the autopilot. [30] For instance, in *Nelson v. American Airlines, Inc*. a passenger brought suit against the airline when she was injured during a sudden and extreme maneuver of the airplane caused by a malfunction of the autopilot. [31] After the malfunction, the autopilot was disengaged and normal flight was resumed. A component of the autopilot had been replaced the day before because of an issue with the altitude-hold feature. The jury found for the airline based upon a judgment that the injuries of the passengers were not caused by any want of due care on the part of the airline. However, the California Appellate court reversed this decision finding that the burden of proof was upon the defendant airline to prove that the accident occurred because of an unknown and unpreventable cause. This case exemplifies one class of suit in which the airline is found to be strictly liable.

A more common class of case involves a pilot's utilization of an autopilot. For example, in *Klein v. United States* a small airplane crashed after trying to land in the wake of

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[27] It is also worth considering that extreme states of technological advancement, such as those characterized as "autonomous" or "intelligent," may find meaning *in contrast* to existing possibilities and as necessarily just beyond what is possible. For a parallel argument about the shifting historical definitions of "artificial life" see Jessica Riskin. 2003. "The Defecating Duck, or, the Ambiguous Origins of Artificial Life." *Critical Inquiry* 29 Summer, 599-633.
[28] Leveen 1982.
[29] For an excellent review of products liability law as it relates to driverless cars see John Villasenor. 2014. *Products Liability and Driverless Cars: Issues and Guiding Principles for Legislation*. Washington DC: Brookings Institute.
[30] James E. Cooling and Paul V. Herbers. 1983. "Considerations in Autopilot Litigation." *Journal of Air Law and Commerce* 48, 693- 723.
[31] 263 Cal. App. 2d 742, 70, Cal. Rptr. 33 1968.

turbulence created by a large jet liner.[32] The plaintiff alleged liability on the part of air traffic controllers for giving improper instructions to the small airplane pilot before landing. However, the court found that the pilot had not engaged the airplane's autopilot, which would have correctly adjusted for the turbulence. The court therefore held that the cause of the crash was the pilot's decision *not to utilize* the autopilot and to misuse the other instruments onboard. Pilot negligence was also found in another case involving the non-use of an autopilot. In this case, a pilot was directed to change his flight path due to bad weather and subsequently when flying through clouds entered into a spiral and crashed.[33] The trial court held that it was the pilot, not the air traffic controller, who was responsible for the crash because the pilot had attempted to fly into clouds without using his autopilot.

Sometimes manufacturers appear as defendants in autopilot litigation when there is an accusation of negligent design or failure to warn. In one such case, *Goldsmith v. Martin Marietta Corp*, a suit against the autopilot manufacturer, Bendix, was unsuccessful because of warnings stated in the product manual about the product design. This case resulted from the inexplicable crash of a passenger airplane into a mountain. The plaintiff's theory of the case was that the crew had inadvertently and unknowingly switched off the autopilot on landing because of an unguarded switch. Bendix was sued for the design and manufacture of a flux gate caging without a guard. However, because the Bendix equipment manual contained warnings about the flux gate and warned that accidental operation could result from bad positioning, the district court held that "the design of the caging switch, in fact, did include a guard.... It did not guard against negligent actuation of the switch; rather it gave warning of the occurrence of such negligence."[34] In recent years, according to aviation law experts, it is extremely rare for plaintiffs to win suits against autopilot manufacturers.[35] Autopilot manufacturers, such as Honeywell, fight every case and settle in rare cases without admitting fault.[36]

As autopilots became central to commercial flight, courts incorporated new technologies into existing liability regimes without disruption. While these early cases are mixed – regulations make it clear that the responsibility and risk rests with the operator, and not the automated system.

B. Regulation

While there are hundreds of pages of regulations that apply to aviation certification requirements, two sections are of keystone importance to understanding how the courts have addressed issues of liability around the use, misuse or even failure of autopilots.

