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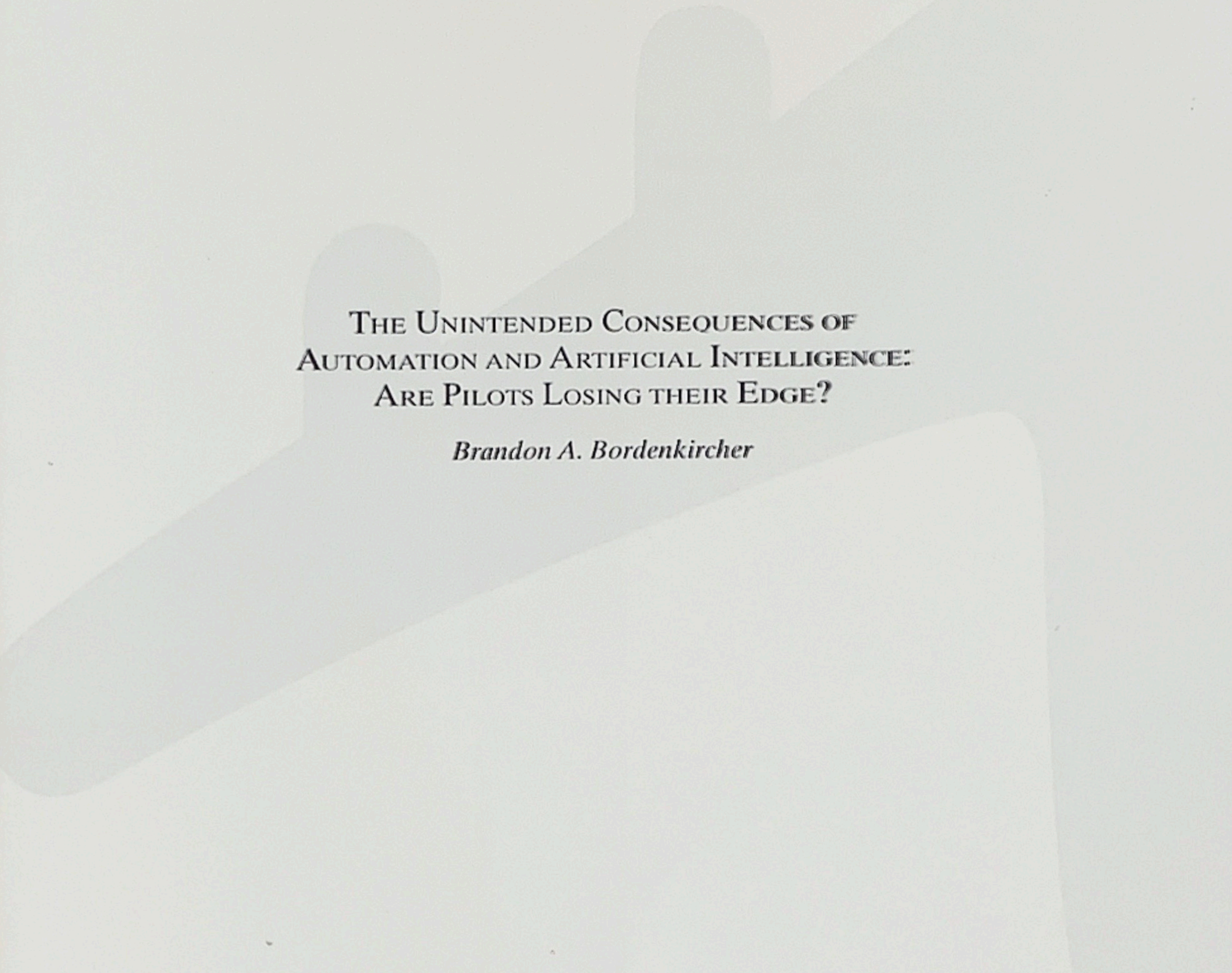

THE UNINTENDED CONSEQUENCES OF AUTOMATION AND ARTIFICIAL INTELLIGENCE: ARE PILOTS LOSING THEIR EDGE?

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The Unintended Consequences of Automation and Artificial Intelligence: Are Pilots Losing their Edge?

by Brandon A. Bordenkircher*

Introduction

Automated systems and artificial intelligence (AI) have been used to advance industries such as finance (where financial services firms are achieving companywide revenue growth of 19 percent), health care (with AI-enabled robots helping surgeons perform minimally invasive operations), public health (where AI is helping to fight pandemics), education (where it is taking over tasks such as grading and optimizing coursework), transportation (where companies like Waymo are testing autonomous trucks in the United States), and more.[1]

Commercial airline safety is at an all-time high. Advances in the aviation sector, thanks to automated systems, have allowed for gradual improvements to safety, particularly due to a decline in cognitive fatigue facing pilots. This fact was driven home in a recent study that showed airline fatalities have been reduced by roughly a factor of two every decade and have edged toward a factor of three in the last decade.[2]

One such automated system being utilized in the cockpit is known as the Maneuvering Characteristics Augmentation System (MCAS) a system designed for the Boeing 737 MAX, in order to help it fly more smoothly (due to its bigger engines) during maneuvers to avoid

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[1] Louis Columbus, *Why AI Is The Future of Financial Services*, FORBES.COM (Aug. 15, 2019, 8:47 AM), https://www.forbes.com/sites/louiscolumbus/2019/08/15/why-ai-is-the-future-of-financial-services/#3ae2cbad3847; Sam Daley, *Surgical Robots, New Medicines and Better Care: 32 Examples of AI in Healthcare*, BUILTIN.COM (Sept. 23, 2019), https://builtin.com/artificial-intelligence/artificial-intelligence-healthcare; Craig S. Smith, *The Machines Are Learning, and So Are the Students*, NYTIMES.COM (Dec. 20, 2019), https://www.nytimes.com/2019/12/18/education/artificial-intelligence-tutors-teachers.html; Amrita Khalid, *Waymo Resumes Testing Self-Driving Trucks in Arizona*, ENGAGET.COM (May 29, 2019), https://www.engadget.com/2019/05/29/waymo-resumes-testing-self-driving-trucks-in-arizona/?guccounter=1.

[2] Arnold Barnett, *Aviation Safety: A Whole New World?*, 54 TRANSP. SCI. 84, 89 (2020).

obstacles and to escape a powerful vortex from another plane, as well as to help adjust the tendency of the plane to nose up excessively during takeoff.[3]

However, as flying has become safer, recent issues with MCAS have resulted in two Boeing 737 MAX crashes: Lion Air Flight 610, which crashed minutes after taking off from Jakarta, Indonesia, killing 189 people and Ethiopian Airlines Flight 302, which crashed minutes after takeoff from Addis Ababa, killing all 157 on board.[4] These recent tragedies have shown us that not only is there still room for improvement, but that technological gains in one area can have unintended – and negative – impacts in others areas.

The question we seek to answer: are technological advances, such as automation, eroding piloting skills? Other sectors, such as health care, seem to be facing the same dilemma with artificial intelligence and surgery. The paper consists of three parts. Part 1, *Automation and Artificial Intelligence in Context*, defines and explores the history of automation and artificial intelligence, lays out how automation came to airplane cockpits, and explains its value to the cockpit. Part 2, *The Negative Implications of Automation and Artificial Intelligence*, covers the problems introduced by these new technologies. Finally, Part 3, *Moving Forward*, conducts a brief analysis of issues involving automation in the cockpit, what we should be doing to address these issues, and what other sectors are doing to address their own automation and AI issues.

Part 1 – Automation and Artificial Intelligence in Context

1. *Definitions: Automation vs. Artificial Intelligence*

For the purpose of this paper, it is important to distinguish the definitions of automation and artificial intelligence. The dictionary definition of automation is "the technique of making an apparatus, a process, or a system operate automatically," while the International Society of Automation's definition is "the creation and application of technology to monitor and control the production and delivery of products and services."[5] In automation, the environmental parameters are known at the time of programming and do not change during operations, with the purpose of letting machines perform monotonous repetitive tasks. This allows people (e.g., pilots) to focus on more important tasks that require human judgment and creativity.

On the other hand, artificial intelligence is a system that can respond and make decisions according to varying environmental parameters, which are not known at the time of design, by mimicking human decision-making. The term "artificial intelligence" is the overarching branch of computer science that focuses on building smart machines capable of performing tasks that usually require human intelligence.[6] The difference between artificial intelligence and machine learning is that machine learning is the *utilization of* artificial intelligence (i.e., inputting data,

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[3] Jack Nicas et al., *Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change*, NYTIMES.COM (June 1, 2019), https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html.

