Failsafe? The Effect of Advanced Automation on Commercial Aviation Liability Law

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Abstract

"Look at you, hacker: a pathetic creature of meat and bone, panting and sweating as you run through my corridors. How can you challenge a perfect, immortal machine?"

— Ken Levine, System Shock 2 (1999).

Modern aviation is most arguably defined by the presence of automation in the cockpit. From the inception of jet transport, computers have been an omnipresent symbol of assurance against the certain uncertainty of human error. In the business of commercial aviation, computers are considered to be the first line of defense against risk. Major manufacturers, such as Boeing, Airbus, Bombardier, Embraer, Dassault, and Eclipse have updated the design of their most modern aircraft to include state-of-the-art computing systems and "fly-by-wire" technology under the guise that the computers always know best. However, pilot certification programs and the international regulatory laws that govern them must be equally revised to insure the human component — as the other side of the equation of modern day aviation — is always up to task.

Many of the most recent major accidents and incidents over the last three decades have been the result of automation errors or failures in human response to those errors. This thesis explores the effect automation and the incidents caused as a result thereof have had on the dissemination of liability amongst major aircraft manufactures, insurers, and airlines in the wake of such events. It also explores the effect, if any, these issues have had on products liability, aviation insurance, and private international air law. And lastly, this thesis suggests both regulatory and educational reforms the industry could adopt to reduce dangers associated with automation complacency[1] in hopes of eventually reducing or even eradicating such risk. Despite the threat of catastrophic litigation and demands by the public and leading regulatory authorities

[1] The references "automation over-dependence" and "automation complacency" are used interchangeably throughout this work.

for improvements in regulatory policy and laws, however, industry motivation to address problems with automation through specific improvements in training, technology and design continues to remain low; therefore creating a seminal question lingering amongst all members of the modern aviation industry: can the advanced complexity of automation ever be considered failsafe against the imperfection of man? This thesis sets out to explore this quandary.

RÉSEUMÉ

L’aviation moderne se caractérise sans aucun doute par l'automatisation des diverses opérations de la cabine de pilotage. Ainsi, depuis les débuts du transport aérien, les ordinateurs ont contribué à pallier aux possibles erreurs humaines. Dans le secteur de l'aviation commerciale, les ordinateurs sont considérés comme l’un des moyens de défense les plus efficaces face aux risques. D’importants manufacturiers tels que Boeing, Airbus, Bombardier, Embraer, Dassault et Eclipse conçoivent désormais leurs avions en y incluant les toutes dernières technologies informatiques et des systèmes de commandes de vol électriques, au motif que les ordinateurs sont plus efficaces. Toutefois, les programmes de certification des pilotes et les réglementations internationales qui les encadrent doivent également faire l’objet d’une révision afin d’assurer que la composante humaine, l’autre partie de l'équation de l'aviation moderne, puisse également être mise à jour.

Bon nombre des plus récents incidents et accidents majeurs dans le domaine de l’aviation au cours des trois dernières décennies ont été le résultat d'erreurs d'automatisation ou encore d’échecs dans la réponse humaine apportée à ces erreurs. Le présent mémoire abordera les conséquences de l'automatisation et les incidents provoqués par celle-ci quant à la responsabilité des grands manufacturiers, des assureurs et des transporteurs aériens à la suite de ces événements. De plus, ce mémoire étudiera également les effets, le cas échéant, que ces questions ont eu sur la responsabilité des produits, l'assurance dans le domaine de l’aviation ainsi que le droit international privé de l'aviation.

Enfin, ce mémoire suggère deux réformes à la fois règlementaire et éducationnelle pouvant être adoptées par l’industrie. Ces réformes permettraient de réduire les dangers associés à l'automatisation de complaisance, dans l'espoir de finalement réduire et possiblement même éradiquer ce risque. Malgré les menaces de poursuites et demandes répétées par les autorités

publiques réglementaires visant une révision des politiques et des lois dans ce domaine, les motivations du secteur privé à résoudre les problèmes d'automatisation par le biais notamment d'amélioration au niveau de la formation, de la technologie et de la conception demeurent faibles. Par conséquent, cela engendre une question fondamentale persistante entre tous les membres de l'industrie de l'aviation moderne: la complexité de l'automatisation pourrait-elle un jour être considérée comme infaillible face à l'erreur humaine? Ce mémoire se propose d'explorer ce dilemme.

CHAPTER ONE:
A Brief History of Advanced Automation in Commercial Aviation

The concept and definition of automation in any context — notwithstanding that of aviation — has been deceptive and enigmatic throughout history. According to aviation human factors consultant Antonio Chialastri,[2] "automation" is generally defined as, "the use of control systems and information technologies to reduce the need for human work in the production of goods and services."[3] Alternatively, the Oxford English Dictionary defines automation as: (1) automatic control of the manufacture of a product through a number of successive stages; (2) the application of automatic control to any branch of industry or science; and (3) by extension, the use of electronic or mechanical devices to replace human labor.[4] However, another plausible definition for automation better suited to aerospace is, "the technique of controlling an apparatus, a process or a system by means of electronic and/or mechanical devices that replaces the human organism in sensing, decision-making and deliberate output."[5]

In his book *Automation,* Chialastri asserts the presence of three definitive types of automation systems: mechanical, electrical, and electronic.[6] In the early pioneering days of aviation, innovators such as the Wright Brothers relied entirely upon direct mechanical connections between cockpit controls and the moving parts of an aircraft to actively control the plane. Basic systems consisting of cables and pulleys connected the control yoke and stick and rudder pedals of an aircraft to three primary control surfaces: the ailerons, elevator and rudder.

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[2] *See generally,* Antonio Chialastri, Automation, Ed by Florian Kongoli, ed, (Rijeka: InTech, 2012).
[3] Chialastri, *supra* n 2 79-80.
[4] *The Oxford English Dictionary*, (1989), *sub verbo* "automation."
[5] Chialastri, *supra* n 2 at 79-80 (citing *The Oxford English Dictionary*, 1981, *sub verbo* "automation").
[6] *Ibid* at 85.

Rudimentary piston engines with fixed-pitch propellers fitted to early aircraft required only mechanical throttle, fuel mixture and carburetor heat controls to maintain thrust — establishing mechanical failure of the airplane structure or engine as the main concern for first generation pilots during flight.[7]

During the formative years of commercial aviation there were no instrumental aids available to help pilots fly. A piece of string attached to the wing to indicate airflow was the only gauge a pilot had to determine whether sufficient air lift existed to sustain an airplane in flight. Altimeters and anemometers, both of which became crucial instruments to measure altitude and airspeed, were introduced a few years later as the first steps to aiding the pilot in "virtualization of the flight environment."[8] Later on, the addition of pneumatic gyroscopes (replaced shortly thereafter by the electric gyroscope) created an artificial horizon to help pilots understand and stabilize the environment around them. The gyroscopes could also be used in meteorological conditions of extremely poor visibility, to help guide aircraft through dangerous weather and to prevent pilots from developing vestibular illusion (a false sense of equilibrium in the inner ear).[9]

In the 1950s and 60s the aviation industry's main safety concern shifted to issues with "human factors" (also known as ergonomics) — or the study of how humans behave physically and psychologically in relation to particular environments, products, or services.[10] The immediate cause of such accidents was often found to be "active failures," — e.g. the loss of control of an aircraft due to the pilot's failure to maintain adequate control in a specific situation,

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[7] "Automation in Aircraft: The Changing Role of the Pilot," online: *HubPages* <http://flyingvet.hubpages.com/hub/Automation-in-aircraft-the-changing-role-of-the-pilot>.
[8] Chialastri, *supra* n 2 at 85 (citing Ralli, M. (1993), *Fattore umano ed operazioni di volo,* Libereria dell'orologio, Roma).
[9] *Ibid* at 85.
[10] Margaret Rose, "Human Factors (ergonomics)" Definition, *Searchsoa.techtarget.com*, online: <www.searchsoa.techtarget.com/definition/human-factors>.

such as reaching aircraft over-speed limits, aerodynamic stalling, excessive bank angles, and other potential threats.[11] However, many such errors were eradicated or at least vastly improved by the introduction and utilization of early stabilization systems — also known as autopilots — capable of stabilizing aircraft altitude and motions through constant mechanical manipulation of flight controls.[12]

Although autopilot stabilization was not introduced on a widespread scale into commercial aviation until the jet age of the1950s and 60s, the concept of automation at that time was not entirely new. Early signs of automation (also known as "first generation" autopilots) were introduced on board aircraft as early as the 1920s and 30s, based upon rudimentary mechanical engineering concepts designed to simply keep the plane flying straight.[13] Later iterations based upon electric devices replacing mechanical systems (or "second generation" autopilots) such as VOR (or Very High Frequency Omni-Directional Range) navigational systems followed tracks based upon ground aids,[14] or the more advanced ILS (Instrument Landing System), which follows a horizontal and vertical path based upon radio localizer signals until the aircraft intercepts the runway threshold.[15] Such automation systems were further improved by the introduction of auto-throttle technology, flight directors, airborne weather