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[32] 13 Av. Cas. 18,137 (D. Md. 1975)
[33] 16 Av. Cas. 17,914 (W.D. Wash. 1981).
[34] 211 F. Supp. 91 (D. Md. 1962).
[35] Jim Cooling and Paul Herbers. 2015. Personal communication with author. Feb 16.
[36] *Harman III. v. Honeywell International Inc*. 273 Va. at 160 S.E.2d

The first section of regulation applies to the certification of autopilots themselves as found in 14 CFR 23.1329. This section lists the requirements that the design of any autopilot must meet. The first two sub-points of 23.1329 dictate the necessary ability of the autopilot to be disengaged by the pilot, specifically "each system must be designed so that the automatic pilot can:

1. Be quickly and positively disengaged by the pilots to prevent it from interfering with their control of the airplane; or
2. Be sufficiently overpowered by one pilot to let him control the airplane.[37]

In a 2011 amendment to 14 CFR 23.1329, the amount of force and time to positively disengage the autopilot are specified. The following are the reasonable periods of time established for "pilot recognition between the time a malfunction is induced into the autopilot system and the beginning of pilot correct action following hands-off or unrestrained operation":

1. A three-second delay following pilot recognition of an autopilot system malfunction, through a deviation of the airplane from the intended flight path, abnormal control movements, or by a reliable failure warning system in the climb, cruise, and descent flight regimes.
2. A one-second delay following pilot recognition of an autopilot system malfunction, through a deviation of the airplane from the intended flight path, abnormal control movements, or by means of a reliable warning system, in maneuvering and approach flight regimes.[38]

More simply stated, an autopilot must be designed to allow the pilot three seconds to correct a malfunction and still maintain safe flight when climbing, descending or cruising. During periods of takeoff and landing the pilot must have a one-second time frame to correct the malfunction.[39]

The second section of significant regulation is found in 14 CFR 91.3 and states simply:

> The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft.

[37] 14 CFR 23.1329 1982

[38] FAA. 2011. AC 23-17C - Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships. Available online: https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1019689 (accessed 8/11/2017).

[39] We are not aware of any studies that support or indicate these time frames. Cooling et al. reached the same conclusion, Cooling et al. 1983: 716.

Courts have consistently upheld this authority of the pilot as the ultimate designation of liability.[40] The pilot (and by extension in most cases, airline) is responsible for the plane's operation whether he uses the autopilot, chooses not to use the autopilot, uses the autopilot incorrectly or acts incorrectly because the autopilot gives faulty information. Still, there are cases in which the pilot in command is not at fault, including when negligence or strict liability can be proved against the manufacturer for a defect.[41] For instance, in *Federal Insurance Co. v. Piper Aircraft Corp* the Tenth Circuit Court of Appeals upheld a jury verdict against the aircraft manufacturer based upon breach of implied warranty and strict liability in tort. The court found sufficient evidence to demonstrate that the autopilot had been engaged during flight and that at the necessary point of disengagement the autopilot caused a malfunction. The possibility of providing such sufficient evidence is rare due to the fact that most evidence is destroyed in a crash. With advances in GPS and other avionics technology, tracking the flight path of a plane has become more reliable. Yet, as electrical components have replaced mechanical components, it has become more difficult to prove when and how malfunctions occur.[42] With physical evidence a case against a manufacturer is likely successful. When there is a lack of evidence or conflicting expert testimony, it becomes extremely difficult to prove negligence on the part of the autopilot manufacturer.

C. Accident Investigation

Psychologists and human factors researchers have begun to problematize the relationship implicit in the regulations cited above. Regulators, in addition to the engineers and managers of aviation systems, have created a schizophrenic dynamic in which automation is seen as safer and superior in most instances, unless something goes wrong, at which point humans are regarded as safer and superior. Unfortunately, creating this kind of role for humans, who must jump into an emergency situation at the last minute, is something humans do not do well.[43] A leader in the field of human factors has stated, "the assumption that automation can eliminate human error must be questioned."[44] Indeed, researchers have pointed to ways in which automation does not eliminate human error, but rather creates new and unexpected errors. While automation is generally assumed to relieve humans of menial tasks, freeing them to think about more important decisions, this has proven not to be the case. More free time does not necessarily lead to high-level judgments, although more free time does create opportunities for skills to degrade and