[4] Megan Specia, *What We Know About the Lion Air Flight 610 Crash*, NYTIMES.COM (Nov. 9, 2018), https://www.nytimes.com/2018/11/09/world/asia/air-lion-crash-610.html; Hadra Ahmed et al., *Ethiopian Airlines Plane Is the 2nd Boeing Max 8 to Crash in Months*, NYTIMES.COM (Mar. 10, 2019), https://www.nytimes.com/2019/03/10/world/africa/ethiopian-airlines-plane-crash.html.

[5] Int'l Soc'y of Automation, *What is Automation?*, https://www.isa.org/about-isa/what-is-automation/ (last visited Feb. 17, 2020).

[6] John McCarthy et al., A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence (Aug. 31, 1955) (unpublished manuscript available at http://www-formal.stanford.edu/jmc/history/dartmouth/dartmouth.html).

from which the machine then learns without any human involvement).[7] Machine learning can produce a system capable of artificial intelligence by taking in data and weighing that data in order to adjust responses, which is what the brain does: analyze information in order to adjust responses.[8] For the purposes of this paper, we will refer to the utilization of artificial intelligence as AI.

2. *A Brief History of Automation*

The term "automation" first appeared in 1936, when used by D.S. Harder to describe General Motors Corporation's production process;[9] however, the history of automation is extensive, with its earliest mention in Homer's *Iliad*.[10] In this epic poem, Homer describes the god Hephaestus, who was tasked with manufacturing all of the weapons used by the gods of Mount Olympus. To help Hephaestus build a mass of weapons in his workshop, he created what he called "automata," which were self-operating machines made from metal.[11]

Automation in the field of manufacturing began to take root in the 11th century with innovations in mining as population booms resulted in an increased demand for metals.[12] Water wheels, water-powered draining engines, were invented to assist with draining water out of shafts and tunnels.[13] By 1722, we saw the appearance of the horse-and-water-powered cotton spinning wheel called a "water frame."[14] By the 1800s, the Industrial Revolution was in full swing, particularly in the cotton and textile industries. In the 1900s, developments in electronics and control engineering helped advance the use of automation as we continued to see further developments by World War II with the manufacturing of tanks, warships, and fighter planes.

3. *A Brief History of Artificial Intelligence*

Although the term "artificial intelligence" wasn't coined until 1955, for a study titled *A Proposal For The Dartmouth Summer Research Project On Artificial Intelligence*,[15] its history can be traced back to 1308 when the Catalan poet Ramon Llull had a visionary, yet simple, idea. Llull utilized input (i.e., intake) and output, via a mechanical device made of paper, in order to create new knowledge from combinations of concepts, which he used to publish *The Ultimate*

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[7] Bernard Marr, *What Is the Difference between Artificial Intelligence and Machine Learning?*, FORBES.COM (Dec. 6, 2016, 2:24 AM), https://www.forbes.com/sites/bernardmarr/2016/12/06/what-is-the-difference-between-artificial-intelligence-and-machine-learning/#76b7a5482742.

[8] Anila Siraj, *How Artificial Intelligence and Machine Learning Have Advanced with Data Proliferation*, KALIBRATE.COM (Oct. 13, 2017), https://www.kalibrate.com/hot-topics/how-ai-and-machine-learning-advanced-with-data-proliferation.

[9] Katsundo Hitomi, *Automation – Its Concept and a Short History*, 14 TECHNOVATION 121, 122 (1994).

[10] Dimitrios Kalligeropoulos & Soultana Vasileiadou, *The Homeric Automata and Their Implementation*, *in* 6 HISTORY OF MECHANISM AND MACHINE SCIENCE: SCIENCE AND TECHNOLOGY IN HOMERIC EPICS 77, 78–79 (Stephanos A. Paipetis ed., 2008).

[11] *Id.*

[12] Product Handling Concepts, *A Brief History of Automation* (Sept. 7, 2016), www.phcfirst.com/words-in-motion/2016/9/7/a-brief-history-of-automation (last visited Feb. 17, 2020).

[13] Brigitte Weinsteiger, *The Medieval Roots of Colonial Iron Manufacturing Technology*, www.engr.psu.edu/mtah/articles/roots_colonial_iron_technology.htm.

[14] *Richard Arkwright*, HISTORY.CO.UK, www.history.co.uk/biographies/richard-arkwright.

[15] *See* McCarthy, *supra* note 6.

General Art.[16] However, it wasn't until 1763 that Thomas Bayes developed a framework for reasoning the probability of events, called "Bayesian inference," that became a leading approach in machine learning.[17] By 1914, Spanish engineer Leonardo Torres y Quevedo created the first chess-playing machine, capable of playing king and rook against king endgames without any human intervention.[18] Then, in 1943, Warren S. McCulloch and Walter Pitts published *A Logical Calculus of the Ideas Immanent in Nervous Activity*, discussing networks of idealized and simplified artificial "neurons" able to mimic the brain and perform simple logical functions.[19]

It wasn't until the 1950s that the concept of artificial intelligence made a significant jump forward with Alan Turing, whose paper, *Computing Machinery and Intelligence*, suggested that humans utilize all accessible information and reason to make decisions, and that it might be possible for machines to do the same thing.[20] Turing discussed how to build intelligent machines and how to test their intelligence by proposing "the imitation game" which later became known as the "Turing Test." Turing's studies were stunted due to the primitive technology available at the time: first, computers couldn't store commands, only execute them (i.e., computers could be told what to do but couldn't remember what they did); and second, computing was extremely expensive (leasing a computer could cost up to $200,000 a month).[21]

In December 1955, Allen Newell, Cliff Shaw, and Herbert Simon developed the first artificial intelligence program that was created to imitate the problem-solving skills of a human; the program was called the "Logic Theorist."[22] With technological advances, computers were able to store more information and compute faster, making them more accessible. This persuaded government agencies, such as the Defense Advanced Research Projects Agency (DARPA), to fund AI research at several institutions, leading to AI advancements from 1957 to 1974.[23] DARPA was especially focused on building a machine that could translate spoken language and transcribe it.

AI continued to progress in the 1980s with the assistance of increased capital and the introduction of "deep learning" techniques that allowed computers to learn by experience and expert systems which copied the decision-making process of a human expert.[24] Expert systems

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[16] RAMON LLUL, ARS MAGNA GENERALIS ET ULTIMA [THE ULTIMATE GENERAL ART] (Minerva-Verlag ed. 1970) (1308). *See* Gil Press, *A Very Short History of Artificial Intelligence (AI)*, FORBES.COM (Dec. 30, 2016, 9:09 AM), www.forbes.com/sites/gilpress/2016/12/30/a-very-short-history-of-artificial-intelligence-ai/#66ce64c56fba.

[17] TYLER D. DEVLIN ET AL., SEEING THEORY 49 (2018), https://seeing-theory.brown.edu/bayesian-inference/index.html.

[18] Jon Turi, *Chess and the Automaton Endgame*, ENGADGET.COM (Feb. 9, 2014), www.engadget.com/2014/02/09/torres-quevedo-chess-player-automaton/.

[19] Warren S. McCulloch & Walter Pitts, *A Logical Calculus of the Ideas Immanent in Nervous Activity*, BULL. MATHEMATICAL BIOPHYSICS, Dec. 1943, at 115–33.

[20] Alan M. Turing, *Computing Machinery and Intelligence*, 59 MIND 433 (1950).

[21] Robert Garner, *Early Popular Computers 1950–1970*, ENG'G & TECH. HIST. WIKI, https://ethw.org/Early_Popular_Computers,_1950_-_1970.

[22] Leo Gugerty, *Newell and Simon's Logic Theorist: Historical Background and Impact on Cognitive Modeling*, 50 HUM. FACTORS & ERGONOMICS SOC'Y ANN. MEETING PROC. 880, 881 (2006).

[23] Rockwell Anyoha, *The History of Artificial Intelligence*, HARV. U. SITN BLOG (Aug. 28, 2017), http://sitn.hms.harvard.edu/flash/2017/history-artificial-intelligence/.

