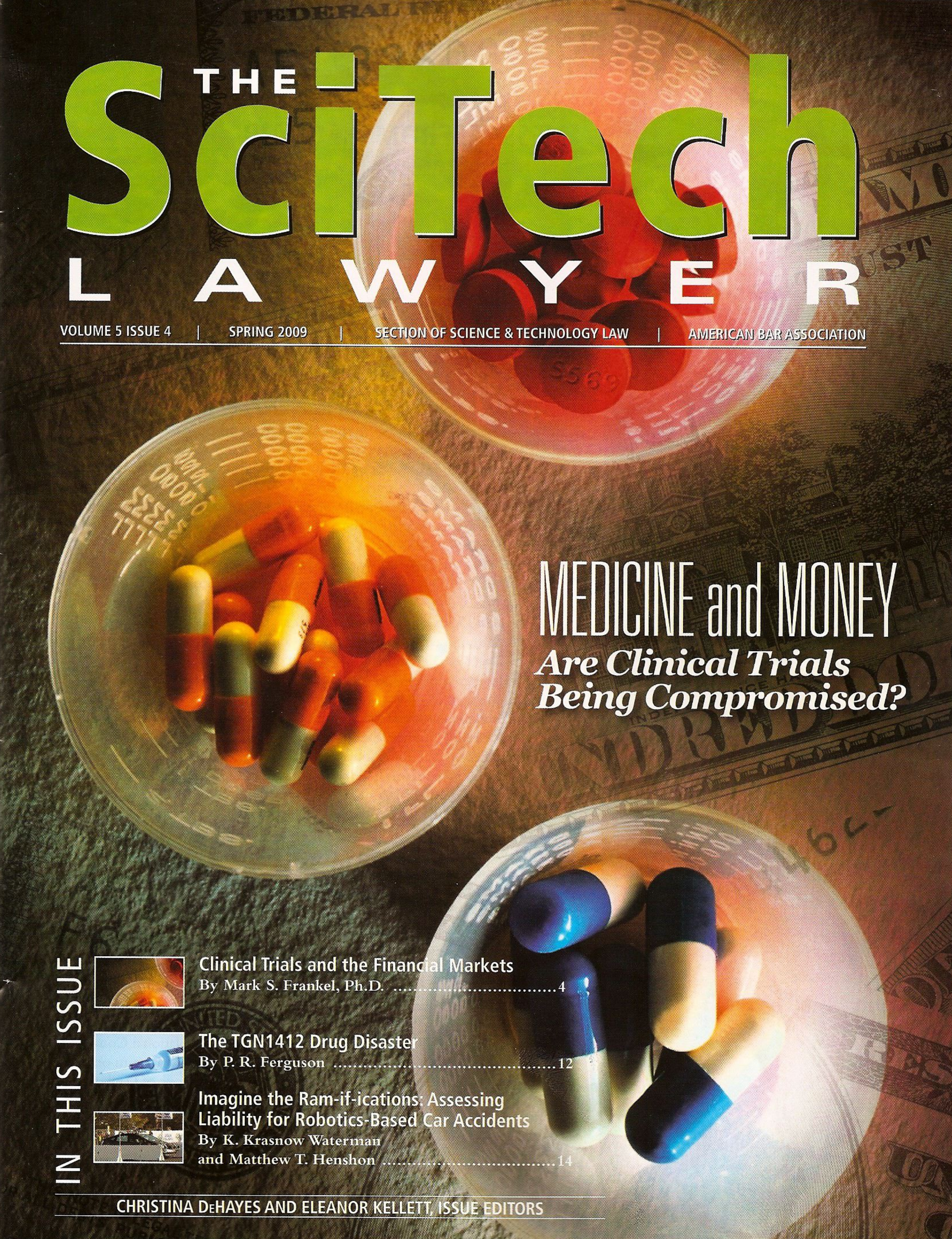

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MEDICINE and MONEY

Are Clinical Trials Being Compromised?