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[40] For example, Air Line Pilot's Assoc., Int'l v Federal Aviation Administration, 454 F.2d 1052 (D.C. Cir. 1971). See also Cooling et. al 1983: 713-714.
[41] Cooling et al. 1983.
[42] Jim Cooling and Paul Herbers. 2015. Personal communication with author. Feb 16.
[43] See Maria Konnikova. 2014. "The hazards of going on autopilot." *The New Yorker* 4 Sept. Available online: http://www.newyorker.com/science/maria-konnikova/hazards-automation (Accessed 1/1/2015).
[44] Earl L. Weiner and Renwick Curry. 1980. "Flight-deck automation: promises and problems." *Ergonomics* 23(10), 995-1011: 995.

minds to wander.[45] Pilot awareness generally decreases with increased automation.[46] A growing number of researchers advocate for rethinking how complex, highly automated and autonomous systems are designed to interact with humans.

Another productive perspective from which to view the impact of automated technologies on liability regimes can be found in accident investigation trends. Since the early 20th century and the rise of modern flight, the majority of accidents have been attributed to the classification of 'human error.'[47] Pilot error has been a consistent catchall for explaining commercial and private aircraft accidents. One of the first fatal accidents involving a US carrier occurred in 1934 when both engines of a Lockheed Electra-10A failed shortly after takeoff. The Bureau of Air Commerce, the regulatory body at the time, cited the probable cause of the accident as "pilot error for failing to attempt to use the right fuel tank…." [48] This report also cited two other errors that contributed to the accident, both involving aspects of flight that influenced the pilot's error: supervisors had failed to determine the airplane's fuel consumption characteristics before placing it in service, and the fuel tank gauge had failed to function adequately. Still, pilot error was cited as the probable cause of the accident.[49] According to the National Transportation Safety Board (NTSB), pilot or crew error was the cause of the majority of US carrier accidents between 1978 and 1990. It bears noting that this was a period of steadily increasing automation in the cockpit and a steadily improving safety record. A report commissioned in 1994 attempted to understand why human error was the most likely cause of an accident (fatal and non-fatal). The report acknowledged that, "Decades of aircraft accident investigations have shown that accidents in which flight crew performance is cited typically involved other human, mechanical and environmental factors."[50] Still, according to federal agencies, pilot error is the most likely official cause of a crash.

As a specific case in point we can look to one of the deadliest crashes in the last decades, Air France Flight 447, in which an Airbus A330 en route from Brazil to France crashed into the Atlantic Ocean in 2009 killing all 228 people on board. American news outlets,

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[45] A recent study published in *Quartz* documented the widespread—and illegal—trend of pilots posting cell phone or GoPro photos of their flight and themselves while in the cockpit. David Yanofsky. 2012. "The pilots of Instagram: beautiful views from the cockpit, violating rules of the air." *Quartz* December 14. Available online: http://qz.com/233165/the-pilots-of-instagram-beautiful-views-from-the-cockpit-violating-rules-of-the-air/ (Accessed 2/10/2015).

[46] Stephen M. Casner and Jonathan Schooler. 2014. "Thoughts in Flight: Automation Use and Pilots' Task-Related and Task-Unrelated Thought." *Human Factors* 56(3), 433-422; A.H. Roscoe. 1992. *Workload in the glass cockpit. Flight safety digest*. Alexandria, VA: Flight Safety Foundation; Earl L. Weiner. 1989. *Human factors of advanced technology ("glass cockpit") transport aircraft* (NASA Contractor Report 177528). Moffett Field, CA: NASA Ames Research Center.

[47] Leveen 1982.

[48] Ibid.

[49] Quoted in National Transportation Safety Board (NTSB).1994. *Safety Study: A review of flight crew-involved major accidents of U.S. air carriers, 1978-1990*. Washington, DC: Department of Commerce National Technical Information Service PB94917001 NTSB/SS-94/01: 1

[50] NTSB 1994: 2.

quoting the official French report stated that "a series of errors by pilots and a failure to react effectively to technical problems led to the crash." A CNN news report explained,

> When ice crystals blocked the plane's pitot tubes, which are part of a system used to determine air speed, the autopilot disconnected and the pilots did not know how to react to what was happening. In the first minute after the autopilot disconnection, the failure of the attempt to understand the situation and the disruption of crew cooperation had a multiplying effect, inducing total loss of cognitive control of the situation.[51]

Buried in the second half of the story, it is explained that there were other factors involved in the crash, including a known but not yet fixed problem of pitot tubes failing due to icing in Airbus 330s.