[24] Edward A. Feigenbaum, Expert Systems in the 1980s (1980) (unpublished manuscript, available at https://pdfs.semanticscholar.org/40d4/a42f70a7436b2ddf21d88187c874186cf97e.pdf).

and other AI-related endeavors were heavily funded from 1982 to 1990 as part of the Japanese government's Fifth Generation Computer Project (FGCP) that invested $400 million into improving artificial intelligence, developing computer processing, and implementing logic programming.[25]

AI thrived even after the FGCP's funding dissolved, and by the 2000s AI had achieved many of its milestones: Arthur Samuel wrote the first computer learning application in 1952; a program allowing a computer to create a set of rules based on training data – called Explanation Based Learning (EBL) – was introduced in 1981; NetTalk, a program where computers learned to pronounce words, was introduced in 1985; machine learning shifted in the 1990s from a knowledge-driven approach to a data-driven approach focusing on extracting patterns from large amounts of data; and in 1997, IBM's Deep Blue system defeated the world champion of chess.[26] A computer beating the world's greatest chess player is impressive, but what has arguably been more impressive is the implementation of artificial intelligence and machine learning for practical uses, such as stopping the spread of pandemics and even utilizing AI-enabled robots to assist surgeons with minimally invasive operations.[27]

4. *History of Automation in the Cockpit*

As aircraft design progressed, the need for more complicated systems became a necessity. Automated flight systems have made long flights simple by freeing pilots of the tiresome constant handling and correction of aircraft controls. It is estimated that today, "over 90 percent of most flights are flown with the autopilot engaged," with autopilot utilized for the climb, enroute, and descent phases of flight. The autopilot system has a minimum engagement altitude, meaning once a certain altitude is reached, it is up to the pilot to decide whether or not to turn it on.[28] Cockpit automation evolved in three phases: mechanical, electrical, and electronic.[29]

a. Phase One: Mechanical

Automation in aviation was introduced not long after Wilbur and Orville Wright first took to the skies in 1903. The first automation was put in place in the 1920s, to keep the aircraft flying straight. Prior to this introduction, there were no instrumental aids to help pilots fly, such as systems to indicate airspeed and altitude, which were not introduced for many years.

During this time, a piece of string was attached to the wings to indicate if airflow was adequate to sustain flight. Soon after, the first anemometers and altimeters, tools to indicate airspeed and altitude, were introduced, followed by the pneumatic gyroscope. This device was

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[25] *Japan Gain Reported in Computers*, N.Y. TIMES, Nov. 12, 1984, at D1.

[26] Anyoha, *supra* note 23; Bella Wilson, *Major Milestones of Artificial Intelligence from 1949 to 2018*, MEDIUM.COM (Apr. 18, 2018), https://medium.com/@angelapowell/major-milestones-of-artificial-intelligence-97d42bb5714c.

[27] Eric Niiler, *An AI Epidemiologist Sent the First Warnings of the Wuhan Virus*, WIRED (Jan. 25, 2020, 7:00 AM), https://www.wired.com/story/ai-epidemiologist-wuhan-public-health-warnings/; Daley, *supra* note 1.

[28] John Cox, *Ask the Captain: How Often is Autopilot Engaged?*, USATODAY.COM (Aug. 11, 2014, 6:10 PM) https://www.usatoday.com/story/travel/columnist/cox/2014/08/11/autopilot-control-takeoff-cruising-landing/13921511/.

[29] Antonio Chialastri, *Automation in Aviation*, *in* AUTOMATION 79, 84 (Florian Kongoli ed., 2012), https://cdn.intechopen.com/pdfs/37990/intech-automation_in_aviation.pdf.

used to help stabilize an artificial horizon and help pilots understand their situation during poor visibility, thus preventing dangerous vestibular illusions caused by the inner ear.

In phase one, the purpose of automation was to assist pilots with their manual flying and with situational awareness. As planes grew in size, the aerodynamic forces increased, and pilots' physical force was insufficient to control the aircraft. At this time, it became necessary to amplify the pilot's physical force via pneumatic or hydraulic actuators. In the 1930s, the first fly-by-wire system was introduced. It replaced conventional mechanical flight controls with an electronic interface to control the actuators, which in turn moved the aircraft's control surfaces.[30]

b. Phase Two: Electrical

Electric innovations in the cockpit followed with electrically driven instruments replacing older instruments that were powered pneumatically. New electronic navigation systems, such as VORs (Very High Frequency Omni-directional Range) were introduced that allowed pilots to navigate from one ground-based station to another using onboard equipment. With the introduction of the ILS (Instrument Landing System), pilots were provided with lateral and vertical guidance to the runway, allowing planes to safely land in lower-visibility conditions.

The 1960s brought additional electric advancements, such as autopilot, autothrottle (controlling power to the engine), flight directors (the brain of the autopilot system), onboard weather, and system-monitoring equipment capable of alerting the pilot of impending equipment malfunctions. With up to 600 various devices, the second phase of automation gave rise to a new worry: "the inflation of information with hundreds of additional gauges and indicators inside the cockpit."[31]

c. Phase Three: Electronic

The third phase of automation, characterized by electronics in the cockpit, came in the 1980s. This new wave of automation replaced conventional instruments with colorful glass displays (e.g., liquid crystal displays (LCDs)) that presented air data, attitude, heading, reference, and system-monitoring information in an easily readable format. Known as "glass cockpits," the displays also helped to cut down on the clutter of multiple instruments, and individual LRUs (Line Replaceable Units) made for easier maintenance and technology upgrades.

During the third phase, the Flight Management System shifted from tactical to strategic. In Phase Two, pilots received immediate feedback after entering their input; however, in Phase Three, after the data was entered, the effects were no longer immediately accessible. This made coordination, mutual cross-checking, and operational discipline – in flying tasks and also in monitoring activity – extremely important. The Flight Management System database has an enormous amount of data (i.e., navigational routes and performance capabilities).

This phase also birthed the "electronic echo-system," a phrase used to describe the extremely complex electrical systems pilots are currently forced to utilize. Prior to this phase, pilots were acquainted with the inner logic of the systems they utilized, the components, and

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[30] Stephen Pope, *Fly by Wire: Fact versus Science Fiction*, FLYING (Apr. 23, 2014), http://www.flyingmag.com/aircraft/jets/fly-by-wire-fact-versus-science-fiction/.

[31] *Id.* at 85 (citing Guy A. Boy, *A Human-Centered Design Approach*, *in* THE HANDBOOK OF HUMAN MACHINE INTERACTION: A HUMAN-CENTERED DESIGN APPROACH (Guy A. Boy ed., 2011)).

procedures for dealing with potential issues. In this new phase, pilots were found to sometimes be “out of the loop.” This is a big part of the issue with automation in the cockpit.[32]

d. Automated Systems

1. Fly-by-wire Controls and Automated Flight Systems

Fly-by-wire (FBW) systems are semi-automatic, computer-controlled flight control apparatus that replace traditional mechanical flight controls with an electronic interface.[33] The concept of fly-by-wire systems evolved slowly as aircraft design progressed with increases in size and speed. Since the beginning of flight in the early 1900s, flight control systems that allow pilots to climb, bank, turn, and descend, were originally controlled by cables, bellcranks, and pushrods connected to sticks and rudder pedals in the cockpit.[34] Increases in aircraft size and speed required power-boosted controls in order to enable the pilot to fully maneuver the aircraft. The first aircraft to utilize the FBW system was the Avro Arrow, which used an analog circuit dual-channel fly-by-wire system.[35] The Apollo Lunar Module was fly-by-wire, and NASA’s F-8 aircraft also tested the system.[36]

As aircraft continued to progress, the Digital Fly-By-Wire (DFBW) program (pioneered by the Concorde and Airbus A320 in civil aviation) – an electronic flight control system teamed with a digital computer – was introduced.[37] This successfully replaced mechanical control systems between 1972 and 1985. Electronic signals transmitted via *electronic wires* were the linkage between the cockpit and control surfaces on a DFBW aircraft.[38] Command signals from the cockpit are processed by the digital flight control computer and transmitted to actuators that move control surfaces correspondingly. The fly-by-wire system allows the aircraft’s computers to send automatic signals to carry out work without the pilot’s input. Flight control computers determine the ordered response, which automatically helps stabilize the aircraft and prevent unsafe maneuvers outside of its performance capabilities. Together, machine learning (ML) and AI technology were able to reduce the workload of pilots.[39]

In 1983, Airbus introduced fly-by-wire to control flaps and spoilers in the A310, as well as parts of the A300-600 the following year. The biggest advantage of fly-by-wire is that it is ideally suited for computer use. Aircraft manufacturers adopted fly-by-wire technology to control supersonic aircraft, like fighter jets, which would be impossible to control by human inputs alone. Planes under computer control have quicker response time to turbulence and other changes in flying conditions, and the use of computers placed limits on pilot behavior, to ensure

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[32] Chialastri, *supra* note 29, at 86.

[33] *What are Fly-by-Wire Systems?*, BAESYSTEMS.COM, https://www.baesystems.com/en-us/definition/what-are-fly-by-wire-systems (last visited Feb.18, 2020).

[34] *NASA Dryden Technology Facts – Digital Fly By Wire*, NASA, https://www.nasa.gov/centers/dryden/about/Organizations/Technology/Facts/TF-2001-02-DFRC.html (last visited Feb.18, 2020).

[35] *What is Fly-by-Wire?*, STACK EXCHANGE, https://aviation.stackexchange.com/questions/21690/what-is-fly-by-wire (last visited Feb.18, 2020).