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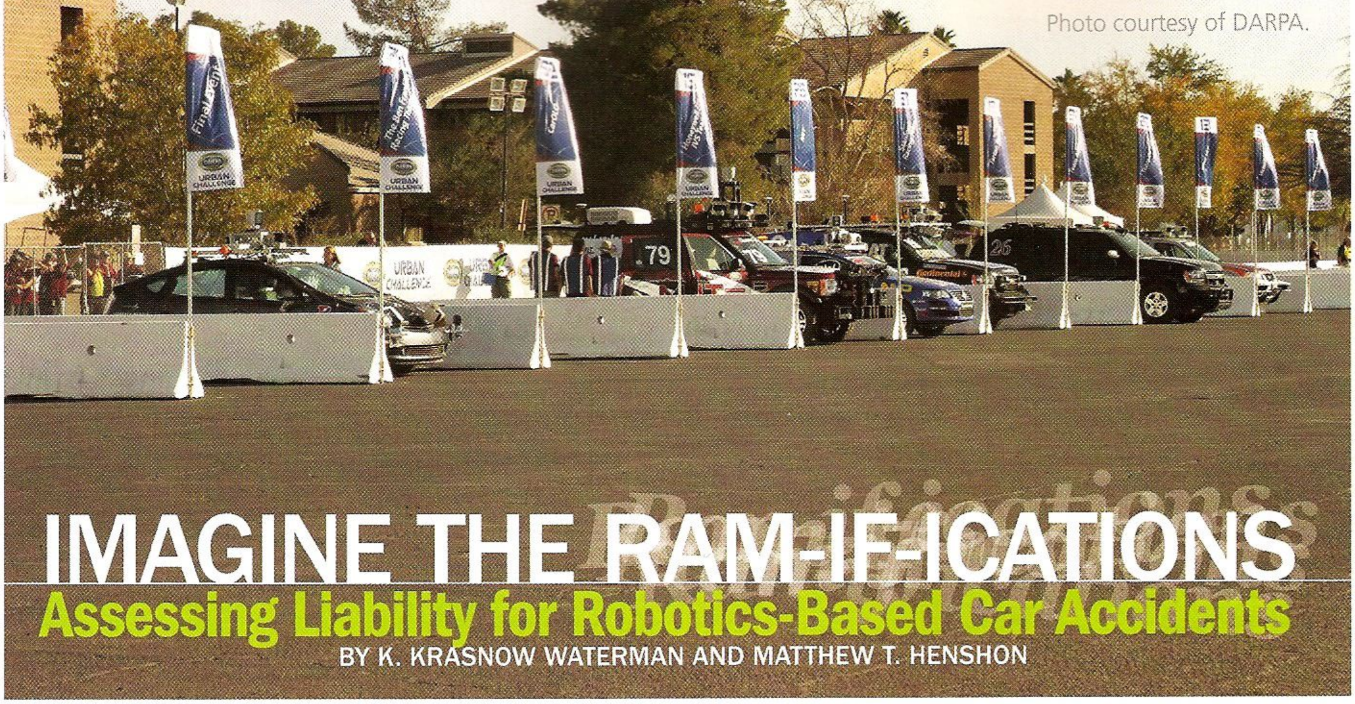

Photo courtesy of DARPA.

IMAGINE THE RAM-IF-ICATIONS

Assessing Liability for Robotics-Based Car Accidents

BY K. KRASNOW WATERMAN AND MATTHEW T. HENSHON

Robotic Car Finalists in the DARPA Urban Challenge Final Event, November 3, 2007, Victorville, California.

Since 2004, the Defense Advanced Research Projects Agency (DARPA[1]) has sponsored a series of "challenges" for robotic cars. These cars are true "robots," in the sense that they are autonomous vehicles where the on-board computer is driving; the cars are not controlled by humans via videolink.

In 2004 and 2005, the race course was in the California desert. In the first race, no car was able to complete the 150-mile course.[2] A year later, five cars completed a slightly shorter, 132-mile, course.[3] In 2007 (there was no event in 2006), the challenge was a 60-mile course set in an urban environment, complete with four-way stop signs, lanes that merge, and moving vehicle traffic.

Although none of the robotic cars collided with any of the obstacles on the course, two of the robot cars (from Cornell and MIT[4]) did collide with each other—albeit at low speed—as they both tried to merge into the same lane. And although the Cornell/MIT incident was in the context of a controlled experiment, the event raises a question: How would courts attribute liability if two robotic cars collided in the real world?