In contrast, consider the marketing and reporting around an early model of the A330, the Airbus A320, the first fly-by-wire commercial jet.[52] An American news article from 2009 echoes the sentiment of the 1947 article quoted earlier declaring the advent of a "fool-proof" aircraft. Quoting an aviation expert, the article states,

> ...most significant is that computers controlling the fly-by-wire system can be programmed to ensure that the plane flies safely at all times, even though the pilot may make an error. … It will be smart enough to protect the airplane and the people aboard it from any dumb moves by the pilot.[53]

The explicit point in this article, as well as similar media from the time, is that the autopilot and associated automation are smart enough to outsmart and save the human every time. The idea that the automation and its software could fail is never a possibility.

In the previous sections we examined how the work of flying a plane has been distributed among crew and automation and how, in turn, responsibility for carrying out that work has shifted and scaled accordingly. What we have seen in the contexts of court litigation, federal regulations and accident investigation trends is that airlines, and pilots especially, bear the burden of accountability even as the nature of the work is dominated and structured by automation.

Why has this disjuncture between work and responsibility developed? Why has the agency of software not been accounted for in product liability and tort cases? One

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[51] CNN Wire Staff. 2012. "Final Air France crash report says pilots failed to react swiftly" *CNN.com* 5 July. Available online: http://www.cnn.com/2012/07/05/world/europe/france-air-crash-report/ (Accessed 17 Jan 2015).
[52] In a fly-by-wire aircraft the pilot interfaces with a computer which in turn controls the aircraft through hydraulic or electric actuators. This is in contrast to the pilot using manual hydraulic controls via a yoke which control flight control surfaces via cables and pulleys.
[53] John Oslund. 1986. "NWA Airbus 320s to be most advanced jets ever." *Minneapolis Star Tribune*. 9 Oct.

explanation might derive from the unequal power dynamics between airline crew and large airlines and manufacturers. Pilot error is the most convenient explanation for all parties except the pilot.[54] In addition, historians of technology have demonstrated in a variety of contexts and in a variety of time periods that it is a social tendency to overestimate the capacity of machines and underestimate the abilities of humans.[55] Our concern in this paper is not so much why this is the case, and more so that this pattern of belief exists and has continuing social influence.

The dualism encompassed in explaining accidents as either human error or machine failure is unsurprising. This has been a sustained frame for analyzing accidents in a Western historical context.[56] It intuitively makes sense. Moreover, it is reasonable to hold the humans involved accountable because non-human entities cannot be held as accountable to society in ways that contribute to justice and the greater public good. Yet it seems reasonable to question if this enduring dualism is sufficient for accounting for the complex and distributed agency within human-computer systems.[57] More often than not, as demonstrated above, the human operator becomes a metaphorical "liability sponge," absorbing in one concentrated place liability for actions which are in fact distributed throughout the system.

In our view, the existing law crafted by the courts and federal legislation is insufficient for the current technological landscape. We do not advocate for finding non-human entities accountable; we suggest that locating liability and accountability must be expanded beyond the immediate physical system of human and machine, to the actions of designers and systems engineers who create the software and human-machine interface (HMI) of automated and autonomous systems. The advent of commercially available autonomous vehicles, like the driverless car, presents an opportunity to reconfigure problematic regimes of accountability.

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[54] Leveen 1982.
[55] See David Mindell's recent work for an analysis of similar themes in the domains of sea, air, war and space. David Mindell. 2015. *Our Robots, Ourselves: Robotics and the Myths of Autonomy*. New York: Viking.
[56] K.C. Barnaby, 1968. *Some Ship Disasters and Their Causes*. Cranbury N.J.: A.S. Barnes. Cf. Leveen 1982, Chapter 4.
[57] A leader in accident investigations, Jerome Lederer took a position against the prevailing one held by the NTSB, arguing that classifications of pilot error do not explain truly explain *why* an accident occurred. Instead, he insisted that it was necessary to use "categories that would acknowledge the interactions between humans and machines, such as a pilot error induced by design of aircraft, error as a result of ignorance, error due to deliberate acts not in accordance with good practice, error caused by environment, and error caused by psychological or social reasons." See Jerome Lederer. 1974. "Human Factors & Pilot Error," *Air Line Pilot* July, 13-14.