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[11] Chialastri, *supra* n 2 at 81.
[12] Manningham, Dan, "The Cockpit: A Brief History" (1997) 80 No. 6 Business & Commercial Aviation, 36.
[13] For more information on "first generation" automation systems and the specific technology behind them *see* Chialastri, *supra* n 2 at 85.
[14] *See* "Very High Frequency Omni-Directional Range," *U.S. Federal Aviation Administration*, online: <www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gbng/vor/>.
[15] *See* "Introduction — Instrument Landing System," *Landing Systems* (2015), online: <http://instrument.landingsystem.com>.

radars, navigation instruments, inertial platforms and improved alarming and detection systems capable of monitoring several engines or other instrument parameters.[16]

Today, after more than 80 years of constant evolution,[17] cockpit automation has progressed to the point of permanently altering the primary role of aircraft commanders. In the beginning, pilots were active and manipulated the airplane through direct, mechanical systems. Due to these changes in automation, pilots have evolved into passive complex system operators in charge of constant computer system and sub-system monitoring, essentially altering the definition of commercial aircraft piloting forever.[18]

As the complexity of aircraft grew and reliable computer systems became more available, aircraft manufacturers began to incorporate increasing levels of automation into their designs. Today, automation in aviation is ubiquitous throughout all types of modern aircraft, and is organized into three distinct categories. The first category is "control automation," or automation

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[16] Chialastri, *supra* n 2 at 85.
[17] The evolution of automation began in airplanes of the late 1920s and early 30s with systems mainly characterized by four stages. The first stage, or autopilot stage, encompasses the ability of the pilot to assign, and the automation to perform specific tasks to the autopilot, becoming the first step in separation of the pilot from direct authority over the airplane. This results in the masking of basic feedback cues, such as control feel and airplane response time. The second stage, or controller stage feeds information to the autopilot using either general altitude or navigation information or rate of descent commands. In this stage of automation, the pilot must program and monitor controllers to ensure the correct commands are sent to the autopilot, and in turn, to monitor the autopilot to ensure its correct operation. The majority of first and second-generation jet aircraft have employed second level automation beginning in the mid-to-late 1960s and 70s up until today. The third level of automation is characterized as the Flight Management Computer or System (or FMC/S), which must be programmed by the pilot to instruct the second level controllers to transmit instructions to the autopilot flying the plane. The fourth level of automation combines the FMC with other plane systems such as fuel and environmental controls to allow effective control of the entire airplane by an advanced FMC. The fifth and final level of automation will potentially allow for partial, or eventually complete control of the airplane by external authorities, such as air traffic control. *See* Manningham, *supra* n 12 at 59. For a discussion of such "fully automated" aircraft *see* Chapter 4, *infra* at 104.
[18] *See ibid* at 58.

whose functions are the control and direction of the plane.[19] Examples of such technology are FADEC (Full Authority Digital Engine Control) engine control systems,[20] fly-by-wire electronic movement of the airplane's control surfaces,[21] and other state-of-the-art navigation and autopilot systems capable of landing aircraft with little to no pilot intervention whatsoever other than manual control of flaps and lowering of landing gear.[22]

The second category is "information automation," or automation devoted to the calculation, management and presentation of relevant information to flight crewmembers. Examples of information automation include crew alerting systems, such as integrated caution and warning systems like Terrain Awareness and Warning Systems (TAWS), and integrated flight deck displays (such as moving map displays and Heads-up Displays (HUD)) — all of which affect pilot management of the airplane's flight path.[23] Additionally, information automation can include advanced alerting systems to alert pilots to various abnormal system or operational conditions and systems that change display characteristics in real-time based upon assessments of current aircraft situations, such as electronic navigational charts.[24] The third and

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[19] Federal Aviation Administration (FAA), "Operational Use of Flight Path Management Systems — Final Report of the Performance-Based Operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group" (5 September, 2012), 52.

[20] *See* "FADEC Electronic Engine Control, Engine Control Systems," *UTC Aerospace Systems*, online: <http://utcaerospacesystems.com/cap/products/Pages/fadec-engine-electronic-controller.aspx>.

[21] *See* "Digital Fly By Wire: Aircraft Flight Control Comes of Age," National Aeronautics and Space Administration (NASA) (17 December, 2003), online: < www.nasa.gov/vision/earth/improvingflight/fly_by_wire.html>.

[22] *See* "Automation in Aircraft, *supra* n 7. Indeed, at some point aircraft automation could also potentially be capable of lowering landing gear and appropriately controlling aircraft flaps.

[23] *See* FAA Operational Flight Path Systems Report, *supra* n 19 at 52.

[24] *Ibid*.

final category of automation is "management automation," or automation of aircraft management tasks, such as automatic aircraft pressurization monitoring and selective cabin temperature and humidity control.[25]

With the incorporation of such technologies into modern aircraft, aircraft operators and manufacturers have begun to study how integration of all three categories of automation can be purposefully combined to optimize and control all aspects of aircraft operations. For instance, with regards to pilot action and decision-making capabilities, automation is specifically advantageous because it allows for the augmentation or replacement of flawed human decision-making processes with the more predictably reliable logic of a machine. Operators and manufacturers justify the utilization of such automation because of the generally universal conclusion that human logic can be undeniably flawed and subject to several errors, among them an aversion to algorithmic thinking, a tendency towards confirmation bias, inability to grasp sufficient understanding of complex systems, and heavy influence by emotional, rather than rational thought.[26] Therefore, automation is necessary to protect against such human errors.

Automation also has pronounced economic and safety benefits, in that it has allowed for tremendous advancements in fuel savings, enhanced aircraft reliability, simplification and ease in aircraft maintenance and support, reduction in the number of required crew members in the cockpit, and in overall cockpit crew training time.[27] Because of these advantages, the aviation industry became an early forerunner in incorporating the technologies afforded by the 20th century computer revolution. By quickly incorporating such improvements and more, both

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[25] *Ibid*.
[26] Chialastri, *supra* n 2 at 80.
[27] Amalberti, R., "Automation in Aviation: A human factors perspective, in D.Garland, J.Wise & D. Hopkin, eds *Aviation Human Factors*, (Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1998) 173-192.

operators and manufacturers alike have reaped a multitude of benefits afforded via automation through increased levels of aircraft reliability, better economics and improved operational accuracy of onboard controls.[28]

One of most pronounced improvements of automation, however, is the diminution, or the eventual elimination of safety threats related to pilot error. Because of their biology, human pilots can be susceptible to diminishing performance during flight due to fatigue, lapses in attention, distraction and other issues — such as emotional and cognitive impairment — thus rendering them less reliable and more apt to committing errors than machines.[29] To alleviate these risks, automation has played an important role in the advancement of aviation technology to allow for the augmentation, and in some segments of flight, the total replacement of human performance in the cockpit.

Because of the significant advantages computer-controlled automation provides in precision and efficiency, as well, systems such as autopilots and auto-throttles (which later evolved into thrust computers such as FADEC) have gradually replaced the need for "hand-flying" the aircraft for a majority of the flight.[30] In general terms, an autopilot can tolerate

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[28]For example, one of the most revolutionary manifestations of automation in commercial aviation was the introduction of the quad engine, wide-body Boeing 747-400 in 1988 to serve as a replacement of the original, or "classic" 747-100, 200 and 300 series. The 747-400 was particularly noteworthy for essentially rendering the role of flight engineers in a cockpit crew obsolete, therefore reducing the minimum number of required flight crew from three (Captain, First Officer and Flight Engineer) to two (Captain and First Officer). Boeing was able to do this by employing automation to monitor and display the status of a number of on board systems and monitors — originally displayed by use of numerous analogue "steam" gauges normally oversaw by the Flight Engineer — to digital electronic liquid crystal (LED) displays, capable of incorporating several manual functions into automatic sequences, effectively reducing the original number of dials, gauges and knobs in the classic 747 from 1000 down to 365 in the 747-400.

[29] *See* "Automation in Aircraft," *supra* n 7.

[30] *See* FAA Operational Flight Path Systems Report, *supra* n 19 at 11.

workloads significantly more demanding than a human operator. In order to ensure the smoothest and safest flight possible for passengers, autopilots can actively manage thousands of minute manipulations and adjustments in altitude, speed, and heading within milliseconds, while other types of automation, such as management automation, simultaneously work to monitor airplane status and other tasks. All of these systems work together to replace onerous, repetitive and demanding tasks that would otherwise run the risk of fatiguing the pilot, thus improving safety by safeguarding passengers from potential human error.

Regardless of increased safety, efficiency and other benefits afforded to the aviation industry by automation, the incorporation of such technology has not been without risk. While aviation was in its infancy and automation was not largely used, human performance was potentially impaired by "under-redundancy" — the insufficiency of aids available to help pilots avoid the effects of pernicious factors such as fatigue, distraction, over-abundant workloads and undue stress which may reduce pilot performance. Now, after the implementation of automation and subsequent reduction of these manual tasks, aviation experts warn that the effects of "over-redundancy" are the aviation industry's newest threat.