To the authors' knowledge, no real-world collision between robotic cars has occurred yet. Accordingly, no court has considered how liability would be determined. However, it is clear that the day a court must assess liability for robotic driving mistakes is fast approaching. BMW,[5] VW, Toyota,[6] and Lexus[7] either now sell or plan to sell automobiles that will automatically parallel-park themselves.[8] In 2006, BMW demonstrated an enhancement of that parking feature (not yet available to the public) *that does not require the driver to remain in the car*,[9] which it expected to offer for sale by next year. And in late 2008, Nissan announced development of a new crash avoidance system for robotic cars that is based on the flight pattern of the bumblebee.[10] Much greater automation appears to be coming in the relatively near future.

How a court will look at a tort caused by a robotic car is an exercise in prediction—always dangerous in the legal field. But by looking at the history of other "self-driven devices," it is possible to imagine the factors that a court might consider by analogy.

Rules and Decisions Relating to Autopilots

One seeming analogy to a robotic-controlled car is the autopilot found on many airplanes. Developed by Lawrence B. Sperry in 1914, the autopilot was originally called a "gyroscopic stabilizer apparatus," and incorporated Sperry's insight that an "autopilot" needed to control three flight axes of an aircraft: yaw, pitch, and roll. The gyroscopes essentially offset movement in the aircraft through the air, opening or closing valves to change wing or rudder angles.[11] So unlike a DARPA/robotic car, a plane controlled by an autopilot does not attempt to adapt to changing environment, but rather continues on its current heading, at the same altitude.

The law of aircraft accidents is extensive, as torts involving airplanes are usually "high impact" events and are often well publicized.[12] But most airplane accidents involve departures or landings, which are generally not when autopilots are in use. In fact, there are regulatory limitations in using autopilots below 500 feet.[13] Although there are a handful of reported cases where autopilots played a role in the accident, in most cases the autopilot plays a lesser role than human oversight.[14]

One such case is *Beverly Richardson v. Bombardier*,[15] where an Army National Guard pilot engaged the autopilot on the C-23B that he was flying to go to the lavatory in the rear of the plane. While he was away, the plane hit a wind shear "that caused [the plane] to pitch upward and gain altitude" by driving the nose of the plane upward. The autopilot attempted to adjust by lowering the elevator. But the autopilot's actions essentially overcorrected, and the plane went into a dive. As the court found, "shortly thereafter, the increasing airspeed exceeded the structural limitations of the airplane, which broke apart and crashed."[16]

The *Richardson* court ultimately found human error as the cause of the crash, not the autopilot. But the human error was not the C-23B's pilot. Instead, the

Richardson court upheld the jury's verdict that found, in effect,[17] that the design of the plane was the source of liability; the center of gravity of the plane was aft of the maximum design limit for the plane's weight;[18] accordingly, the autopilot could not cause the plane to recover from the dive once it started.

Another case where an autopilot had a key role in an accident eventually turned on human error. In 1983, the crew of Korean Air Lines Flight 007 set the plane's autopilot to a specified heading and apparently did not oversee the plane's actual course. Most likely because of a navigational error in entering coordinates, the aircraft drifted 360 miles into restricted USSR air space and was eventually shot down as a potential spy plane by the Soviet Union's military; a court found that "[g]iven the crew's knowledge of the grave danger of being fired upon in Soviet airspace, and the length and severity of the flight's deviation from its course, the crew's failure to follow mandated navigational procedures and it's [*sic*] 'lack of situational awareness' in this Court's view, amounts to willful misconduct."[19] Thus, the autopilot in the KAL case worked: it was human error[20] that set the course heading incorrectly.