[36] *Digital Fly By Wire: Aircraft Flight Control Comes of Age*, NASA, https://www.nasa.gov/vision/earth/improvingflight/fly_by_wire.html (last visited Feb.18, 2020).

[37] *NASA Dryden Technology Facts – Digital Fly By Wire*, *supra* note 34.

[38] *What is Fly-by-Wire?*, *supra* note 35.

[39] Alyson Behr, *More Than an Auto-Pilot, AI Charts Its Course in Aviation*, ARSTECHNICA.COM (Dec. 5, 2018, 10:00 AM), https://arstechnica.com/information-technology/2018/12/unite-day1-1/.

that an aircraft is never forced into a maneuver it is not designed to handle (e.g. a turn so sharp that it would crack an aircraft's body).[40]

Aircraft design engineers prefer the all-electric approach because it offers weight savings, easier installation, and lower maintenance costs.[41] Other fly-by-wire benefits include a decrease in cost of ownership and savings pertaining to design (flexibility of cockpit layout and incorporation of automatic flight and landing systems), an increase in flight control system reliability, improved aircraft handling qualities, and resistance to aircraft structural changes due to flexing, bending, and thermal expansion.[42]

2. Autopilot and Flight Director (FD)

Autopilot is a system with the ability to automate maintenance of altitude, climbing or descending to an assigned altitude, maintaining and intercepting a course, guiding an aircraft between waypoints, and flying a precision or nonprecision approach. The first part of the autopilot system is a set of servo actuators that physically control movement, along with control circuits that make the servo actuators move the correct amount for the selected task. The second part is the flight director (FD) – the brain of the autopilot system – which has the power to accomplish these tasks and usually displays the indications to the pilot for guidance.[43]

3. Control Wheel Steering

Control Wheel Steering (CWS) is a cross between fully automated flight and manual flying. It is less used as a stand-alone option in modern airliners. CWS autopilots typically have three positions: off, CWS, and CMD. CMD mode, short for Command mode, gives the autopilot full control over the aircraft, as it receives input from the heading/altitude setting, radio and navaids, or the FMS (Flight Management System). In CWS mode, the pilot controls the autopilot through inputs via the stick. The inputs are translated to heading and attitude, which the autopilot holds until notification from the pilot.

4. Stability Augmentation Systems (SAS)

As aircraft performance and size increased, adding stability augmentation became requisite in order to aid the pilot. SAS were limited in the scope they controlled; however, for some flight regimes, SAS was required for the safety of the aircraft. SAS's success led to the development of the Control Augmentation System (CAS), which was an electrical system that worked in parallel with the mechanical control system.[44]

5. Automatic Dependent Surveillance Broadcast (ADS-B)

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[40] Barnaby J. Feder, *The A320's Fly-by-Wire System*, N.Y. TIMES, June 29, 1988, at D7.

[41] *Id.*

[42] J.P. Sutherland, Fly-By-Wire Flight Control Systems, Presented at the Joint Meeting of Flight Mechanics and Guidance and Control Panels of AGARD (Sept. 3, 1968), https://apps.dtic.mil/dtic/tr/fulltext/u2/679158.pdf.

[43] FED. AVIATION ADMIN., ADVANCED AVIONICS HANDBOOK 4-2 (2009), www.faa.gov/regulations_policies/handbooks_manuals/aviation/advanced_avionics_handbook/media/aah_ch04.pdf.

[44] *Id.*

The Automatic Dependent Surveillance Broadcast (ADS-B) system was originally developed for unmanned aerial vehicle (UAV) safety for traffic situational awareness but was later introduced to manned aircraft.[45]

6. Maneuvering Characteristics Augmentation System (MCAS)

Systems such as MCAS were developed to increase safety to compensate for aircraft handling characteristics (i.e. using sensor data to adjust the control surfaces of an aircraft automatically, based on flight conditions). In the case of the Boeing 737 MAX, the MCAS was used to help stabilize the plane during flight and help correct the plane from going nose up during takeoff due to its bigger engines.[46]

7. Runway Overrun Protection (ROPS)

Runway Overrun Protection software was introduced to calculate aircraft approach speed and weight, comparing it with the runway length and current local weather. If an unsafe situation is detected, an alert sounds "Runway too short!" ROPS also has the ability to assist in landing approach, taxiing, takeoff, and other aspects of flight.[47]

e. U.S. Automation Regulations

With the increase in cockpit automation, and with the exception of most landings and takeoffs, planes have largely been flying themselves. While it is irrefutable that automation has led to the airline industry's much-improved safety record in the past few decades, it is perhaps ironic that it has also been a cause of several crashes in the past few years. The co-chairman of the FAA committee on pilot training warned of a pattern of accidents in state-of-the-art planes, due to U.S. regulations requiring greater reliance on computerized flying.[48]

In 2014, the FAA created the Air Carrier Training Aviation Rulemaking Committee (ACT ARC) to gather feedback from the U.S. aviation community in order to develop recommendations regarding flight automation. The Committee, which specifically focused on operations and training pertaining to 14 C.F.R. parts 121, 135, and 142,[49] resulted in the issuance of an Audit Report by the DOT's Office of Inspector General.[50]

As of 2016, the FAA had implemented more than 1,550 automated procedures, and with advances in cockpit automation that number is set to increase. As the number of automated procedures increases, manual flight opportunities will continue to diminish. New procedures that hinder pilots' ability to practice manual flying skills include the utilization of automated systems

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[45] Fed. Aviation Admin., *Automatic Dependent Surveillance-Broadcast (ADS-B)*, www.faa.gov/nextgen/programs/adsb/ (last visited Feb. 18, 2020).

[46] Nicas et al., *supra* note 3.

[47] Press Release, Airbus, Airbus' Runway Overrun Prevention System (ROPS) Certified by EASA on A330 Family (July 20, 2015), https://www.airbus.com/newsroom/press-releases/en/2015/07/airbus-runway-overrun-prevention-system-rops-certified-by-easa-on-a330-family.html.

[48] *Study: Automatic Pilot May Add to Flight Risk*, CBSNEWS.COM (Aug. 30, 2011, 10:13 AM), https://www.cbsnews.com/news/study-automatic-pilot-may-add-to-flight-risk/.

[49] Part 121 regulates the operating requirements for, inter alia, scheduled commercial airlines. Part 135 regulates commuter and on-demand air carrier operations. Part 142 regulates training centers.

[50] DEP'T OF TRANSP., OFFICE OF INSPECTOR GENERAL, AUDIT REPORT: ENHANCED FAA OVERSIGHT COULD REDUCE HAZARDS ASSOCIATED WITH INCREASED USE OF FLIGHT DECK AUTOMATION (Jan. 7, 2016), www.oig.dot.gov/sites/default/files/FAA%20Flight%20Decek%20Automation_Final%20Report%5E1-7-16.pdf.

such as area navigation (RNAV) and required navigation performance (RNP), as well as the requirement to maintain a reduced 1,000-foot vertical separation minimum at altitude.[51]

As automation continues to progress, the Federal Aviation Regulations (FARs) will need continued revisions and updates. A 1996 report by the FAA's Human Factors Team resulted in a series of regulatory revisions, including: warning, caution, and advisory lights (§ 25.1322); flight director (§ 25.1335); reporting automation failures and anomalies (§ 121.703); and the consideration of pilot errors (§ 25.1309).[52] The specific section pertaining to automation – 14 C.F.R. § 25.1329 – is titled "Autopilot Regulatory Standards."

5. *Why Automation is Valuable to the Cockpit*

As stated *supra*, automation in the cockpit has helped give rise to many benefits resulting in safer airline travel. A recent study noted that airline fatalities have been reduced by a factor of two in every decade for 50 years and have edged toward a factor of three in the last decade.[53] Automation helps pilots by preventing unsafe maneuvers and helping to reduce pilots' cognitive load and cognitive fatigue.

a. Preventing Unsafe Maneuvers

With the introduction of the Digital Fly-By-Wire (DFBW) program, an electronic flight control system with a digital computer, commands from the cockpit were processed by the computer and sent to actuators that shift the corresponding control surfaces.[54] The flight control computer then determines how to move the actuators at each control surface to administer the ordered reaction. These systems help to automatically steady the aircraft and avoid unsafe maneuvers beyond the aircraft's performance capabilities. Fly-by-wire technology allows aircraft manufacturers to design supersonic airplanes that are easier to manipulate while being less inherently stable than a conventionally built airplane. Airplanes, such as fighter jets, which are unstable, are both more maneuverable and more efficient than stable ones. Increased maneuverability allows pilots to perform maneuvers without exceeding the structural limits of aircraft (e.g., a turn so sharp that it would crack an aircraft's body).[55] Thus, unstable aircraft are more desirable in all ways except that they are more difficult for humans to handle, hence the need for fly-by-wire systems.[56]

b. Reducing Pilot Cognitive Load and Cognitive Fatigue

Modern airplanes collect an incredible amount of data through their sensors, and it would be next to impossible for pilots to analyze all of that data in order to make an educated decision for every issue during a flight. Approximately 50,000 sensors gather 2.5 terabytes of data daily on an Airbus A350 XWB. Obviously, this is an immense amount of data to analyze. Automated

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[51] Bill Carey, *FAA's Oversight of Pilot Automation Training Questioned*, AINONLINE.COM (Jan. 12, 2016, 10:12 AM), https://www.ainonline.com/aviation-news/air-transport/2016-01-12/faas-oversight-pilot-automation-training-questioned.