IV. The Potential of Autonomous Systems

A. The Future of Automotive Safety

Human error, according to the U.S. Department of Transportation, causes or contributes to more than 85 percent of all highway accidents.[58] Similarly, the U.S. Coast Guard estimates that over 80 percent of marine casualties are attributable to human error and 58 percent of the tanker accidents that occurred in the United States during 1989 and 1990 resulted from human error.[59] In the previous section, we drew attention to the complexity and potential inaccuracy of citing "pilot error" as the cause of accidents. Nonetheless, the safety record in aviation over the past decades demonstrates that highly automated systems have resulted in significantly safer air travel overall. Given this information, it is reasonable to assume that increasingly automated systems within automotive context will result in safer car travel. In this section we will explore the potential questions of liability in autonomous cars by briefly examining the emergence and regulation of basic cruise control and then considering questions of autonomous or driverless cars in the aviation context described above.

B. A Brief History of Cruise Control

In the late 18th century automatic governors were developed to control and regulate energy in steam engines. This kind of control and regulation existed before the advent of what we think of as the digital microprocessor revolution of the 1980s. Just as the early autopilots employed analog technology to generate computations that could control the surfaces of an aircraft, the early decades of automatic speed regulators in automobiles relied on analog technologies. Invented by Ralph Teetor in 1948, cruise control was first introduced into the American marketplace in the 1958 Chrysler Imperial. It was marketed as a luxury feature, much as the rearview camera systems of the early 2000s were advertised as luxury features and produced for Toyota and Nissan high-end models. As a *Popular Science* article in 1958 reviewing the technology stated, "Like it or not, the robots are slowly taking over a driver's chores."[60]

Cruise control, which during the 1950s and 1960s was also known as autocruise and speedostat, became commonplace in car models before the era of formal automotive regulation. While there were industry *standards* to which companies generally adhered,

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[58] U.S. Department of Transportation. 1995. "Pena Calls National Summit to Study Truck, Bus Safety. WL 98150 News release, March 10.

[59] U.S. Department of Transportation. 1993. "Coast Guard Distributes Tests Electronically" WL218920. News release, June 22; U.S. Department of Transportation. 1992. "Coast Guard Proposes Tanker Bridge Manning Rules." WL366630. News release, October 1.

[60] "What It's Like to Drive an Auto-Pilot Car." 1958. *Popular Science*. April, 105-107. Available online: http://books.google.com/books?id=vSUDAAAAMBAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false (Accessed 2/2/2015).

no federal regulations existed for the manufacture of cars before the late 1960s. The National Traffic and Motor Vehicle Safety Act of 1966 opened the era of federal safety standards for motor vehicles and other standards related to road and traffic safety. The act created the National Highway Safety Bureau, which was recreated as the National Highway Traffic Safety Administration (NHTSA), which is given the authority to set and regulate standards for motor vehicles and highways.

As part of the established safety regulations, cruise control was and is still considered a component of accelerator control systems. As in autopilot certification, the accelerator control system must be demonstrated to reliably stopped or discontinued. According to 49 CFR 571.124:

> This standard establishes requirements for the return of a vehicle's throttle to the idle position when a driver removes the actuating force [which may be the gas pedal or the cruise control button] from the accelerator control, or in the event of a severance or disconnection in the accelerator control system.[61]

Although the wording of this regulation is more opaque with regard to the responsibility of the operator over the automated system, the courts have been decisive and explicit when it comes to the liability of a driver using cruise control. When Mr. Milton Packin attempted to appeal a speeding ticket in New Jersey in 1969, he claimed that he "was not driving the vehicle since it was being operated through a 'cruise control.'" [62] The court rejected this contention, stating,

> A motorist who entrusts his car to the control of an automatic device is 'driving' the vehicle and is no less responsible for its operation if the device fails to perform a function which under the law he is required to perform. The safety of the public requires that the obligation of a motorist to operate his vehicle in accordance with the Traffic Act may not be avoided by delegating a task he normally would perform to a mechanical device.[63]