Over-redundancy occurs when the level of automation employed in the cockpit is so extensive that it ostensibly removes the pilot from engagement with the majority of the processes completed by computers flying the plane. Removal of human engagement is ill-advised because it induces risks such as reduced pilot situational awareness and automation complacency[31] —

[31] "Automation complacency," or "automation dependence" occurs when a pilot over-relies on and excessively trusts system automation, and subsequently fails to exercise his or her vigilance and/or supervisory duties in the cockpit. *See* Hemant Bhana, "By the Book: Good Written Guidance and Procedures Reduce Pilots' Dependence on Automation," *AeroSafety World* (March 2010), online: <http://flightsafety.org/asq/mar10/asw_mar10_p47-51.pef?dl=1> (citing R. Parasuraman and V. Riley, "Humans and Automation: Use, Misuse, Disuse, Abuse," *Human Factors* 39:230-253).

causing both false confidence, and the loss of basic piloting skills — due to a lack of vigilance or failure to practice manual flight operations, since neither is specifically required to maintain a modern plane in flight. In turn, these dangers manifest themselves in situations where over-redundancy renders pilots either incapable of regaining control of an aircraft once automation has failed, or incapable of effectively monitoring the performance of automated systems in scenarios where the automation itself cannot be trusted or controlled.[32]

Although the introduction of advanced automation into commercial airplanes has continued to increase, there has been little change in commercial pilot training or manufacturer design to account for changes necessitated since automation's initial release. This has led to several problems in ensuring pilot proficiency in such automation systems incorporated into aircraft design — ultimately exacerbating automation's already palpable risks. Despite humble beginnings based upon good intentions to protect passengers and pilots from inevitable human fallibility, as automation and the use of airplanes in which it was incorporated grew and became more complex, so too did the problems accompanying it. Now, with a majority of recent major accidents and incidents being attributed to problems related to human interfacing with computer automation, the issues facing the aviation industry related to automation dependency and over-redundancy are more prevalent and challenging than they have ever been before.

[32] *See* Chialastri, *supra* n 2 at 82.

<u>Chapter Two</u>:
The Effect of Advanced Aviation: Reaping the Benefits of Increased Cockpit Efficiency or Sowing the Seeds for Automation Over-Dependence?

As discussed in Chapter 1, one way in which automation has majorly effected modern commercial aviation is by its permanent alteration of the aircraft pilot's role from "performer" to "onlooker."[33] Gone are the days in which commercial pilots actively manipulated the flight controls to achieve a desired end (or destination). In their place, commercial pilots have instead become computer system operators, whose primary responsibilities are now oriented towards flight management control and computer programming. As a result, pilots have been forced to trade intimate knowledge of mechanical aircraft systems for more procedural and standardized airplane interactions required for optimum automation control. For example, pilots with pre-automation backgrounds from the "Pioneering/Golden Boys" days of aviation placed the greatest emphasis on actual piloting skills in training, in order to prepare for the very real possibility at that time that a pilot could experience a major emergency during flight.[34] Such pilots flew a variety of aircraft types, and spent little time in simulators, which, were too rudimentary to offer productive instruction to pilots in that era.[35]

As pilots began to be trained alongside the development of automated cockpit environments; however, emphasis from actual piloting abilities and "hero readiness" in case of

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33 "Automation in aviation, "*Aviation Knowledge*, online: <http://aviationknowledge.wikidot.com/aviation:automation>. *See also* Chapter One, *supra* at 11.

34 Max Scheck, "Training and Management of Pilots across Generations," *International Journal of Business and Social Science* (February 2012) 3:3 at 137, 144 (discussing the defining characteristics and specific attributes of varying piloting generations. For more information on the "Pioneering Days" and "Golden Boys" eras of aviation, *see ibid* at 143-44 and 144-45, respectively).

35 *Ibid* at 146.

unexpected technical failures[36] shifted to that of becoming observational team players, programmed to maintain uniformity and strict adherence to airline guidelines executing automation policies during flight.[37] This new generation of pilots were also schooled in new concepts such as human factors and "Crew Resource Management" (CRM) [38] — the importance of which only became greater with the continued inclusion of advanced automation. These pilots typically trained in fewer aircraft types than their predecessors and experienced most every type of major flight anomaly almost exclusively in simulators, allowing them to go the majority of their careers without a major emergency in flight, due to major improvements in aircraft technology and reliability.[39] Alternatively, these pilots spent a great deal of time training to become "system managers" — constantly striving for system optimization and maximum aircraft efficiency.[40]

Because automation processes have allowed aircraft to become inherently safe, and due to major changes in industry economics over the last thirty-five years, system optimization and aircraft efficiency have become pilots' main focus during flight. These changes in procedure and

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[36] *See ibid* at 145. ("[Indeed][t]he image of the pilot in this era was almost that of a superman who could handle any situation calmly, and afterwards enjoy a cocktail with you at the bar as if nothing had happened.").

[37] *Ibid* at 146.

[38] Crew (or Cockpit) Resource Management (CRM) training originated from a NASA workshop in 1979 that focused on improving air safety. The NASA research presented at this meeting found that the primary cause of the majority of aviation accidents was human error, and that the main problems were failures of interpersonal communication, leadership, and decision-making in the cockpit. CRM training encompasses a wide range of knowledge, skills and attitudes including communications, situational awareness, problem solving, decision-making, and teamwork, together with all the attendant sub-disciplines which each of these areas entails. Thus, CRM can be defined as a management system that makes optimum use of all available resources — equipment, procedures and people — to promote safety and enhance the efficiency of flight operations. *See Introduction — Crew Resource Management – Human Factors for Pilots*, online: <www.crewresourcemanagement.net/introduction>.

[39] *See* Scheck, *supra* n 34 at 147.

[40] *Ibid*.

training emphasis were somewhat the result of the “Deregulation Era,” which oversaw a seismic shift in industry prerogatives from that of delivering the most out of the total aviation experience to a select few capable of affording the ticket price to that of an unlimited travel opportunity readily available to the masses at much more reasonable prices. Airline deregulation also meant the removal of all government-imposed entry and price regulations forced upon airlines.[41] In the United States, deregulation began with the Airline Deregulation Act of 1978.[42] Deregulation is viewed as a watershed moment in aviation history in which the U.S. Civil Aeronautics Board (CAB) was sunset and absorbed by the larger U.S. Department of Transporation,[43] leaving airlines to self-regulate fares and establish their own route structures.[44] Deregulation was the specific brainchild of Cornell University economist Alfred E. Kahn, who was appointed by then-President Jimmy Carter to lead the soon-defunct CAB to its own demise.[45] Although originally intended as a plan to stimulate the airline industry by stirring competition so as to encourage lower fares, deregulation had several unforeseen consequences that permanently changed the way U.S. airlines operated both at home and abroad.

Before elimination of the CAB, airlines were constrained to compete only with regards to aircraft food, cabin crew quality, capacity, and route frequency, and aircraft, leaving virtually all other operating decisions and investment to be determined under the authority of the

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[41] *See* Paul S. Dempsey and Lawrence E. Gesell, *Public Policy and the Regulation of Commercial Aviation* (Chandler, AZ: Coast Aire Publications, 2013), 99.
[42] Pub. L. 95-504; 49 U.S.C. 1371 et seq.
[43] The U.S. Civil Aeronautics Board was officially phased out under the U.S. Civil Aeronautics Board Sunset Act on December 31, 1984. *See* 98 Stat. 1703 (1984).
[44] “Deregulation: A Watershed Moment,” *America By Air, Smithsonian National Air & Space Museum*, online: <https://airandspace.si.edu/exhibitions/america-by-air/online/jetage/jetage08.cfm>.
[45] *Ibid*.

government.[46] Under CAB regulation, fares and frequency were high, while load factors — the percentage of the seats that were filled — were low. In fact, the average load factors in the 1970s hovered just around 50 percent.[47] Today, fares are much lower because airlines are forced to compete based almost entirely on seat price, rendering the air transport market remarkably different today than it was in the past. Because of lower prices, more people can purchase tickets to travel by air then ever before, increasing load factors by as much as 86 percent in 2014.[48]

Secondary effects have also materialized from deregulation, such as the creation of low cost carrier airlines (or LCCs)[49] and utilization of a "hub-and-spoke" route distribution paradigm — a system whereby airlines offer service from a collection of origination cities to select destination points, or "hubs." The hub-and-spoke system is mainly utilized by "legacy carriers," defined as airlines with established interstate routes before route liberalization was permitted by the Airline Deregulation Act in 1978 — as opposed to a "point-to-point" system utilized by LCCs.[50] Deregulation also led to the creation of highly complex pricing models optimized via

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[46] Fred Smith Jr. and Braden Cox, "Airline Deregulation," *The Concise Encyclopaedia of Economics, Library of Economics and Liberty*, online: <www.econlib.org/library/Enc/AirlineDeregulation.html>.
[47] *Ibid.*
[48] *See* Teresa Cederholm, "Must-know: Why airlines should improve their load factor," *Market Realist* (15 September, 2014), online: <marketrealist.com/2014/09/must-know-airlins-improve-load-factor/>.
[49] A Low Cost Carrier is defined as an airline which operates a point-to-point network, pays workers below the industry average wage and offers no frills service (i.e. transportation from Point A to Point B by air with very little, if any variation in levels of class, service, basic amenities — such as water and lavatory access — and an overall emphasis on lower fare price). *See* Charles Nadja, "Low Cost Carriers and Low Fares: Competition and Concentration in the U.S. Airline Industry" (12 May, 2003) Stanford University Department of Economics, 8, online: <https://economics.stanford.edu/files/Theses/Theses_2003/Najda.pdf>.
[50] *See* Smith and Cox, *supra* n 46. For more information on the utilization of the "point-to-point" system versus the "hub-and-spoke" system *see* Gerald N. Cook and Jeremy Goodwin, "Airline Networks: A Comparison of Hub-and-Spoke and Point-to-Point Systems, *Journal of Aviation/Aerospace Education* & Research (Winter 2008) 17:2 Article 1.

exclusive computer reservation systems (or CRS)[51] linked to online travel search engines such as Expedia.com and Travelocity.com.