[52] FED. AVIATION ADMIN., HUMAN FACTORS TEAM, THE INTERFACES BETWEEN FLIGHTCREWS AND MODERN FLIGHT DECK SYSTEMS (June 18, 1996), http://www.tc.faa.gov/its/worldpac/techrpt/hffaces.pdf.

[53] Barnett, *supra* note 2. *See also* Peter Dizikes, *Commercial Air Travel Is Safer than Ever*, SCIENCEDAILY.COM (Jan. 24, 2020), https://www.sciencedaily.com/releases/2020/01/200124124510.htm.

[54] *NASA Dryden Technology Facts – Digital Fly By Wire*, *supra* note 34.

[55] Pope, *supra* note 30.

[56] Feder, *supra* note 40.

systems, such as the DFBW program, have the ability to reduce the amount of data analyzed by the pilots by making unsafe maneuvers impossible to initiate, which reduces the cognitive load, and the resulting cognitive fatigue, placed on the pilots. Assigning these analytical tasks to automated systems allows the crew to spend more time focusing on the broad strategy and mission and less time concentrating on the "small sub-problems of piloting an aircraft."[57]

Part 2 – The Negative Implications of Automation and Artificial Intelligence

1. *The Issues with Automation in the Cockpit*

As stated *supra*, it is somewhat ironic that automation has been a cause of several airplane crashes in the past few years. One of the reasons might be because humans stop relying on their own intellectual abilities as they rely more on computer assistance and automation.[58] According to Robert P. Mark, some of the most frequent mistakes made by pilots pertaining to the automated systems are:

- Pushing the wrong buttons at the right time;
- Pushing the right buttons at the wrong time;
- Pushing the right buttons in the wrong sequence;
- Thinking that an automated function is off when it is on; and
- Thinking that an automated function is on when it is off.[59]

In addition to those common mistakes, there are other human factors in relation to automation that also cause problems.[60]

a. Automation Bias

Automation bias occurs when users of an automated system tend to apply greater weight to the system's recommendations than to their own judgment or expertise. Three main factors contribute to the occurrence of automation bias. The first factor is to favor the automated system to handle more complex analysis. The second is referred to as "complacency," where pilots do not conduct sufficient checks of the system and assume everything is fine, even though a dangerous condition may be developing. The final factor, "diffusion of responsibility," occurs when humans reduce their own effort when working with an automated system. These three components arise when a pilot becomes overly comfortable with automated systems. As long as the automation works properly, these factors are insignificant; however, if the automated system fails to alert the pilot or provides an incorrect recommendation the results can lead to tragedy.[61]

b. Automation Surprise

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[57] Behr, *supra* note 39.

[58] Masoud Yazdani, *Intelligent Machines and Human Society*, *in* ARTIFICIAL INTELLIGENCE: HUMAN EFFECTS 63, 65 (Masoud Yazdani & Ajit Narayanan eds., 1984).

[59] Robert P. Mark, *Cockpit Automation Is Still Very Much a Work in Progress*, AINONLINE.COM (Jan. 11, 2008, 9:10 AM), https://www.ainonline.com/aviation-news/aviation-international-news/2008-01-11/cockpit-automation-still-very-much-work-progress.

[60] *Id.*

[61] Julian Hiraki & Mike Warnink, *Cockpit Automation Fact Sheet: Automation Bias and Surprise*, AVIATIONFACTS.EU (Feb. 2016), https://aviationfacts.eu/uploads/thema/file_en/56cb04c570726f3ee1010000/Cockpit_Automation_Fact_sheet.pdf.

Automation surprise occurs when a pilot is "out-of-the-loop" while confronted with an unpredictable and difficult-to-grasp system performance. Automation was initially developed to improve accuracy and eliminate the chance for human error. As automation continues to advance, the computer performs more operations that have typically been human-related. With these advances, the human user can become distracted, and disconnected with the flying of the plane and the automated system. When a pilot is out-of-the-loop, s/he becomes less engaged in the process, which limits the pilot's knowledge of the situation. This leads to a pilot's inability to identify problems, verify the state of the system, comprehend the situation, and react to the situation. In short, pilots suffer from a loss of situational awareness, where they are surprised by the demeanor of the automation.[62]

c. Additional Human-Factor Issues

In addition to automation bias and automation surprise, experts warn about the following human-factor issues when flying automated aircraft:

- Absorption – when a pilot is so focused on a task that other issues are excluded;
- Fixation – when a pilot becomes locked into one solution despite evidence suggesting other actions;
- Preoccupation – when a pilot is distracted because the plane is flying smoothly; and
- Underload – when workload is low and it becomes difficult to pay attention.[63]

2. *Negative Effect on Pilots*

The FAA completed a study in 2011 that found 60 percent of 46 accidents occurred due to a lack of manual flying skills and lack of ability to handle the automated controls.[64] The study also found that complicated automation systems confuse pilots, causing them to respond when they do not need to.[65]

Pilots currently spend less time practicing hands-on flying and more time learning these new automated systems. According to interviews with pilots at major airlines and aviation universities around the world, this has resulted in novice pilots being less comfortable with taking manual control when the automated system is not working correctly.[66] With the pilots' skills dulled, they may not know how to recognize what is happening or have the time to figure out how to fix the problem. Some airline pilots and experts have worried this has led us to a false sense of security – and they may have a point. With Lion Air Flight 610 and Ethiopian Airlines Flight 302, the pilots failed to control the aircraft because they did not fully understand how the automated system (MCAS) functioned.[67] In 2014, investigators found the crash of an

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[62] *Id.*

[63] Mark, *supra* note 59.

[64] *Study: Automatic Pilot May Add to Flight Risk*, *supra* note 48.

[65] Mark, *supra* note 59. *See also Study: Automatic Pilot May Add to Flight Risk*, *supra* note 48.

[66] Jack Nicas & Zach Wichter, *A Worry for Some Pilots: Their Hands-On Flying Skills Are Lacking*, NYTIMES.COM (Mar. 14, 2019), https://www.nytimes.com/2019/03/14/business/automated-planes.html.

[67] *Id.*

Asiana Airlines jet in San Francisco that left three dead in 2013 was caused by pilots over-relying on the automated systems in the cockpit.[68]

There were hundreds of casualties from 2006 to 2011 due to "loss of control" accidents where planes got into abnormal positions and pilots were not able to recover them. In a few cases, pilots made incorrect fraction-of-a-second decisions, with fatal results (e.g., turning the plane's nose skyward causing a stall when it should have remained down to stabilize the flight).[69]

The issue of automation eroding piloting skills has been known for decades, as an American Airlines pilot-training video warned about the issue back in 1997.[70] In 2013, the FAA released a 267-page report that concluded pilots relied on automation too much while recommending they be required to improve their manual flying skills.[71] Even with knowledge of these fatal issues, the FAA has been slow to correct them. The DOT's Office of Inspector General issued a report in 2016, with the finding that the FAA did not track how often pilots flew manually, and the additional finding that airline companies had not adequately trained pilots on how to monitor a plane on autopilot or for hands-on flying.[72]

The aviation industry's most experienced pilots are being forced into retirement[73] and, as a result, the global pilot shortage is forcing airlines to hire pilots with less experience in the cockpit. Automation in the cockpit masks this lack of experience. Boeing and Airbus have encouraged a reliance on automation and have been marketing aircraft to accommodate less-experienced pilots, according to a spokesman for an airline pilots' union.[74]

3. *An Example from Medicine: The Negative Impact of AI-Assisted Surgery*

AI-assisted surgery, with the physician operating a robotic system that performs the surgery through small incisions, is beginning to replace traditional surgery, in which a surgeon operates through a long skin incision. According to some doctors, it leads to less blood loss, shorter hospital stays, faster recoveries, a better chance of not leaving behind parts of a malignant tumor, and is actually easier to master than traditional open surgery. The main advantage for doctors is precision, as it uses smaller instruments, allowing for more exacting movements during procedures. Smaller, more precise cuts result in much faster healing and less pain medication. Robotic surgery also has a quicker learning curve by eliminating certain negative human aspects of the surgery, such as vibrating or shaky hands.[75]

There are many positive aspects of AI-assisted surgery; however, because of this reliance on technology, surgeons are facing a dilemma much like that of the pilots. A study was

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[68] Press Release, Nat'l Transp. Safety Bd., Board Meeting: Crash of Asiana Flight 214 Accident Report Summary (June 24, 2014), https://www.ntsb.gov/news/events/pages/2014_Asiana_BMG-abstract.aspx.