A similar ruling was issued in 1977 in *State v. Baker* when Mr. Keith Baker argued that he was not responsible for speeding because he did not *intend* to speed, and the cruise control mechanism was defective. In both cases, the courts found that a motorist is responsible for the operation of his vehicle even when part of its operation is delegated to an automated device.[64]

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[61] 49 CFR 571.124 [38 FR 2980, Jan. 31, 1973; as amended at 60 FR 13645, Mar. 14, 1995] Although not discussed in this article, cruise control/autopilot systems for maritime vessels are analogously regulated, cf 49 CFR 131.960.
[62] *State v. Packin* 257 A.2d 120 107 N.J. Super 93 (1969): 93.
[63] *State v. Baker* 170. Vt. 194, 744 A.2d 864 (1999): 95-96.
[64] An important and substantial exception is the round of cases involving unintended acceleration in 2006-2010 Toyota Corrolla models. Although Toyota maintained there was no negligence of design, they offered multiple settlements to victims' and their families, Toyota owners and

Simple cruise control systems and autopilot systems are comparable only to a limited extent for technological and industry-specific reasons. Simple cruise controls (as opposed to adaptive cruise controls) are relatively straight-forward systems; a user makes a decision to maintain a certain state (i.e. driving 65 mph), and the device makes the appropriate calculations necessary to maintain that state. The cruise control makes no "decision" to change state, only to maintain a specified state that involves straightforward mathematic calculations of speed. In contrast, autopilots of today are required to make many more complicated calculations which may involve changing states without human intervention. The kinds of technologies to be employed in driverless cars are likely to involve even more complicated calculations and potential state changes.

Moreover, while considering automation developments across industries is productive, there are significant differences between the automobile and aviation industry. These differences include modes of product marketing, product cycle timelines and substantial differences in customer base. The customers of the aviation manufacturing industry are the airlines and by extension, pilots. These customers have highly specialized knowledge, and pilots receive extensive training. In comparison, customers of driverless cars are likely to be individuals, with minimal training and no required specialized knowledge of how the systems they operate function.

C. The Case for Reframing Liability

To what extent might current debates about the regulation of "smart" and autonomous transportation systems benefit from looking at how past leaps in automation were regulated? This paper has addressed this question by examining how aviation autopilots and automobile cruise control have seamlessly integrated into existing tort and product liability law. While these technologies had the potential to disrupt modes of legal accountability because they distributed action between operator and automation in new ways, government legislation and court rulings did not take advantage of these opportunities. This is troubling because the failure to distribute liability with the shifting balance of responsibilities between operator and system has negative consequences for consumer safety and industry growth.

As an initial gloss, one might argue that the operator should still bear full responsibility because she, the operator, is making the choice to use a vehicle with a control system not fully under her control. Even if the "self-driving" feature of a car could not be toggled on or off, the operator still chooses to purchase or ride in a self-driving car. So, she accepts the risk and should be liable even if the system is fully autonomous. However, in the

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federal agencies. See *In re Toyota Motor Corp. Unintended Acceleration Mktg, Sales Practices, & Prod. Liab. Litig.,* __F. Supp. 2d__, 2013 WL 5763178 (C.D. Cal. Oct. 7, 2013).

consumer context, it is difficult for the operator to assess the risk of an autonomous system.

First, consumers of these new technologies will be extremely vulnerable to system failures. Consumers, unlike pilots, do not receive the extensive professional training and certification that would prepare them for system failures and accidents. In the context of other highly automated technologies relying on big data, scholars have advocated for policies of transparency, arguing that the black-boxing of how a system operates leaves the user at an unfair disadvantage.[65]

Second, because of a generalized lack of literacy around robotics and autonomous systems, consumers are unable to assess the actual risk to themselves presented by these technologies. While the majority of Americans consider themselves to be technologically savvy, anecdotal and quantitative survey data demonstrate that the majority of consumers are technologically illiterate when technological literacy is defined as 'one's ability to use, manage, assess, and understand technology."[66] Although consumers are captivated by new technology, they generally lack a comprehension of how technologies function.