The increase in passenger traffic has not been exclusively advantageous for the airline industry however, which has suffered tremendous post-deregulation financial distress, especially in the global post-economic recessionary environment following the events of September 11, 2001. As traffic increased, so did the pressure on airlines to provide lower fares to remain competitive. As a result, airlines began to do what they could to cut costs — such as focusing on operations management so as to increase aircraft and crew utilization, reduce technical engineering department sizes, and minimize pilot training costs.[52] In addition to intensely focusing upon operational efficiency, airlines also began making adjustments to business overhead expenses, including employee contracts and crew salaries.[53] Some of the hardest hit were pilots, who experienced the most contract concessions of any group during company restructurings, and suffered significant reductions in salary in the years following deregulation than they had ever before, even though U.S. airlines had hired a record 8,000 pilots in 1985 — seven years after deregulation was imposed.[54]

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[51] For more information on automated airline booking computer systems developed exclusively for the airline industry *see* Jae Allen, "About Airline Reservation Systems," *USA Today*, online: < http://traveltips.usatoday.com/airline-reservation-systems-62595.html>.

[52] Federal Aviation Administration (FAA), "Operational Use of Flight Path Management Systems — Final Report of the Performance-Based Operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group" (5 September, 2012), 33.

[53] Steven Morrison & Clifford Winston, *The economic effects of airline deregulation*, Studies in the regulation of economic activity (Washington, D.C: Brookings Institution, 1986), 46.

[54] *See ibid.* at 47 ("Pilot's real income in 1984 was lower than it was in both 1975 and 1980.").

This high demand for pilots, combined with lower salaries, drastically began to change the draw and appeal of piloting as a profession. Prior to deregulation, most pilots came from military backgrounds, completing the training and requisite flight hours to earn commercial licenses through a highly regimented and disciplined regime.[55] Once comfortably entrenched as a professional pilot on a legacy carrier, these pilots enjoyed higher salaries and lower work hours, while also benefiting from a unique sense of status and prestige associated with commercial airline piloting at the time.[56] But since deregulation, the perception and status of airline pilots has changed, as airlines drew potential candidates from more collegiate backgrounds, offering cadets the ability to train for a career in commercial piloting via a number of alternate avenues in addition to a military career.[57]

Some programs, labeled as "*ab initio* training" programs allow candidates from a non-military background interested in becoming corporate or commercial pilots an opportunity to initiate their career and complete their flight training as a cadet in an exclusive training program under the direction of an airline.[58] Typically, *ab initio* flight training involves less actual flight hours, but a more structured and complex overall training scheme.[59] This new generation of trainees are expected to bring higher levels of computer skills, with most demonstrating an acceptable level of computer aptitude suited for advanced flight operations and automation

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[55] *See* Scheck, *supra* n 34 at 145.
[56] *Ibid.* For a specific discussion and examples of the status and prestige enjoyed by commercial airline pilots prior to deregulation *see* Endr Klein, "Come Fly With Me — The Story of Pan American Airlines" (10 April, 2014), online YouTube < https://www.youtube.com/watch?v=6Gs4koOS-WA>.
[57] *Ibid.* Up until the period following Deregulation, a majority of pilots and pilot cadets came almost exclusively from military or other specific public service backgrounds. *See* Scheck, *supra* n 34 at 144.
[58] For more on *ab initio* training *see* "Ab initio training — from the beginning," Aircraft Owners and Pilots Association, online: <www.aopa.org/asf/publications/inst_reports2.cfm?article=132>.
[59] *See* Scheck, *supra* n 34 at 137.

tools.[60]As a result, many *ab initio* pilots graduate flight training with more computer operation skills and less overall flying experience — a complication that has been blamed for rendering newer pilots more reliant upon advanced aircraft automation — especially in scenarios where new pilots might be insecure about their level of experience and overall piloting skills. This concern is heightened even more in pilots training for positions in high demand and high growth regions such as Europe and Asia,[61] in that such trainees and entry-level pilots are perceived to have less overall aeronautical flight experience than their American or European counterparts.[62]

In addition to changes in pilot compensation, airlines have also looked to automation as a way to maximize operational efficiency. As well as eliminating the number of required crew positions in the cockpit,[63] automation also allows for increased passenger comfort, improvements in flight path control, and reduction in weather disruptions.[64] It also allows for systems monitoring displays coupled with diagnostic assistance systems.[65] Because humans are not optimally-suited for highly repetitive or non-rewarding tasks,[66] automation can relieve pilots from having to perform such actions; however, pilots forced to monitor automation exclusively

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[60] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 36.
[61] *See* "Passenger Demand Maintains Historic Growth Rates in 2013," *International Air Transport Association* (IATA) (6 February, 2014), online: <www.iata.org/pressroom/pr/Pages/2014-02-06-01.aspx>.
[62] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 34; *see also* Interview with Earl F. Weener, PhD on 17 November, 2015. Mr. Weener is an aerospace engineer and active member of the U.S. National Transportation Safety Board, which investigates aviation incidents and accidents around the world. He is also a consultant and fellow to the Flight Safety Board, working to reduce accidents through coordinated industry approaches.
[63] *See* Chapter 1, *supra* n 28.
[64] "Cockpit Automation — Advantages and Safety Challenges," Skybrary.aero, online: <www.skybrary.aero/index.php/Cockpit_Automation_-_Advantages_and_Safety_Challenges>.
[65] Such diagnostic assistance systems include Electronic Centralized Aircraft Monitor (or ECAM) and Engine-indicating and crew-alerting system (or EICAS). For more information *see* Alexander T. Wells and Clarence C. Rodrigues, *Commercial aviation safety*, 4th ed. (McGraw-Hill Professional: 2004), 245.
[66] *See* Chapter 1, *supra* at 13.

could be problematic in that they are poorly suited for such roles due to perceived risks of boredom and possible lapses of attention after long periods of time.[67]

Automation also offers great advances in fuel burn and power plant efficiency to lessen the impact of commercial airplanes on the environment. As a result, airlines have retired older, less efficient aircraft without modern automation systems and fuel-saving technology.[68] Fuel is one of the most costly budgeted items of airline operations and oil prices historically have been volatile.[69] Increased public attention has been focused upon the nefarious effects of greenhouse gasses emitted by jet engines. Thus, logically there is a direct link between reduced fuel consumption, reduced cost, and enhanced environmental performance of aircraft.[70] Because engine-monitoring automation plays a crucial role in lessoning fuel burn in modern jet engines, such technology plays a crucial part in diminishing total airline expenditures on and the environmental impacts of jet fuel.[71]

To ensure they reap the optimum benefits of automated technology and save the most possible fuel, airlines (and the manufacturers selling to them) have instated policies to ensure

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[67] Liu, Kuo Kuang, "The Highly Automated Airplane: It's Impact on Aviation Safety and an Analysis of Training Philsophy" (1997), 30 (citing T.A. Demosethenes & J.G. Oliver, "Design principles for commercial transport aircraft: A pilot's perspective," (1989) SAE Technical Paper 892375 doi:10.4271/892375)).
[68] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 33.
[69] Air Transport Action Group, *Beginners Guide to Aviation Efficiency* (November, 2010) at 5, online: < www.atag.org/component/downloads/downloads/59.html>.
[70] *Ibid.*
[71] Other technological advancements, such as the elimination of aerodynamic drag, reductions in component weight, and increases in aircraft ability for high altitude flight also contribute to fuel efficiency. For more information on modern engine management technology and other advances in fuel conservation in the airline industry *see* "The future of flight: Changes in the air," *The Economist* (3 September, 2011), Technological Quarterly: Q3 2011, online: <www.economist.com/node/21527035>; "How Some Airlines Are Striving Toward Sustainability," *Responsible Travel Report*, the Online Magazine of Sustainable Travel International, online: <www.responsibletravelreport.com/component/content/article/2648-how-some-airlines-are-striving-toward-sustainability>.

pilots operating advanced automation technology utilize it to the fullest extent. Therefore, in order to maximize benefits, the periods in which pilots do not engage full automation assistance must be minimized, as human beings are not capable of discerning and executing the millions of minute and timely adjustments necessary to fly the aircraft as efficiently as possible.[72] Automation is also preferred in that it eliminates the possibility of human error in common operations, thus theoretically rendering automated flight safer than that of human-controlled flight.[73]

Another justification for automation came with the transition from classic flight instruments and ground-based navigation aids to modern flight decks built around the "glass cockpit" design of the early 1980s introduced in the Boeing 757, 767 and the Airbus A320.[74] These airplane types incorporated navigational flight guidance systems based upon ILS technology,[75] with the addition of flight management systems integrated with auto flight and auto throttle control.[76] As time passed, airplanes became even more advanced, eventually evolving to the point of including computer systems capable of maintaining "complete" aircraft management, based upon a litany of "sub" systems — including control, informational, and

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[72] *See* "Autopilot in Aeroplanes reduce fuel consumption," *University of Portsmouth School of Engineering* (3 January, 2009), online: <http://mosaic.cnfolio.com/B101CW2008B133>.; *see also*, International Civil Aviation Organization, *2010 ICAO Environmental Report: Chapter 2 — Aircraft Technology Improvements*, online: < www.icao.int/environmental-protection/Documents/EnvironmentReport-2010/ICAO_EnvReport10-Ch2_en.pdf>; the minimization of pilot interference with automation is also discussed as necessitated by new standardizations of modern air traffic control procedures, such as the utilization of Reduced Vertical Separation Minimum (RVSM) airspace, explained *infra* in Chapter 3 at 85.