[69] *Study: Automatic Pilot May Add to Flight Risk*, *supra* note 48.

[70] Videotape: Automation Dependency: Children of the Magenta Line (Am. Airlines, Apr. 21, 1997), https://vimeo.com/159496346.

[71] FED. AVIATION ADMIN., OPERATIONAL USE OF FLIGHT PATH MANAGEMENT SYSTEMS: FINAL REPORT OF THE PARC/CAST FLIGHT DECK AUTOMATION WORKING GROUP (Sept. 5, 2013), www.faa.gov/aircraft/air_cert/design_approvals/human_factors/media/OUFPMS_Report.pdf.

[72] DEP'T OF TRANSP., *supra* note 50.

[73] U.S. airline pilots are required to retire at age 65. *See* 14 C.F.R. § 121.383(d)–(e) (2019).

[74] Nicas & Wichter, *supra* note 66.

[75] *Is Robotic Prostate Surgery Better Than Traditional Surgery?*, WALL ST. J. (June 24, 2018, 10:03 PM), www.wsj.com/articles/is-robotic-prostate-surgery-better-than-traditional-surgery-1529892180.

published showing how robotic surgery practices may be limiting the amount of hands-on surgical practice trainees receive, and leaving many new surgeons unequipped to perform surgery without the aid of artificial intelligence.[76] Matthew Beane, Ph.D., conducted two studies: the first, a two-year study comparing the outcomes of traditional and robotic surgical practices. The study found traditional surgical training methods were successful in teaching trainees how to become surgeons, while the robotic surgery techniques limited the abilities for trainees due to lack of experience.[77] Dr. Beane concluded that premature specialization in robotic surgery led to incompetence in general surgery and contributed to troubling outcomes for the group of novice surgeons and the profession as they begin to see a decreasing supply of experts. In summary, these new surgeons are comfortable working within the context of artificial intelligence and robotic surgery, which led to what Beane calls "premature specialization." If a problem were to arise and they had to perform surgery without assistance from a machine, they were ill-prepared.[78] Or, as Andrew Hill stated in an article on the strategic dilemmas of artificial intelligence: "When the Machine suffers a cataclysmic failure, the . . . society collapses with it."[79] This problem is not siloed specifically in the aviation and surgery spaces. Another paper notes that wide usage of Web agents (AI helpers that help people navigate websites and answer questions for them) can cause the erosion of people's Internet competence over time.[80]

4. *The Negative Impact of Self-Driving Vehicles*

Autonomous vehicles have the potential to make the road safer for both drivers and pedestrians. The U.S. government's National Highway Traffic Safety Administration (NHTSA) has found that 94 percent of all serious motor vehicle crashes are due to human error, and although automated safety technology can help mitigate these crashes, autonomous vehicles still have a way to go.[81] Three autonomous-vehicle-related deaths have demonstrated that automation bias, automation surprise, preoccupation, and underload are not just phenomena found in aviation. The first autonomous vehicle crash occurred in Florida in May of 2016. A Tesla Model S was driving on autopilot mode and failed to detect a tractor-trailer crossing the highway. The incident, which left the driver of the Tesla dead, occurred because the system failed to differentiate a white tractor-trailer crossing the highway from the bright sky behind.[82]

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[76] Matthew Beane, *Shadow Learning: Building Robotic Surgical Skill When Approved Means Fail*, 41 ADMIN. SCI. Q. 404 (2018).

[77] Emily Rappleye, *Robot-Assisted Surgery Leaves New Surgeons Without Crucial Skills, Study Finds*, BECKER'S HOSP. REV. (Mar. 19, 2019), https://www.beckershospitalreview.com/artificial-intelligence/robot-assisted-surgery-leaves-new-surgeons-without-crucial-skills-study-finds.html.

[78] *Id. See also* Jingyan Lu, *Will Medical Technology Deskill Doctors?*, 9 INT'L EDUC. STUD. 130 (2016).

[79] Andrew Hill, *Artificial Intelligence Creates Real Strategic Dilemmas*, FIN. TIMES (May 19, 2019) (*citing* E.M. FORSTER, THE MACHINE STOPS (Penguin Classics 2011) (1909)), www.ft.com/content/8e3d9386-77c6-11e9-bbad-7c18c0ea0201.

[80] Alexander Serenko, Umar Ruhi & Mihail Cocosila, *Unplanned Effects of Intelligent Agents on Internet Use*, 21 AI & SOC'Y 141, 157 (2007), https://link.springer.com/article/10.1007/s00146-006-0051-8.

[81] Nat'l Highway Traffic Safety Admin., *Automated Vehicles for Safety*, https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety.

[82] *Tesla Driver Dies in First Fatal Crash While Using Autopilot Mode*, THEGUARDIAN.COM (June 30, 2016), www.theguardian.com/technology/2016/jun/30/tesla-autopilot-death-self-driving-car-elon-musk.

The driver in the Florida crash had his hands on the steering wheel for 25 seconds out of the 37 minutes that the vehicle was in automated control mode.[83]

The second autonomous vehicle-related death, and the first to involve a pedestrian death, occurred in March 2018, when a self-driving Uber struck and killed a woman on an Arizona street.[84] Police reported the self-driving car was in autonomous mode when it hit the woman, who was walking outside of the crosswalk.[85] Investigators instead highlighted the human errors, including the fact that the vehicle operator in the car at the time of the crash was not paying attention. Investigators found that the driver had been glancing down at a telephone for over a third of the car ride, and during the crash the driver was streaming a television show on the phone, in violation of Uber's policy banning phone use during driving.[86]

The driver had one chance to save the pedestrian's life, as she was detected by the car 5.6 seconds before impact; however, because the driver was not paying attention, the pedestrian was killed. Bruce Landsberg, a National Transportation Safety Board member, said that "automation complacency" was the culprit, but we could just as well call it automation bias.[87]

The third autonomous-vehicle-related death occurred in 2018 in Mountain View, California. The accident could have been avoided; however, the driver was playing a game on his phone and had been relying too heavily on Tesla's Autopilot driver-assistance system. The system had been engaged for nearly 19 minutes during the trip, and post-crash data showed the driver's hands were not on the wheel in the six seconds before impact. According to investigators, the driver had previously complained of problems with Autopilot on that part of the highway and the data from the vehicle confirmed a similar problem near another part of the highway.[88]

Part 3 – Moving Forward

1. *Addressing the Issues of Automation in the Cockpit*

Adding more computers in the cockpit may not be the best solution. Solving one problem can create an entirely new set of problems. According to Dr. David Woods, a professor at Ohio State University and a technical advisor for an FAA human-factors report: "One of the myths about the impact of automation on human performance is that as the investment in

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[83] NAT'L TRANSP. SAFETY BD., COLLISION BETWEEN A CAR OPERATING WITH AUTOMATED VEHICLE CONTROL SYSTEMS AND A TRACTOR-SEMITRAILER TRUCK NEAR WILLISTON, FLORIDA MAY 7, 2016, NTSB/HAR-17/02, PB2017-102600 (2017).

[84] *Self-Driving Uber Kills Arizona Woman in First Fatal Crash Involving Pedestrian*, THEGUARDIAN.COM (Mar. 19, 2018), www.theguardian.com/technology/2018/mar/19/uber-self-driving-car-kills-woman-arizona-tempe.

[85] *Self-Driving Uber Car Hits, Kills Pedestrian in Tempe*, ABC15.COM (Mar. 21, 2018, 2:51 PM), www.abc15.com/news/region-southeast-valley/tempe/tempe-police-investigating-self-driving-uber-car-involved-in-crash-overnight.

[86] Andrew J. Hawkins, *Uber Is at Fault for Fatal Self-Driving Crash but It's Not Alone*, THEVERGE.COM (Nov. 19, 2019, 4:46 PM), www.theverge.com/2019/11/19/20972584/uber-fault-self-driving-crash-ntsb-probable-cause.

[87] Andrew J. Hawkins, *The World's First Robot Car Death Was the Result of Human Error – and It Can Happen Again*, THEVERGE.COM (Nov. 20, 2019, 2:23 PM), www.theverge.com/2019/11/20/20973971/uber-self-driving-car-crash-investigation-human-error-results.