Nor are planes the only vehicles with autopilots. Ships, including cruise ships, often have autopilots, which are an adaptation of Sperry's original invention. But it is the captain, or officer-in-charge, who bears responsibility for determining whether engaging such a device is appropriate. For instance, the captain of the *Crown Princess* was criticized by the National Traffic Safety Board (NTSB) for engaging the ship's autopilot too soon after leaving port just one hour out of Port Canaveral, Florida, in 2006; when the ship (thanks to the autopilot) began executing a turn in shallow water at a high rate of speed, the second officer (then the senior watch officer on deck), noting the danger, overrode the controls, but subsequently overcorrected the wheel. The ship subsequently "breeched," and more than 300 passengers were injured.[21]

In both of these contexts (i.e., planes and ships), the autopilots are used during the middle part of the journey, not for takeoffs or landings (in the case of planes) or near port (shallow water) in the case of ships.[22] With autopilots for both planes and ships, these decisions have turned on error(s) by human operators: the design-engineer (*Richardson*) or pilot (*KAL*); and the captain (*Crown Princess*) in the case of an ocean-going vessel. Moreover, constant human oversight is both implied and expected, to determine whether then-current use of the autopilot is appropriate. But with the case of robotic cars, it is the end of the journey (i.e., parking) where the machine seems most likely to play a role in the immediate future.

Thus, while the analysis (and issues) in the autopilot cases may offer guidance in future times when cars are truly autonomous, they seem not to offer much assistance now, when cars are subject to autopilots only at the end of the journeys. We will have to look for other analogies.

Elevators, Operators, and Regulations

Another less obvious analogy that may inform decisions about liability for autonomous vehicles is the elevator. Elevators in the United States and Canada move 245 million passengers per day, more passengers than any other mode of transportation except the automobile.[23] The elevator, too, is a moving vehicle. It used to be unsafe and human controlled and now is safe and almost always autonomous.[24]

The concept of hoisted platforms is attributed to Archimedes in the third century BC, although there are many who believe that it is significantly older. The first "personal lift" is attributed to a commission by Louis XV in the mid-eighteenth century.[25] An "ascending room" was unveiled in London in the early nineteenth century.

By the midnineteenth century, elevator-type devices were in use in mining and freight, but were considered unsuitable for passengers other than high-risk workers. By that time, steam power was available to raise and lower the car, but if the rope broke, the car would fall the length of its shaft. That all changed when Elisha Graves Otis demonstrated the "safety elevator" at an exposition in New York in 1854;[26] in front of a large crowd, he cut the elevator's rope causing his newly designed safety spring to lock the elevator in place. Thus began the rapid adoption of passenger elevators and substantially taller buildings.

For most of the next century, elevators were operator driven. Elevator operators were responsible for safely opening and securely latching the door and gate; starting and stopping at the right locations; observing through the port hole whether there were potential passengers waiting to get on; and leveling the elevator with the floor so passengers could get safely on and off.[27] The safety risks were considered so great that the age of elevator operators was regulated by law.[28]

As late as 1952, an elevator operator strike was front page news in the *Chicago Tribune*.[29] Although the first "self-service" elevator was installed in 1926,[30] early versions were "clunky and unsophisticated."[31] It took until the 1960s for them to be so improved as to be widely accepted and adopted, and therefore most operators eliminated.[32] Technologies had been adopted to open and close the doors, find the floors, and level the elevator.[33] Push buttons could now call the elevators from the outside and tell them where to stop from the inside.[34] And, eventually in recent years, smart technology has been introduced to create efficient traffic flow in a bank of elevators, referred to as "destination elevators."[35] The public had accepted the concept, and nearly all elevator operators are gone.

Some of us, who are old enough, remember uncomfortable moments in the transition: elevators suddenly dropping a floor or two and elevator doors opening a foot or more from the floor. How did the law participate in the transition, and what does it say now about these autonomous vehicles? It appears that there were two major legal innovations that permitted the transition: the advent of new insurance contracts and the creation of elevator safety regulations.

Three decades after the famous elevator safety demonstration, elevator safety

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The authors cochair the Artificial Intelligence and Robotics Committee. The Committee's website is available at www.abanet.org/dch/committee.cfm?com=ST248008. The authors would like to thank Dr. Edwin Olson (U. Mich.) for his first-hand insights on the DARPA Challenge and the legal questions it raised in his mind.

remained a significant issue. In 1886, Otis was the first company in New York to contract for "employers liability" insurance to mitigate the risk of employee injuries.[36] And, despite continued improvements over the early years, elevator accidents were one of the most common causes of multiple deaths in the early twentieth century.[37] By 1915, a new form of liability insurance, "elevator liability," had been created specifically to address the broader issue of liability to the public.[38]

Interestingly, the legal standard of care appears to have arisen at the same time as the new contractual vehicle for insurance. The first elevator code is believed to have been enacted in the City of Boston in 1914. New York City followed in 1918.