[73] *See* Chapter 1, *supra* at 13; Tom Meltzer, "Why its probably safer if your pilot is asleep than awake," *The Guardian* (27 September, 2013), online: <www.theguardian.com/world/shortcuts/2013/sep/27/safer-pilot-asleep-awake-autopilot>.

[74] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 38.

[75] *See* ILS technology discussed *supra* in Chapter 1 at 10.

[76] *Ibid*; *see also* Chapter 1 n 17.

management automation[77] — each tasked with a different aspect of flight: such as radio-based navigation, engine/thrust control and altitude maintenance. Over time, the scope of flight operations, together with the growing complexity of airspace, navigational procedures and automated controls has resulted in a corresponding increase in the set of required skills and specialized knowledge pilots must have to operate today's modern aircraft.[78]

This increased emphasis on automation utilization and pilots as system operators has had several consequences, however, eliciting criticism that it has caused aviation to become too "impersonal, generalized, and group-oriented."[79] Although technology has played an important role in improving pilot productivity and safeguarding against human fallibility whilst increasing overall safety and aircraft efficiency,[80] with increased automation utilization comes also increased potential for unwanted actions and uncommanded maneuvers by computers on the plane.[81] Thus, the combination of a dispassionate, impersonalized training orientation, along with the possibility of unanticipated actions or misunderstood computer processes becomes a recipe for impending disaster, exposing the dark side of automation as an unknown factor in an increasingly complex machine.

I. From "Performer" to "Onlooker" and Differences in Automation Philosophy

[77] *See* Chapter 1, *supra* at 11-13.
[78] *Ibid.*
[79] *See* Kuo Kuang, *supra* n 67 at 30 (citing T.A. Demosethenes & J.G. Oliver, "Design principles for commercial transport aircraft: A pilot's perspective," (1989) SAE Technical Paper 892375 doi:10.4271/892375)).
[80] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 3.

[81] *See* "Automation in Aircraft: The Changing Role of the Pilot," online: *HubPages* <http://flyingvet.hubpages.com/hub/Automation-in-aircraft-the-changing-role-of-the-pilot>.

Although the evolution of the commercial pilot's role from "performer" to "onlooker" is undisputed throughout the aviation industry, the reason why this change is of any consequence is a subject of great debate. As said by Captain Heino Caesar of Lufthansa, "For the first time in aviation history, pilots no longer ha[ve] undisputed and direct access to the flight controls of the aircraft, but [are] dependent upon what the construction engineers programmed into the software."[82] There are a number of automation systems and modern technologies that some claim has culminated in the ultimate removal of the pilot from the flight control process. One of the systems most often criticized for this removal is "fly-by-wire" technology currently in use in both commercial and military planes.[83]

First demonstrated in 1957 in the Boulton Paul Tay-Viscount,[84] and again in the Avro 707 from 1960 to 1966,[85] fly-by-wire technology works by replacing the direct mechanical connection between the pilot's controls and the aircraft's control surfaces with an electronic interface. This interface then interprets the pilot's control inputs and translates them into electronic signals that, in turn, cause hydraulic actuators to move the control surfaces as commanded.[86] Particularly useful in larger airplanes utilizing hydraulic-powered flight controls enabling the prospect of electrical signaling, such systems are used to improve flight stability by automatically correcting disturbances from desired flight states.[87] Fly-by-wire is also particularly

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[82] *See* Kuo Kuang, *supra* n 67 at 28 (citing Nicholas Faith, *Black Box* (Motorbooks International Publishers, Osceola, WI: 1996).
[83] *See* "NASA Armstrong Fact Sheet: F-8 Digital Fly-By-Wire Aircraft" (28 February, 2014), online: < http://www.nasa.gov/centers/armstrong/news/FactSheets/FS-024-DFRC.html>.
[84] For more information on the Tay Viscount *see* "Boulton Paul and the Tay Viscount," *Flight Global* (1957), online: < http://www.flightglobal.com/FlightPDFArchive/1957/1957%20-%201091.PDF>.
[85] *See* "Avro 707 Delta Wing Research Aircraft" (11 April, 2014) *Military Factory*, online: <www.militaryfactory.com/aircraft/detail.asp?aircraft_id=1240>.
[86] Hill, H, "Fly-by-wire" (1972) Flight International 95.
[87] *Ibid*.

crucial in modern fighter jets, which are highly maneuverable but inherently unstable, rendering them virtually unflyable without computer aid.[88]

Although various aircraft manufacturers have adopted fly-by-wire technology in different forms, Airbus Industrie was the first major airframe developer to adopt digital fly-by-wire technology in the context of a large commercial plane. Although the same technology was used in the Aéropostiale BAC Concorde in an earlier analogue form,[89] the American space shuttles, were the first aircraft to utilize a fully digital fly-by-wire system.[90] By using it to a limited degree in its A310 model and fully implementing fly-by-wire technology on its A320 in 1988, Airbus became generally known as the producing the first fully "Electric Jet," due to the degree with which electronic computer systems were used on the new aircraft to replace older, more traditional systems of mechanical means.[91] By using Electronic Centralized Aircraft Monitors (or ECAMs), in addition to digital flight control systems, a thrust control computer (TCC), and two flight augmentation computers (FACs), the A320 changed the way by which pilots interacted traditionally with their planes, superseding pilot action entirely by computer interactions over which the pilot has no direct control.[92]

Another manner in which human action was replaced with automation was by Airbus' adoption and use of "flight envelope" protections pre-programmed into aircraft automation to override pilot inputs the computer determines would either put the aircraft into a dangerous

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[88] *See "*Automation in Aircraft*," supra* n 81.
[89] For more information on the Concorde *see* "Concorde ESST, Celebrating an Aviation Icon," online: <http://www.concordesst.com>.
[90] *See* NASA Fact Sheet, *supra* n 83.
[91] *See* "Automation in Aircraft" *supra*, n 81.
[92] *See* Kuang, *supra* n 67 at 26.

position or exceed the structural limits of the plane.[93] Instead, the computer will only allow the flight maneuvers up to a predetermined limit, while sounding a cockpit warning, ultimately granting final authority for aircraft control to the computer, depending upon which particular flight mode is currently employed. [94] Although Boeing has adopted similar restrictions, the flight envelope protections afforded by Boeing fly-by-wire airplanes can more easily be manually overridden, leaving final authority to the Pilot In Command.[95] Such protections have been included in flight control systems of the Boeing 777, 787 and 747-8.[96] Similar restrictions and fly-by-wire control systems have also been incorporated into smaller modern business jets by manufacturers such as Embraer for use on its E-Series[97] jet and the Dassault Falcon 7X.[98]

i. Automation Complacency as the New Silent Killer in Aviation

[93] *See* "Automation in Flight," *supra*, n 81. Airbus has utilized fly-by-wire technology and flight envelope protections on every commercial airliner model since the A310, including, the A318/319/320/321, the A330/340 series, the A380, and now, the A350XWB.
[94] For a complete explanation of flight control modes and each particular modes' physical and operative limitations, *see* Eurocontrol, "Flight Control Laws," Skybrary, online: <http://www.skybrary.aero/index.php/Flight_Control_Laws>. Although with most Airbus flight control modes final authority is granted to the computer, such protections may be overridden if the computer is operating in a mode where such protections are diminished or eliminated, either by pilot preference or in cases where flight automation is damaged or completely lost. *See* "Tyler Cowen, "More on the difference between Airbus and Boeing control systems," *Marginal Revolution* (28 December, 2013), online: <http://marginalrevolution.com/marginalrevolution/2013/12/more-on-the-difference-between-airbus-and-boeing-control-systems.html>.
[95] *See* Cohen, *supra* n 94. In Boeing aircraft, such flight envelope protections can be overridden by simply applying a specific amount of pressure on the control yoke, which indicates to the flight computer that the action is, indeed, one which the pilot intends to make.
[96] For more information on the technical specifications of each Boeing commercial airplane, including particularized information on Boeing's fly-by-wire and flight management system computers *see* http://www.boeing.com/commercial/.
[97] Robert Goyer, "Fly-by-Wire Wonders: Legacy 450 and 500," Flying Magazine (7 January, 2010), online: <http://www.flyingmag.com/pilot-reports/jets/fly-wire-wonders-legacy-450-500>.
[98] J. Mac McClellen, "Falcon 7X," Flying Magazine (26 October, 2008), online: <http://www.flyingmag.com/pilot-reports/jets/falcon-7x>.