[88] Niraj Chokshi, *Tesla Autopilot System Found Probably at Fault in 2018 Crash*, NYTIMES.COM (Feb. 25, 2020), https://www.nytimes.com/2020/02/25/business/tesla-autopilot-ntsb.html.

automation increases, the investment needed in human expertise decreases. In fact, increased automation creates new knowledge and skill requirements."[89]

Some options for addressing the deleterious effects of automated systems in the cockpit are: more flight simulator training; abnormal-situation training simulations; mandated manual flying training; more automated system training and encouragement to override automation; enforcement and regulation; simplifying cockpit design; and monitoring pilots' attention via artificial intelligence. The genie is out of the bottle, automation is here to stay, and artificial intelligence in the cockpit is not that far into the future. It is time we start to redefine the role of the pilot.

a. More Flight Simulator Training

In a reversal of Boeing's long-held stance that computer-based training alone was adequate, the company has recommended that pilots receive additional flight simulator training before they allow the 737 MAX to return to the skies.[90] The previous position of Boeing and the FAA was that pilots who can fly older 737s can avoid time-consuming and costly training in simulators, and only needed a minimal hour-long course (completed on a tablet computer) in order to fly the MAX.[91]

b. Abnormal-Situation Training Simulations

Another possibility is improving training simulators in order to reproduce realistic scenarios of abnormal situations and recreate the effects of automation surprise, so pilots are prepared to face these phenomena on the job. This training would focus on helping pilots understand when to abandon the automated system and revert to manual flying.[92]

c. Mandate Manual Flying Training

Some scholars have called for an entirely new training process because the current process is generating less well-rounded pilots.[93] The European Aviation Safety Agency (EASA) performed a study that concluded that manual flying skills are declining due to lack of practice.[94] As stated *supra*, the FAA found in 2011 that 60 percent of 46 accidents resulted from human

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[89] Mark, *supra* note 59.

[90] David Koenig, *In a Reversal, Boeing Says Pilots Need Simulator Training Before 737 Max Returns to Skies*, CHICAGOTRIBUNE.COM (Jan. 7, 2020, 1:35 PM), www.chicagotribune.com/business/ct-biz-boeing-737-max-pilot-simulators-20200107-tyijydnyorgrdo7hw3aucpx5am-story.html.

[91] *Id.*

[92] Hiraki & Warnink, *supra* note 61.

[93] Karlene Kassner Petitt, Safety Culture, Training, Understanding, Aviation Passion: The Impact on Manual Flight and Operational Performance (Jan. 2019) (unpublished Ph.D. dissertation, Embry-Riddle Aeronautical University), https://commons.erau.edu/edt/436/.

[94] *See* EUR. AVIATION SAFETY AGENCY, EASA AUTOMATION POLICY: BRIDGING DESIGN AND TRAINING PRINCIPLES (May 28, 2013), https://www.easa.europa.eu/sites/default/files/dfu/sms-docs-EASp-SYS5.6---Automation-Policy---28-May-2013.pdf. *See also* EUR. AVIATION SAFETY AGENCY, EASA SAFETY INFORMATION BULLETIN: MANUAL FLIGHT TRAINING AND OPERATIONS, SIB No. 2013-05 (Apr. 23, 2013), https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiLotaV9oPoAhVGBs0KHceUC7oQFjAAegQIAhAB&url=https%3A%2F%2Fad.easa.europa.eu%2Fblob%2FSIB_201305_Manual_Flight_Training_and_Operations.pdf%2FSIB_2013-05_1&usg=AOvVaw0ULy__dmuSUkso4kuqTx2g.

error due to pilots who lacked proficiency in hand flying aircraft and the ability to handle automated controls.[95] The fix seems fairly simple: mandate manual flying training.[96]

d. More Automated System Training & Encouragement to Override Automation

The pilots of Lion Air Flight 610 and Ethiopian Airlines Flight 302 failed to control the aircraft after the MCAS system malfunctioned because they did not fully understand how the automated system functioned.[97] It has also been shown that the 2013 Asiana Airlines crash was caused by pilots over-relying on the automated system in the cockpit.[98] If pilots are given the training to understand automated systems and the problems that may occur, and they are adequately equipped to handle manual flying, we can potentially avoid tragedies like these crashes in the future.[99]

e. Enforcement and Regulation

In March of 2019, the FAA began enforcing a rule mandating that pilots practice how to handle stalls in flight simulators. The rule was enacted as a reaction to a 2009 accident but took six years to enforce after originally being introduced.[100] The FAA needs to be nimbler in addressing and enforcing issues pertaining to automation.[101]

Manufacturers like Boeing and Airbus are increasingly committed to automating flight and transferring control of the airplane from pilots to computer systems to prevent pilot error.[102] It is the job of the FAA to ensure that things don't go too far too fast without proper training. This issue has the potential to worsen as automation in the cockpit continues to expand with the development of artificial intelligence. NASA's Ames Research Center is currently developing aviation-related AI, and DARPA's Aircrew Labor In-Cockpit Automation System (ALIAS) project is expecting to perform its first zero-pilot test in 2020 with an unmanned Black Hawk helicopter.[103] Correcting the issues we are currently facing with automation is a must, but being forward-thinking about future technologies potentially exacerbating our current problems is something the FAA should keep in mind.

f. Simplifying Cockpit Design

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[95] *See Study: Automatic Pilot May Add to Flight Risk*, *supra* note 48.

[96] *Id.*

[97] Nicas & Wichter, *supra* note 66.

[98] Christopher A. Hart, Acting Chairman, Nat'l Transp. Safety Bd., Opening Statement, NTSB Board Meeting: Crash of Asiana Flight 214 (June 24, 2014) https://www.ntsb.gov/news/speeches/CHart/Pages/Hart_140624o.aspx.

[99] Press Release, Nat'l Transp. Safety Bd., *supra* note 68.

[100] *See* Qualification, Service, and Use of Crewmembers and Aircraft Dispatchers, 78 Fed. Reg. 67,800 (Nov. 12, 2013) (codified in scattered sections of 14 C.F.R. Part 121). *See also Air Carrier Training: Enhanced Pilot Training and Qualification Requirements*, FED. AVIATION ADMIN. (Mar. 12, 2019, 6:06 PM), https://www.faa.gov/pilots/training/air_carrier/enhanced_pilot_training/.

[101] Nicas & Wichter, *supra* note 66.

[102] Andy Pasztor & Andrew Tangel, *MAX Crashes Strengthen Resolve of Boeing to Automate Flight*, WALL ST. J. (Dec. 31, 2019, 5:20 PM), https://www.wsj.com/articles/max-crashes-strengthen-resolve-of-boeing-to-automate-flight-11577816304.

[103] Behr, *supra* note 39; Lauren C. Williams, *Aviation Automation Climbs New Heights with ALIAS*, FED. COMPUT. WK. (Apr. 17, 2019), https://fcw.com/articles/2019/04/17/darpa-alias-autonomous-aviation.aspx.

One final consideration is improving and simplifying current cockpit design. This potential solution was proposed in a 2012 study that suggested two choices: Pilot as Pilot and Pilot as Manager.[104] In the *Pilot as Pilot* approach, the cockpit design supports the pilots in their traditional role as pilots. The pilots would be actively involved in flight control and have complete jurisdiction and responsibility over the aircraft. The pilots manage the cockpit automation, and assign tasks to the automation, with the option to resume manual control over the plane as they see fit. A negative aspect of this option is the higher workload, which can result in cognitive fatigue, negatively influencing the ability of the pilots to perform in a complex environment.[105]

The *Pilot as Manager* approach, on the other hand, is where the pilots share responsibility with the automated system. Most flight tasks would be performed by cockpit automation and managed by the pilots. Cockpit automation would be responsible for a large amount of the aircraft control and information processing. One of the benefits of *Pilot as Manager* is that pilots will have more time to oversee other aspects of the flight because they are not encumbered with low-level manual tasks. A negative side effect of the *Pilot as Manager* design is that it may be difficult to keep the pilots engaged in the flying process.[106]

g. Monitoring Pilots' Attention via Artificial Intelligence

Advances in artificial intelligence have the potential to improve human-machine interaction. France's Man Machine Teaming (MMT) defense research program is using nonintrusive monitoring of a pilot's brain during flight to help the pilots better understand their own workload.[107]

In order to improve crew coordination, the MMT and the Neuroergonomics and Human Factors Department of ISAE Supaero, the French national higher institute of aeronautics and space engineering division, have been studying the brains of two people who cooperate while flying to determine whether they are coordinating well. Their experiments have led to the study of human-AI interaction and cooperation where a human pilot was not told when AI was replacing the other human participating. Analysis is ongoing, but results have shown promise. One possible outcome may be to design a communications system that switches over to AI if it notices poor cooperation or a poor mental state (e.g., cognitive overload).[108]

2. *Analogous Applications of Artificial Intelligence*

a. Addressing the Issues of Artificial Intelligence in Surgery

According to Patrick M. McCarthy, MD, the Executive Director at the Bluhm Cardiovascular Institute and Vice President of the Northwestern Medical Group, new surgeons starting their careers "with extensive open surgery [experience] . . . can fall back to the

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[104] Emmanuel Letsu-Dake et al., *Innovative Flight Deck Function Allocation Concepts for NextGen*, *in* ADVANCES IN HUMAN ASPECTS OF AVIATION 301, 304–10 (Steven J. Landry ed., 2012).