Today, every state has laws identifying specific requirements for the construction and maintenance of elevators. Most often they are found in state safety codes or regulations.[39] Though elevators are state regulated, nearly all states have adopted the same industry standards. Neither state legislators nor state safety officials attempt to craft the rules for autonomous elevator construction and maintenance. Instead, they cite two detailed sets of standards created by professional associations: ASCE Code 21 (the American Society of Civil Engineers Code 21 for people movers operated by cables) and ASME Code A17 (the American Society of Mechanical Engineers Safety Code for Elevators and Escalators).

Robotic Standards

At present, the independent engineering societies have not yet developed safety standards for autonomous personal vehicles.[40] The Society of Automotive Engineers (SAE) has published a number of papers on topics such as the history of human accidents in parking,[41] the proper placement of cameras to assist,[42] and the proper modeling of parking sensor placement.[43] The SAE is also establishing computer systems standards for unmanned systems.[44] The U.S. government's National Institute of Standards and Controls, Intelligent Systems Division, is attempting to define standard terms and measurements to describe autonomous vehicle functions.[45] Though none of these efforts will directly produce safety standards, they appear to be the precursors necessary to be able to articulate and enforce standards.

Moving From Human to Machine Controls

Autopilots and elevator controls offer rough analogies to the potential issues driven by robotic cars. With autopilots, courts accept the viability of the technology, but assume that constant human oversight (or proper design) is part of the equation. With elevators, improved technology coupled with increased insurance and more stringent regulation permitted the move away from human operator oversight.

On one level, automobiles are currently the equivalent of elevators during the first half of the twentieth century: by law, they may only be operated by a qualified operator of minimum age. Efficiency—coupled with risk mitigation and regulatory change—eventually drove building owners to replace their elevator operators with automated systems. On the other hand, elevator controls need only master a single axis (i.e., up-and-down) with precision. Autopilots—and robotic cars—need to master at least two and usually three dimensions.

The question of what circumstances might result in a radical shift to autonomous cars is still open. However, as incremental automated functions are added, the law must adapt to offer minimum standards for safety and liability. It is clear that automobile manufacturers can park your car for you—the question is whether and how the law will let them. Resolving the uncertainty of liability may allow more technologies to come to market faster.[46] ◆

Endnotes

1. www.darpa.mil.

2. www.darpa.mil/grandchallenge04/.

3. www.darpa.mil/grandchallenge05/.

4. www.darpa.mil/grandchallenge/index.asp.

5. *Robot Parking: the Blindfold Idiot Test*, The Sunday Time, July 15, 2007, www.timesonline.co.uk/tol/driving/features/article2068943.ece.

6. www.toyota.eu/06_Safety/03_understanding_active_safety/01_parking_assist.aspx, although the Toyota system to date does not appear to be true AI, but rather an "assist" to guide the human operator.

7. www.lexus.com/models/LS/features/exterior/advanced_parking_guidance_system.html.

8. The self-parking feature on the Lexus was even incorporated into the plot of ABC TV's *Desparate Housewives. See* Season 5, Episode 14, Recap for "Mama Spent Money When She Had None" at http://abc.go.com/primetime/desperate/index?pn=recap#t=131881&d=170252 or www.ew.com/ew/article/0,,20257805,00.html.

9. *Precise Parking*, BMW Online News, Apr. 2007, http://74.125.45.132/search?q=cache:7gHOvWZPf4sJ:www.bmw.co.za/onlinenews/issue3/index.asp+bmw+innovations+day+2006+bmw.com&hl=en&ct=clnk&cd=17&gl=us&client=firefox-a.

10. Nissan admits that the application of such technology in production cars is still years away, however. *See Crash Avoidance Robotic Car Inspired by Flight of the Bumblebee*, Sept. 26, 2008, www.nissan-global.com/EN/NEWS/2008/_STORY/080926-01-e.html.