To that end, purchase behavior will be driven by market messaging–which will tend to emphasize the superiority of these systems as compared to human operators. Likely left unaddressed will be the extent to which manufacturers will shy away from liability when these purportedly superior systems fail. This lack of awareness and knowledge must be considered when introducing and regulating new technologies in order to uphold principles of consumer safety.

Finally, manufacturers are in the best position to control the risks of the systems they sell. This is the case in two respects. First, manufacturers possess extensive data about the performance of their systems under different conditions and have substantially greater expertise than consumers in assessing the level of risk presented by their products. Second, manufacturers are able to influence the design of these systems at the lowest cost since they are the source of the goods and determine the design of the product before it enters the flow of commerce.

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[65] Danielle Keats Citron and Frank Pasquale. 2014. "The Scored Society: Due Process for Automated Predictions." *Washington Law Review* 89, 1; Danielle Keats Citron. 2007. "Technological Due Process" *Washington Law Review* 85, 1249-1313. See also Jones, Meg Leta Ambrose. 2015. "The Ironies of Automation Law: Tying Policy Knots with Fair Automation Practices Principles." *We Robot 2014*. Available at online: http://ssrn.com/abstract=2549285 (accessed 20 Jan 2015).

[66] Greg Pearson and A. Thomas Young, eds. 2002. *Technically Speaking: Why All Americans Need to Know More about Technology*. Washington, DC: National Academy of Sciences Press; L. Rose and W. E. Dugger, Jr. 2002. *ITEA/Gallup Poll Reveals What Americans Think About Technology*. Reston, VA: International Technology Education Association. Available online: www.iteaconnect.org/TAA/PDFs/Gallupreport.pdf (accessed 4 Feb 2015); National Science Board. 2004. "Science and Technology: Public Attitudes and Understanding" *Science and Engineering Indicators* NSB 04-01 May, Arlington, VA. Available online: http://www.nsf.gov/statistics/seind04/c7/c7s2.htm#c7s2l4 (accessed 26 Jan 2015).

It is simple to paint this line of argumentation as overly favoring the consumer against the enterprises developing this technology. However, this is not the case. There are several pragmatic reasons for imposing distributed liability proactively that serve to benefit industry. First, without forging legal regimes that produce broader public trust in autonomous systems, consumer demand may never develop for these technologies. Recall that in the early decades of aviation a similar attitude prevailed, emblematized in the statement referenced earlier, "If a man wants to kills himself, let him do it!" The advent of aviation regulation, including pilot certification and airworthiness certificates, was the first step in establishing the reputation of the aviation industry as reliable, feasible—and holding broad commercial opportunity.[67] The same may be true in the autonomous driving context, where adoption of a novel technology might be facilitated rather than hindered by regulation.

Second, without forging a balanced regime that adequately divides risks between consumers and manufacturers, well-publicized accidents may drive a regime that is more extreme. Regulation around autonomous driving is already driven by public perception of the risks of this technology. Numerous commentators have already raised the specter of hypothetical scenarios in which an autonomous system must choose between collisions with different groups of humans.[68] While these circumstances will be highly unlikely in practice, they dominate the public discourse around autonomous driving. This narrative may generate popular attitudes that hinder the trust and widespread adoption necessary to capture the benefits of this technology.

Third, without transparent guidelines a patchwork of court cases and non-standardized regulations will produce regulatory fragmentation that makes it difficult to assess the level of liability a manufacturer will expose itself to when introducing autonomous driving to a new state jurisdiction. Creating a common liability regime that clearly strikes a balance between system creators and consumers will serve to lower compliance costs and permit a more straightforward assessment of risks to manufacturers as the technology matures.

V. Conclusion

A. Enlarged Frames of Accountability

What, then, can we learn from the historical development of liability in aviation autopilot regulation and litigation? And how might these lessons learned be applied to creating effective and fair policies regarding driverless cars? A first lesson we can glean from this history is that new technologies with the potential to redistribute liability do not

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[67] Komons 1978; Leveen 1982.