As a result of the aviation industry's shift towards the incorporation of advanced automation such as fly-by-wire technology and flight envelope protections, a new silent threat has emerged due to the significant increases in control that engineers have afforded such technology — and the resulting dependency modern pilots have developed on such control to manage and fly their airplanes. Automation complacency or addiction (the two terms are interchangeably used) occurs when a pilot over-relies on and excessively trusts system automation, subsequently causing the pilot to fail to exercise his or her vigilance and maintain supervisory duties in the cockpit.[99] Due to dramatic increases in the utilization and complexity of advanced computer automation, and the effect such usage has in creating over-redundancy and pilot alienation from direct management of the plane, a disturbing trend has developed linking automation dependency to recent trends in incidents and accidents — therefore suggesting flight crews are having difficulty using advanced flight path management systems and other automation.[100] Flight Path Management is the "planning, execution, and assurance of the guidance and control of aircraft trajectory and energy, in flight or on the ground.[101] Essentially, flight path management is the moniker given to the broad array of computer automation systems

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[99] Hemant Bhana, "By the Book: Good Written Guidance and Procedures Reduce Pilots' Dependence on Automation." AeroSafetyWorld, March 2010. http://flightsafety.org/asw/mar10/asw_mar10_p47-51.pdf?dl=1 (citing Parasuraman, R.; Riley, V. (1997). "Humans and Automation: Use, Misuse, Disuse, Abuse." *Human Factors* 39: 230–253).

[100] *See* "Automation in Aircraft," *supra* n 81 at 1.

[101] Captain Dave McKenney, "Flight Path Management" (Lecture delivered at the Human Factors and the Automated Flight Deck Workshop at University of New South Wales, Australia, 4-5 February 2015) at 3, online: <https://www.casa.gov.au/sites/g/files/net351/f/_assets/main/lib100025/2_mckenney_flightpath_mgt_hf_workshop_feb15.pdf>.

used in modern day aircraft, and it is the new way by which pilots interact with automation systems in charge of flying the plane.[102]

Although as detailed above, automation has been extremely beneficial in aviation, the threat of automation dependency, in conjunction with the vast complexity of these systems and pilots' unpredictable reactions to them could put an aircraft's safety at risk. For instance, for the first time since the inception of aviation, erroneous keyboard entries or other mistaken input errors and misunderstandings of automation functions could cause a chain of events capable of taking down a commercial plane.[103] Automation also causes pilots to spend excessive time in head-down positions, taking time and focus away from manual flight.[104] Although it reduces workload overall, automation also increases a pilot's mental workload and requires extra time to

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[102] Flight path management is accomplished onboard modern aircraft by "Flight Management Systems" (FMS), which are defined as a multi-purpose navigation, performance and aircraft operations computer designed to provide virtual data and operational harmony between closed and open elements associated with a flight from pre-engine start and take-off, to landing and engine shut-down. An FMS is usually comprised of: (1) the Flight Management Computer (FMC); (2) the Automatic Flight Control or Automatic Flight Guidance System (AFCS or AFGS); (3) the Aircraft Navigation System; and (4) an Electronic Flight Instrument System (EFIS) or equivalent electromechanical instrumentation. *See* "Flight Path Management Systems," Skybrary.aero, online: www.skybrary.aero/index.php/Flight_Management_System; *see also* Chapter 1, *supra* n 17.

[103] *See* Kuang, *supra* n 67 at 28. A prime example of the risk of erroneous data entry is the case of Korean Air Flight 007. The Boeing 747-200 was shot down by a Russian fighter jet after accidentally straying into Russian restricted airspace. The accident investigation revealed that the Korean Air pilots had unwittingly selected the "heading" mode on the plane's navigation system, causing it to maintain the plane's initial northern heading after take-off, instead of selecting the "INS" mode, which would have commanded the plane to follow the flight's original planned flight path. INS works by intercepting a series of pre-programmed radio beacons throughout the flight to lead the plane from its initial location to its final destination. In this case, the INS error unwittingly led the 747 into restricted Russian airspace. *See* Rob Verger, "Newsweek Rewind: When Korean Air Lines Flight 007 Was Shot Down," *Newsweek* (17 July, 2014), online: <www.newsweek.com/newsweek-rewind-when-korean-air-lines-flight-007-was-shot-down-259653>.

[104] *Ibid* at 33.

take command of automation functions and input various commands, [105] causing some in the industry to assert that pilots now "fly with their fingers" rather than their hands.[106]

This overtly procedural, sometimes even sterile approach to pilot interaction by way of automation cannot only be extremely time-consuming, but cognitively demanding as well, causing pilots in some cases to miss the "big picture," or lose situational awareness.[107] This new scenario introduces two major consequences: automation intimidation[108] and a restriction of the available tools pilots can use to cope with unexpected events.[109] This newfound emphasis and dependency on automation also causes a deterioration of manual handling abilities, stick and rudder skills, and basic airmanship and aptitude.[110]

As was predicted, automation dependency, in addition to other concerns regarding the complexity of systems and operations, the degradation of pilot knowledge of these systems, and the integration and interdependence of all computer components of these systems has culminated in the increase of both major aviation incident and accident rates. Since 1996, an independent working group comprised of representatives from the U.S. Federal Aviation Administration

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[105] *Ibid* at 34.
[106] Antonio Chialastri, *Automation* ed by Florian Kongoli, ed, (Rijeka: InTech, 2012), 87.
[107] "Situational awareness" is the ability to identify, process, and comprehend the critical elements of information about what is happening in the moment. It is a critical element for aircraft piloting and taught as a main objective to retain throughout the piloting process. *See* "Situational Awareness," U.S. Coast Guard training materials, online: <https://www.uscg.mil/auxiliary/training/tct/chap5.pdf>.
[108] As identified in the Human factors "Digest No 5. Operational Implications of Automation in Advanced Technology Flight Decks," International Civil Aviation Organization Circular 238-AN/142 (Montreal, Canada: 1992), online: <http://aviationknowledge.wikidot.com/aviation:icao-hf5>.
[109] *See* Chialastri, *supra* n 105 at 87.
[110] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 43.

(FAA) Performance-Based Aviation Rulemaking Committee (PARC)[111] and the global Commercial Aviation Safety Team (CAST)[112] tasked with identifying and rectifying these concerns identified 26 accidents and 20 major incidents that fell under the scope of their work — to address, for current and projected operational use, the safety and efficiency of modern flight deck systems for optimum flight path management (including energy-state management).[113] The study, entitled "Federal Aviation Administration Report on Automation Dependency and Safety," will be discussed *infra* at length in Section III of this Chapter.[114]

Many of the accidents and incidents identified by the FAA Working Group have become the subject of great debate in the aviation industry, and have acted as catalysts for accident litigation worldwide. Of the roughly 26 accidents and 20 major incidents identified, several specific events stand out as having been directly related or caused by the issue of automation dependence, with each event having a catastrophic effect on the aviation industry — either due to the total amount of carrier liability or loss of human life. The first of several noteworthy accidents was China Airlines 140, an Airbus A300 that crashed while on approach into Nagoya, Japan on April 26, 1994. While the Co-Pilot was flying the aircraft as Pilot In Command (PIC), the Captain and non-flying pilot inadvertently triggered the automatic "Take Off/Go Around" feature of the autopilot system normally reserved for implementation in the event of a missed

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[111] *See e.g. "*Performance-Based Aviation Rulemaking Committee," Federal Aviation Authority, online: <https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/parc/>.
[112] *See e.g.* "Commercial Aviation Safety Team," CAST online: < www.cast-safety.org/index.cfm>.
[113] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 30.
[114] Chapter 2, *infra* at 42.

approach.[115] The fully integrated system added power and commanded the plane to pitch up to conduct the unintentionally commanded go-around. The Co-Pilot attempted to continue to manually fly the airplane down the glide scope path[116] while the autopilot attempted to counter the Co-Pilot's attempts by applying nose-up trim. Eventually, the elevator trim exceeded the Co-Pilot's authority and the airplane pitched nose up again, reaching an altitude greater than 50 degrees. The airplane stalled and slid backwards to the ground.[117] Upon examination of the accident, investigators concluded that it was the Co-Pilot's lack of functional knowledge of the FMS that caused the accident.[118] But for the pilot's confusion with regards to the autopilot's command to initiate a go-around, they could have selected manual control of the aircraft and applied basic flying skills to avoid the crash. Because the pilots had difficulty detecting the conflict and unknowingly fought against the automatic commands, this accident highlighted the importance of complete pilot understanding of the theory and function of advanced flight management systems.[119] It also demonstrated the perils of pilot inability to recover from automation failures, reluctance of flight crews to take over from malfunctioning automated systems and unanticipated failure modes, and pilot difficulty in detecting system errors.[120]

A second significant accident was the June 1, 2009 crash of Air France 447 — an Airbus A330-200 while in cruise flight off the northern coast of Brazil. Known as one of the most