11. *See Aviation History*, Nov. 2004, www.historynet.com/lawrence-sperry-autopilot-inventor-and-aviation-innovator.htm.

12. It should be noted that air travel is safe and getting safer; during the decade from 1997 to 2007 (a period that included September 11th, 2001), the rate of fatal accidents decreased from 1 per every 2 million departures in 1997 to 1 per every 4.5 million by 2007. N.Y. Times, Sept. 30, 2007.

13. 14 C.F.R. 121.579.

14. For instance, the Feb. 2009 crash of Continental Connection Flight 3407 near Buffalo, NY, may have been caused by (incorrect) pilot commands contravening an automatic response to a midair "stall." *See Recreating a Plane Crash*, N.Y. Times, Feb. 19, 2009 (p. A21), located at www.nytimes.com/2009/02/19/nyregion/19crash.html?_r=1&scp=1&sq=buffalo%20plane%20crash&st=cse.

15. 2005 U.S. Dist. LEXIS 30025 (U.S.D.C., M.D.Fla.).

16. 2005 U.S. Dist. LEXIS 30025, *3.

17. Technically, the *Richardson* decision rejected plaintiff's motion for a new trial after a jury "rejected Plaintiff's claim that the [elevator cable mount] was negligently or defectively installed, and rendered verdict for Defendant." 2005 U.S. Dist. LEXIS 30025, *23. The *Richardson* court also rejected claims that the autopilot system was negligently designed, including a warning to notify a pilot when the autopilot has "limit[ed] the amount of torque which can be applied to the controls." *Id.*, *51.

18. 2005 U.S. Dist. LEXIS 30025, *5.

19. *In re* Korean Air Lines Disaster of Sep-

tember 1, 1983 (156 F.R.D. 18; 1994 U.S. District LEXIS 10123). Because the court supported a finding of "willful misconduct" because the flight crew was unaware of the deviation from the intended route for more than five hours, the plaintiffs were not limited by a $75,000 per decedent limit under the Warsaw Convention. An earlier *KAL* decision noted that in 1978, a previous KAL flight had flown off course into Soviet airspace, and was forced down on a frozen lake by Soviet military planes; several fatalities resulted. *In re Korean Air Lines Disaster of September 1, 1983*, 932 F. 2d. 1475, 1478 (D.C. Cir. 1991).

20. Interestingly, human error by KAL pilots was a (relatively) common occurrence during this period, as documented in a chapter entitled "The Ethnic Theory of Plane Crashes," in MALCOLM GLADWELL, OUTLIERS: THE STORY OF SUCCESS (Little, Brown, 2008). Gladwell states that during the period 1988 to 1988, the "loss" rate for KAL was 4.79 accidents per million departures, which is 17 times higher than the loss rate for United Airlines (0.27 per million departures) during the same period. *Id.*, pg. 180.

21. NTSB/MAR-08/01, located at www.ntsb.gov/Publictn/2008/MAR0801.pdf.

22. Note the parallel of implicit human oversight with Article XII of UNCITRAL (United Nations Convention on the Use of Electronic Communications in International Contracts), passed in 2005:

> A contract formed by the interaction of an automated message system and a natural person, or by the interaction of automated message systems, shall not be denied validity or enforceability on the sole ground that no natural person reviewed or intervened in each of the individual actions carried out by the automated message systems or the resulting contract.

23. Press Release of the National Elevator Industry, located at www.neii.org/presskit/Safe%20Steps,%20A%20Guide%20to%20Building%20Transportation%20Safety.pdf.

24. A few elevators still require operators. For instance, the New York City Metropolitan Transit Authority employs operators in five subway stations "with platforms that are so deep underground that they can be reached only by elevator." N.Y. TIMES, Dec. 8, 2007. http://query.nytimes.com/gst/fullpage.html?res=9E0CE3DE1531F93BA35751C1A9619C8B63.

25. *See* www.facilities.txstate.edu/operations/Elevator-webpage/History.html.