[68] Patrick Lin. 2013. "The Ethics of Autonomous Cars." *The Atlantic Monthly*. October. Available online: http://www.theatlantic.com/technology/archive/2013/10/the-ethics-of-autonomous-cars/280360/ (accessed 20 Feb 2015).

necessarily realize this potential. In fact, traditional regimes of liability, with particular emphasis on human error, tend to be maintained even as the agency, the capacity to plan and carry out an action, within a complex system is distributed across time and space. While the distributed agency within autonomous systems encompasses the physical operators, as well as the engineers and designers of these systems, this distribution has not been adequately reflected in media and legal discourses. Given the historical patterns described above, we could reasonably expect that in the case of driverless cars liability will shift to the operator (or rather, overseer) of the vehicle, even as media and marketing materials claim the vehicle operates autonomously.

This paper has read automation in aviation as a template, a parallel set of developments that may be followed as intelligent systems become increasingly implemented in the automotive context. In short, liability has continued to be placed on operators of commercial aircraft, even as autopilots have become more advanced in the control of flight systems. The same may be the case in the automotive context. While strict liability can and does continue to be imposed on manufacturers when a product is shipped with a defect, operators are given the responsibility under regulation and case law for the consequences of their choice to deploy an automated system. That is to say, when the vehicle performs exactly as designed, the liability remains with the operator.

This is problematic in the context of driverless automobiles because while the system may perform exactly as designed or provide warnings, it still may perform contrary to user expectations. Thus, while a system may not suffer from a "defect" the system may have behaviors that are unpredictable and adverse to the operator in a way distinct from simple automation like basic cruise control.

However, because these systems are free of a "defect" per se, the existing framework of the law might continue to impose liability on the operator, even as the intelligent system (and the marketing around it) continue to claim more of the cognitive work of driving. This would parallel the case in aviation, as simple systems have given way to more complex ones while the choice to initiate a fully functional autopilot places the liability on the carrier.

For the reasons discussed above, strict liability should be imposed in these cases as if the system itself possessed a defect in which the system performed contrary to its design. This is particularly the case in the general consumer context, where the public will fail to have the extensive training that pilots do in the aviation context.

B. Policy Principles

In light of these observations, we argue for a reframing of the debate around accountability and autonomous technologies in which new legislation and product liability laws reflect the agentive role of designers and engineers in autonomous and intelligent systems. Because aviation will continue the trend of increasing automation, we believe there is also an opportunity to develop these laws in the context of commercial aviation as new technologies arise and require new types of certification.

Critical to the policy position for which we advocate is the notion that significant information asymmetry exists between manufacturers and operators in the function of intelligent systems. This asymmetry prevents consumers from effectively assessing and making informed choices about their use of autonomous vehicles. We would continue to impose strict liability unless manufacturers complied with provisions that eased this information asymmetry.

To that end, we advocate for a set of policy principles to guide future legislation that speaks affirmatively to these issues. These principles are intended to provide a foundation for creating new and effective legislation around these technologies, including certification requirements.

1. **System designers (manufacturers) must be required to disclose agency chains.**
   The historical pattern of autonomous systems is to design away the human even as the human remains part of the automated system. We join other researchers who have called for autonomous systems that incorporate principles of user-centered design. With respect to issues of strict liability, we would then impose liability in instances of failures to disclose the decision-making processes of the system to the operator.

2. **In addition, agency chains must be transparent and legible to the user.**
   Because beliefs around automation tend to overestimate machine capacities and underestimate human capabilities, autonomous systems must be transparent to the user to the extent that a user can make informed and effective decisions around human intervention. With respect to issues of liability imposed on manufacturers this would mean that manufacturers would be required to provide adequate guidance and control systems to the operator in the case of system failure.

3. **The unique skillsets required to operate various levels of autonomous systems must be recognized and accounted for.**
   For instance, states could create a special tier of training for operating self-driving vehicles, and balance the risks where the driver was additionally certified when assessing liability in court cases.

We have argued for a reframing of the debate around liability and autonomous technologies that would reflect the agentive role of designers and engineers and the new and unique kinds of human action attendant to autonomous systems. In this light, we see that there is always a human actor. The question initially posed, "What happens when there is no human actor – only a computational agent – responsible?" becomes "How do we locate the network of human actors responsible for the actions of computational agents?"