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[115] For more information on the "TOGA" feature of the Airbus autopilot system *see* "Take Off-Go Around (TO/GA) Mode," Skybrary.aero, online: < www.skybrary.aero/index.php/Take-off_/_Go-around_(TO/GA)_Mode>.
[116] The glide scope is a crucial element of the Instrument Landing System, or ILS discussed *supra* in Chapter 1 at n 15. More information on the glide scope is discussed in Tom Rogers, "Glidescope 101," Avionics List, online: <www.avionicslist.com/articles/ILS-glideslope.php>.
[117] Manningham, Dan, "The Cockpit: A Brief History" (1997) 80 No. 6 Business & Commercial Aviation, 60.
[118] *Ibid* at 63.
[119] *Ibid* at 64.
[120] *Ibid.*

perplexing and significant airline accidents of modern times, Air France 447 is noteworthy as being one of the first accidents for which automation dependency was declared the first and primary cause.[121] During cruising flight through rough turbulence in the Atlantic Inter-Tropical Convergence Zone,[122] unusual temperatures led to the subsequent freezing and malfunction of the Airbus A330's pitot tubes,[123] which resulted in the loss of available airspeed data to the flight management computer. As a result of airspeed loss, the FMS became unavailable and the autopilot went offline, leaving the second junior Pilot In Command in charge of the airplane without any indication of true airspeed and in an unfamiliar automation mode known as "Alternate Law."[124] Because the Airbus was already at cruising altitude and thus, close to its aerodynamic limitations for maximum altitude and speed (otherwise known as "coffin corner"),[125] it was crucial for the pilot in command at that point — despite the loss of autopilot assistance and missing information of airspeed — to maintain the aircraft's cruising speed and apparent angle of attack[126] to avoid an aerodynamic stall. Inexplicably, the junior pilot instead

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121 William Langewiesche, "The Human Factor" (October 2014) Vanity Fair, online: <www.vanityfair.com/news/business/2014/10/air-france-flight-447-crash>.

122 For more information on the Inter-Tropical Convergence Zone and the effects it may have on aircraft encounters with turbulence *see* National Weather Service website, "Inter-Tropical Convergence Zone" (5 January, 2010), online: < www.srh.noaa.gov/jetstream/tropics/itcz.htm>.

123 For the definition of and working explanation on how pitot tubes function on a commercial airliner *see* Brendan Borrell, "What is a pitot tube?" Scientific American (9 June, 2009), online: < www.scientificamerican.com/article/what-is-a-pitot-tube/>.

124 "Alternate Law" is an FMS control mode in which the pilot flying may be faced with a reduction, or in some cases a complete withdrawal of automated systems to assist him or her during flight. For more information, *see* "Flight Control Laws," *supra* n 93.

125 For a more in-depth explanation of "coffin corner" *see* Aleks Udris, "Coffin Corner: Flying on the Edge," Boldmethod.com (28 October, 2014), online: < www.boldmethod.com/learn-to-fly/aerodynamics/coffin-corner/>.

126 For an explanation of wing "angle of attack," and its importance to the physics of flight *see* The Boeing Co., "What is Angle of Attack?" Boeing.com, online: <www.boeing.com/commercial/aeromagazine/aero_12/whatisaoa.pdf.

chose to command the Airbus to climb — a motion he continued until the last moments of the flight — causing the plane to enter into an unrecoverable stall, claiming the lives of all 228 people on board. [127]

Although a number of factors were cited by the accident report as contributing to the crash, the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civil (BEA) specifically found that the pilots' inexperience with high altitude stalls,[128] as well as Air France's failure to undertake any in-flight training on alternate control modes and manual handling skills at cruising altitudes were two of the main contributors to the crash.[129] From the inception of their careers, both first officers of Flight 447 had been trained by Air France as cadets in the Air France *ab initio* flight training program,[130] which places training pilots directly into Airbus cockpits after only a few hundred hours of flight time — allowing for the accumulation of experience almost exclusively in fly-by-wire aircraft engaged in fully-automated control modes, with little, if any experience in the cockpit of airplanes under manual control.[131] Another contributing factor to the accident specifically cited by the BEA was both the Pilot Flying and Pilot Monitoring's inherent unfamiliarity with the aircraft's automation modes, especially those

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[127] Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civil (BEA), *Final Report on the accident on 1st June 2009 to the Airbus A330-203 registered F-GZCP operated by Air France flight AF 447 Rio de Janeiro — Paris* (July 2012), 19, online: <www.bea.aero/en/enquetes/flight.af.447/rapport.final.en.php>.

[128] At various points in the accident transcript, the BEA report places great emphasis on the facts that the pilot flying during and after the loss of airspeed indication and the subsequent automation failure had failed to recognize distinct indications that the FMS had reverted to alternate law — compounding his loss of situational awareness and confusion with the airplane's response. *See* BEA Report, *supra* n 127 at 175.

[129] *Ibid* at 200.

[130] *See supra* n 58.

[131] *See* Langewiesche, *supra* n 121.

employed under Alternate Law,[132] and their subsequent failure to recover from the malfunction of the FMS to resume normal operations.[133] Because of the Pilot in Command's lack of experience with manual flight at cruise altitude, he had little or no knowledge as to how important maintenance of airspeed and aerodynamic angle-of-attack are in stall prevention at high altitude, and thus, did not have the requisite piloting skills necessary to perceive the current state of the aircraft once the automation had failed. As a result, Air France 447 entered into an unrecoverable stall and dove into the ocean approximately three and a half minutes after the first indication of airspeed loss.[134]

A third automation-related accident occurred on July 6, 2013, in San Francisco, California, when Asiana Airlines flight 214 — a Boeing 777-200ER en route from Seoul, South Korea — crashed while on a visual approach to runway 28L at San Francisco International Airport. Three of the 291 passengers and crew were fatally injured, while another 40 passengers, four flight attendants, and one crewmember received serious injuries when the airplane struck the airport sea wall due to the crew's mismanagement of the airplane's power settings and sink rate.[135] Before experiencing the crash, the flight crew had been set up by approach control for a straight-in visual approach to the runway, and accepted an air traffic control instruction to maintain an approach speed of 180 knots up to 5 nm above the runway. However, the flight crew mismanaged the airplane's descent, which resulted in the airplane being well above the

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[132] *See* BEA Report, *supra* n 127 at 211. Indeed, according to the FAA Working Group report and other industry sources, mode confusion has emerged as perhaps the single-most dangerous mistake made by pilots in automated cockpits; *See Manningham, supra*, n 117 at 61.
[133] *See* BEA Report, *supra* 127 at 199-200.
[134] *Ibid*.
[135] *See* "Executive Summary — Descent Below Visual Glidepath and Impact With Seawall, Asiana Airlines Flight 214" *National Transportation Safety Board* (report adopted 24 June, 2014), NTSB Report No. AAR1401, online: <www.ntsb.gov/investigations/AccidentReports/Pages/AAR1401.aspx>.

desired 3 degree glide path when it reached the 5 nm point directed by the approach.[136] In an attempt to increase the aircraft's descent rate and capture the desired glide path, the pilot flying — a trainee pilot who had just 33 hours on the Boeing 777 and was landing at San Francisco International for the first time[137] — selected the "flight level change speed" mode on the autopilot, resulting in the initiation of an automated climb because the airplane was below the minimum selected attitude while on final approach.[138] The pilot flying then disconnected the autopilot and moved the thrust levers to idle, which caused the auto throttle system in the airplane to change to the altitude "hold" mode; a mode which does not control airspeed. The Pilot Monitoring — an experienced 777 captain who was on his first flight as an instructor pilot supervising a trainee gaining operation experience — had no previous opportunity to instruct student pilots during line operations, and had yet to be observed by an experienced instructor himself. Neither he nor any of the other pilots in the cockpit at the time noticed the change in auto throttle settings.[139] When the aircraft reached the point at which Asiana procedures dictated the approach must be stabilized to land,[140] (500 feet above airport elevation) the Precision Approach Path Indicator System (or PAPI lights)[141] indicated that the airplane was well above

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[136] *Ibid.*
[137] Bart Jansen, "Pilot of Asiana 214 Stressed by San Francisco Approach" *USA Today* (11 December, 2013), online: < www.usatoday.com/story/travel/news/2013/12/11/ntsb-asiana-airlines-fatal-crash/3891213/>.
[138] *See* "Asiana 214 Executive Summary," *supra* n 135.
[139] *Ibid.*
[140] A stabilized approach is one in which the pilot establishes and maintains a constant angle glide path towards a predetermined point on the landing runway, or an airplane descending on final approach at a constant rate and airspeed travel in a straight line toward a spot on the ground ahead. "Stabilized Approach," Skybrary.aero, online: <www.skybrary.aero/index.php/Stabilised_Approach>.
[141] Precision Approach Path Indicators (or PAPI lights) are a colored lighting system installed on the left side of a runway, primarily to assist the pilot by providing visual glide scope guidance in non-precision approaches, to instruct the pilot as to appropriate interception of the runway. *See* "Lighting Systems — Precision Approach Path Indicators (PAPI)," *Federal Aviation*

the desired glide path, and the airspeed, which continued to decrease rapidly, had already decreased past the appropriate landing speed.[142] However, because of the design parameters of the "hold" mode unwittingly selected by the pilot flying, the thrust remained at idle, causing the descent rate to increase even more, passing 1,200 feet per minute — 500 feet per minute above the normally acceptable rate.[143] At 200 feet above the runway, the crew became aware of the low airspeed and low glide path conditions, but failed to initiate a go-around until the aircraft was approximately 100 feet above the runway, at which point the aircraft no longer had sufficient performance capabilities to arrest the descent.[144] Although a go-around was finally initiated, the low energy state of the airplane caused the main landing gear and aft fuselage to strike the seawall located at the beginning of the runway, causing the main landing gear and tail of the airplane to break off at the aft pressure bulkhead.[145] The airplane then continued to slide along the runway, partially lifting into the air, spinning around 330 degrees, impacting the ground and catching fire.[146]

A fourth noteworthy accident was the July 1, 2002 mid-air collision between Bashkirian Airlines Flight 2937, a Tupolev TU-154M and DHL Flight 611, a Boeing 757-200 freighter over the small town of Überlingen, Germany.[147] Seventy-one people, including 60 passengers on the

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Administration, online: <https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/lsg/papi/>. A "non-precision approach" is any approach which utilizes lateral, but not vertical guidance to land the airplane. *See* "Non-Precision Approach," Skybrary.aero, online: < www.skybrary.aero/index.php/Non-Precision_Approach>.