[105] Hiraki & Warnink, *supra* note 61.

[106] Letsu-Dake et al., *supra* note 104.

[107] Thierry Dubois, *Research on Brain Activity to Help Cockpit Design*, AVIATIONWEEK.COM (Jan. 23, 2020), https://aviationweek.com/aerospace/research-brain-activity-help-cockpit-design?utm_rid=CPEN1000000509608&utm_campaign=22915&utm_medium=email&elq2=214236a96af74998bb35581231f03245.

[108] *Id.*

conventional approach when/if needed . . . like pilots can still hand fly the planes when the systems aren't working well."[109] Surgeons who do not have extensive open surgery experience "will have to develop Plan B, C, D with new fallback positions" that other doctors have never had to consider.[110] This adoption will be "slow, methodical, [with] occasional big notable failures." Dr. McCarthy also warned that the next generation of surgeons may not be sufficiently well-trained to fall back on the conventional open surgery approach, much like "pilots who can't land on the Hudson."[111]

b. Addressing the Issues of Self-Driving Vehicles

Parallels can also be drawn between the autonomous vehicle deaths mentioned *supra* and the recent aviation tragedies surrounding the MCAS. The Tesla Model S driver in Florida had his hands on the wheel for only 25 seconds out of the 37 minutes the vehicle was in automated control mode, and the driver in the Arizona Uber crash had been glancing down at a telephone for over a third of the ride. This over-reliance on automation (e.g., automation bias, automation surprise, preoccupation, or underload) led these drivers to be less engaged and unable to respond to the situations at hand, which ultimately resulted in two deaths.

The fatal incidents involving autonomous vehicles demonstrate how dangerous the area between semi-automated driving and human oversight is. This has led Waymo and Ford to push for fully autonomous cars.[112] This is a big ask and is likely to go nowhere. More achievable ideas on how to make autonomous vehicles safer follow.

1. Monitoring Drivers' Attention via Facial-Recognition Technology

Several car companies, such as Subaru, have begun introducing facial-recognition technology to identify whether a driver is distracted. The technology uses an infrared sensor that collects and analyzes the driver's facial image, which performs driver identification (from memory), and identifies the specific driver. The sensor enables the software to determine if the driver is paying attention, and emits an audible beep when a driver is distracted or fatigued.[113]

2. Incident-Response Protocols

One way self-driving car companies can deal with safety issues is to develop incident-response protocols, including sharing data about collisions and other safety-related incidents. The data collected would be shared among autonomous car makers, government regulators,

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[109] E-mail from Patrick M. McCarthy, MD, Exec. Dir., Bluhm Cardiovascular Inst., V.P., Nw. Med. Grp., Chief, Div. of Cardiac Surgery, Heller-Sacks Professor of Surgery, Nw. Med., to Stephen B. Rudolph, Mgr., Air Transp. Pol'y Initiative, Chaddick Inst. for Metro. Dev., DePaul Univ. (May 19, 2019, 6:59 CDT).

[110] *Id.*

[111] *Id.* Not all artificial intelligence has had drawbacks in the health field. A study released in June 2019 shows that a new AI-enabled stethoscope can detect heart murmurs with 96 percent accuracy, while an office- or ER-based doctor may only be 50 percent accurate using a traditional stethoscope. Dr. McCarthy predicts that, eventually, all doctors will lose their skills with traditional stethoscopes and they will be using AI stethoscopes 100 percent of the time.

[112] WAYMO, WAYMO SAFETY REPORT: ON THE ROAD TO FULLY SELF-DRIVING (2017), https://assets.documentcloud.org/documents/4107762/Waymo-Safety-Report-2017.pdf; *Looking Further*, FORD.COM, https://corporate.ford.com/articles/products/autonomous-2021.html (last visited Feb. 18, 2020).

[113] Paul Weissler, *Subaru Introduces Facial-Recognition Technology to Identify Driver Distraction, Fatigue*, AUTONOMOUSVEHICLETECH.COM (Apr. 5, 2018), www.autonomousvehicletech.com/articles/857-subaru-introduces-facial-recognition-technology-to-identify-driver-distraction-fatigue.

academic research labs, and the public. The data would be analyzed and shared to enable all the companies to learn from each other's mistakes and become safer faster.[114]

3. Only Operate in Unambiguous Environments

Research shows that humans are poor at paying constant attention when they are driving and as the technology becomes more sophisticated, situations where human assistance is required are going to be more complex and difficult to diagnose. A possible fix is for automated systems to collect, classify, and respond to information in an unambiguous environment at first because autonomous car manufacturers cannot foresee every possible combination of conditions that will occur on the road (or even foresee whether or not their drivers are going to pay attention).[115]

4. Standardize Driving Environments

Autonomous vehicles have to navigate a shared environment consisting of pedestrians crossing the road, cyclists, animals, debris, inanimate objects, and bad weather. Further complicating matters are road infrastructure, regulations, and driving laws that vary from city to city. It would be very difficult to standardize the driving environment due to the fact that it is governed by many different regulatory bodies; however, standardizing driving environments would allow fewer moving parts for the vehicle to analyze and understand. As smarter infrastructure is constructed (radio transmitters replacing traffic signals, wireless data networks managing vehicle-to-vehicle and vehicle-to-infrastructure communication, as well as sensors supplying real-time weather and traffic data), we will begin to see more standardized environments.[116]

Conclusion

Although advances in the aviation sector have helped reduce airline fatalities by roughly a factor of two in every decade, the recent concerns surrounding automation in the cockpit – and the resulting tragedies – have demonstrated that new safety issues must be considered.

The global pilot shortage has forced airlines to hire pilots with less experience in the cockpit, and as more of the aviation industry's seasoned pilots age out of the profession, large airlines will continue to encourage a reliance on automation to accommodate less-experienced pilots.[117]

As indicated *supra*, the aviation industry has known since at least 1997 that automation is eroding piloting skills, with negative effects such as automation bias, automation surprise, absorption, fixation, preoccupation, and underload adding to a lack of situational awareness.[118] Compound this fact with a lack of manual flying skills and we have a recipe for disaster. Even

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[114] Jamie Williams & Peter Eckersley, *Some Easy Things We Could Do to Make All Autonomous Cars Safer*, ELEC. FRONTIER FOUND. (Mar. 29, 2018), www.eff.org/deeplinks/2018/03/some-easy-things-we-could-do-make-all-autonomous-cars-safer-faster.

[115] Keith Barry, *Too Much Safety Could Make Drivers Less Safe*, WIRED (July 27, 2011, 7:00 AM), www.wired.com/2011/07/active-safety-systems-could-create-passive-drivers/.

[116] Nick Oliver et al., *To Make Self-Driving Cars Safe, We Also Need Better Roads and Infrastructure*, HARV. BUS. REV. (Aug. 14, 2018), https://hbr.org/2018/08/to-make-self-driving-cars-safe-we-also-need-better-roads-and-infrastructure.

[117] Nicas & Wichter, *supra* note 66.

[118] Videotape: Automation Dependency: Children of the Magenta Line, *supra* note 70.

with this knowledge, and several reports documenting these concerns, the FAA has been slow to correct them.

A myth of automation is that "as the investment in automation increases, the investment needed in human expertise decreases."[119] This observation hits the nail on the head, and this paper has identified several ways to invest in human expertise as artificial intelligence and automation progress.

As stated *supra*, some of these investments should take the form of more flight simulator training, abnormal-situation training simulations, mandated manual flying training, more automated system training and encouragement to override automation, more enforcement and regulation by the FAA, simplifying cockpit design, and monitoring pilots' attention via artificial intelligence. These are all viable options that should be considered by the aviation industry and the FAA.

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[119] Mark, *supra* note 59 (quoting Dr. David Woods, Professor, Ohio State University, and technical advisor for the 1996 and 2013 FAA human-factors reports, cited *supra* at notes 52 and 71).