26. *See Otis: A Visual Timeline* (www.otisworldwide.com/d31-timeline.html); www.theelevatormuseum.org/timeline.htm; and *New Exhibit Tracks History of Elevators, Escalators, Moving Sidewalks*, Voice of America (Oct. 1, 2003), www.voanews.com/english/archive/2003-10/a-2003-10-01-24-New.cfm.

27. As late as 1969, the U.S. government job description of elevator operator included the responsibilities: "skill in opening and closing doors and gates by hand, and in using one or several hand controls to start and stop the elevator, control its movement and direction, and 'level' the car with the floor"; "make sure that loads are properly placed and balanced to prevent accidents or damage"; "brings problems, such as doors that do not close properly or other unsafe conditions, to the attention of the supervisor"; and "exposure to cuts, bruises, and scrapes in opening and closing gates or doors by hand." Federal Wage System Job Grading Standard for Elevator Operating, 5438, p. 3, Apr. 1969, www.opm.gov/Fedclass/fws5438.pdf.

28. *See, e.g.,* Fidelity & Casualty Company of New York v. Palmer Hotel Company, 179 Ky. 518; 200 S.W. 923 (Ky. 1918) (case involving insurance policy referencing "the age fixed by law for elevator attendants").

29. *Fail to End Elevator Tie-Up/Slate Secret Session Today in New Move/Buildings North of River Hit*, CHIC. TRIB., Oct. 3, 1952, pg. 1.

30. The first automatic elevator was installed in the Jerome Grand Hotel (Arizona) in 1926. *Otis: A Visual Timeline* ("1926: Self-Service in Arizona"), www.otisworldwide.com/d31-timeline.html.

31. *Id.* at "1948: Thinking Elevators."

32. "Elevators," a virtual exhibit of the Museum of American Heritage, www.moah.org/exhibits/virtual/elevators.html.

33. *Id.*

34. *Supra*, n. 25.

35. BOSTON GLOBE, www.boston.com/business/technology/articles/2006/10/09/elevators_get_smart/.

36. James A. Robertson, *How Umbrella Policies Started, Part 1*, published by International Risk Management Institute, Inc., March 2000; www.irmi.com/Expert/Articles/2000/Robertson03.aspx.

37. *See, e.g.,* James A. Robertson, *How Umbrella Policies Started, Part 2*, published by International Risk Management Institute, Inc., Apr. 2000; www.irmi.com/Expert/Articles/2000/Robertson04.aspx; and *supra* n. 31 (referencing "frequency and severity" of elevator accidents in the 1920s).

38. *Supra*, n. 31.

39. *See, e.g., Elevators, Escalators, and Related Equipment: Inspection, Certification, and Registration*, Texas Health and Safety Code, Chapter 754, Subchapter B.

40. ASME has produced a safety standard for guided industrial vehicles. *See, e.g.,* ASME B56.5, *Safety Standard for Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles.*

41. *Parking Crashes and Parking Assistance System Design: Evidence from Crash Data Bases, the Literature, and Insurance Agent Interviews*, 2006-01-1685 (Apr. 2006), www.sae.org/technical/papers/2006-01-1685.

42. *A Method for Camera Vision Based Parking Spot Detection*, 2006-01-1290 (Apr. 2006), www.sae.org/technical/papers/2006-01-1290.

43. *Ultrasonic Sensor Modeling for Automatic Parallel Parking Systems in Passenger Cars*, 2007-01-1103 (Apr. 2007), www.sae.org/technical/papers/2007-01-1103.

44. *See Fact Sheet: SAE Technical Committee AS-4: Unmanned Systems*, http://74.125.45.132/search?q=cache:tV6jbwDrUbMJ:www.sae.org/servlets/works/committeeResources.do%3FresourceID%3D47225+unmanned+systems+standards+committee&hl=en&ct=clnk&cd=2&gl=us&client=firefox-a.

45. *See* NIST, Intelligent Systems Division, *Autonomy Levels Framework for Unmanned Systems: An Open Working Group Effort*, www.isd.mel.nist.gov/projects/autonomy_levels/.

46. www.timesonline.co.uk/tol/driving/features/article2068943.ece. The article indicates that automakers are resisting introducing features such as self-parking until liability is more clearly defined.

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