142 *See* "Asiana 214 Executive Summary," *supra* n 135.

143 *Ibid.*

144 *Ibid.*

145 *Ibid.*

146 *Ibid.*

147 *See* Giuseppe Contissa et al., "Liabilities and automation in aviation," (Paper delivered at Second *SESAR* Innovation Days Conference, 27–29 November, 2012), 3, online: <http://www.sesarinnovationdays.eu/files/SIDs/2012/SID%202012-36.pdf>

Bashkirian jet, nine crew members and two pilots on the DHL flight lost their lives. The airspace at the time was controlled by Skyguide of Switzerland, at which a single air traffic controller was working two control stations simultaneously during a period of what was considered "low traffic hours."[148] Although a second air traffic controller had been working at the time, he had retired to the rest lounge shortly before the collision occurred, leaving the single controller to manage all of SkyGuide's assigned airspace. The remaining controller contacted the Bashkirian flight less than one minute before the mid-air collision occurred. Both aircraft were equipped with a Traffic Collision Avoidance System (TCAS),[149] a device designed to prevent mid-air collisions by providing location coordinates of surrounding aircraft and issuing resolution advice for aircraft travelling on conflicting flight paths.[150] Unaware that the TCAS system had already issued a resolution instruction to both aircraft, the controller issued conflicting advice. While the Bashkirian flight chose to follow the air traffic controller's commands, the DHL flight conversely chose to follow the instruction issued by the TCAS computer.[151] The resulting mid-air collision ensued. At criminal proceedings conducted before the District Court of Bülach in Zurich, Switzerland, the air traffic controller was charged with criminal liability for multiple counts of manslaughter resulting in death, and negligent disruption of public transport. He was later acquitted by the judge of the Swiss court.[152] During the same trial, several managers of Skyguide were convicted of multiple counts of manslaughter for their failure to follow

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[148] *See* "Investigation Report AX001-1-2," *German Federal Bureau of Aircraft Accidents Investigation* (2 May, 2004), 111–13, online: <www.bfu-web.de/EN/Publications/Investigation%20Report/2002/Report_02_AX001-1-2_Ueberlingen_Report.pdf?__blob=publicationFile>

[149] *See* "Airborne Collision Avoidance System (ACAS/TCAS), *Skybrary.com*, online: <www.skybrary.aero/index.php/Airborne_Collision_Avoidance_System_(ACAS)>.

[150] *See* Contissa, *supra* note 147 at 3.

[151] *Ibid*.

[152] *Ibid*.

established safety standards and to ensure safety within the air traffic management system — actions which were held by the court to be the proximate cause of the accident.[153] More specifically, the Swiss court held that Skyguide was liable for its failure to exercise sufficient care to ensure workstations were sufficiently staffed at all times of the day, and for tolerating the common practice of allowing single controllers to operate two workstations simultaneously during times of low traffic at night.[154] Although the International Civil Aviation Organization (ICAO) had addressed right-of-way issues related to conflicting air traffic resolutions before the Umberlingin disaster occurred, and had established all TCAS resolution instructions as obligatory to all aircraft so equipped,[155] contrary interpretations of the rule granting final resolution authority to air traffic controllers had also been published in several previous ICAO "PAN-OPS" documents and other pilot guides.[156] The previous ICAO PAN-OPS approach had specifically been adopted in the Russian TU-154 operating manual — and thus, was executed by the Bashkirian pilots before colliding with the DHL 757 mid-air.[157]

A similar crash involving pilot misinterpretations of automated information occurred in the case of Turkish Airlines Flight 1951, a Boeing 737-800 that crashed while on approach to Amsterdam Schiphol Airport on February 25, 2009. Four crewmembers, including both pilots, and five passengers were killed, and 117 passengers were injured.[158] The cause of the crash was

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[153] *Ibid*.
[154] *Ibid*.
[155] *See* ICAO, "Rules of the Air," *Annex 2 to the Convention on International Civil Aviation* Doc. No. 42 at § 3.2.2 [19 November, 2009].
[156] *See* Investigation Report AX001-1-2, *supra* note 148 at 79 (citing ICAO PANS-OPS Doc. 8186, PANS-ATM Doc. 4444 and State Letter AN 11/19/82).
[157] *Ibid* at 80.
[158] *See* Dutch Safety Board, "Crashed during approach, Boeing 737-800, near Amsterdam Schiphol Airport, 25 February, 2009" (The Hague, May 2010), 29, online: <http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-63j-system-safety-fall-2012/related-resources/MIT16_63JF12_B737.pdf>.

determined to be a faulty left radio altimeter that read an erroneous height of -8 feet to the primary display of the flight Captain, which, in turn, triggered actions by the 737's autopilot and auto throttle contributing to the crash.[159] Because the Captain failed to detect the discrepancy by crosschecking his left radio altimeter readings with the First Officer's display, and subsequently allowed the landing mode preferences programmed into the Flight Management Computer to proceed with the programmed error,[160] the flight collided with the runway as part of a Controlled Flight Into Terrain (CFIT).[161]

III. The Federal Aviation Administration Report on Automation Dependency and Safety and Potential Solutions for the Automation Dependency Problem

To address the concerns first identified by the 1996 report and reiterated again in the 2014 FAA Operational Awareness Report, several changes were advocated by the FAA in order to eliminate the vulnerabilities identified in flight crew automation management.[162] Although some changes had already been made as a result of the original 1996 report — including the requirement of additional regulatory criteria and new policies for auto flight systems design[163] — the report identified additional vulnerabilities in pilot knowledge and manual flying skills that had yet to be addressed.

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[159] *Ibid* at 18.

[160] Due to the particular selection of FMS modes employed during aircraft landing procedure, additional protections such as the Ground Proximity Warning System (GPWS) were disabled at the time of the accident, essentially allowing the aircraft to be flown into the ground. *See* Dutch Safety Board Report, *supra* n 156 at 29.

[161] For more information on CFIT, *see generally,* FAA Advisory Circular AC No: 61-134, "General Aviation Controlled Flight into Terrain Awareness" (1 April, 2003), 2,

[162] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 14.

[163] *See* 14 CFR Part 25.1329 (Airworthiness Standards —"Flight guidance system,") and FAA Advisory Circular (AC) 25.1329-1C ANM-110 (27 October, 2014).

Such deficiencies include problems in the prevention, recognition and recovery from flight upset conditions, aircraft stalls or unusual attitudes, and appropriate manual handling of the airplane in transition from automated control. According to the FAA report, over 60% of the accident reports reviewed by the PARC and CAST Working Group identified manual handling errors as a major factor in the accidents at issue[164] — with such specific types of manual handling errors including a lack of correct manual handling skills, failure to take back manual control of the aircraft from automation after an auto pilot, auto throttle/auto thrust disconnect, or failure to recognize automation disconnection altogether.[165]

Other problems addressed by the FAA Working Group included inadequate energy management (such as that witnessed in the Asiana 214 accident), inappropriate control inputs for the situation (as seen in the Air France 447 crash) — including visual approaches and crosswind landings[166] — and failure to know what to do and when, especially in situations that occur infrequently. Such situations include having to reconfigure airplane surface controls for normal flight operations after demanding situations, respond to a wind sheer alert, or execute an all engine go-around.[167] Crew coordination — especially related to aircraft control — and the definition, development and retention of such skills, were also discussed as an impending concern.[168]

The Working Group also found that insufficient system knowledge, flight crew procedure, or understanding of aircraft configuration or energy state reduced a pilot's ability to adequately respond to challenging scenarios, malfunctions or threats occurring outside of normal

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[164] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 43.
[165] *Ibid*.
[166] *Ibid* at 44.
[167] *Ibid*.
[168] *Ibid*.

operations, for which applicable procedures do not exist or current checklists do not apply.[169] These issues, combined with over-reliance by pilots on automated systems, may render pilots particularly reluctant to intervene with automated systems controlling the aircraft, especially when confusion or errors with regards to auto flight mode selection occurs.[170] Because the use of automation in aviation continues to grow, especially with manufacturer implementation of increasingly advanced technologies such as modern FMS and other programming-intensive activities, the Working Group warned that additional programming errors of increasing magnitude could result in worsening pilot confusion and loss of control.[171]

With regard to over-reliance by pilots on automation systems specifically, in roughly one quarter of all accidents examined by the Working Group, pilots were found to be overconfident with automated systems and reluctant to intervene.[172] Loss of pilot situational awareness was also identified in over 50% of the accidents reviewed, as was pilots being out of the control loop and not ready to assume control of the aircraft when necessary.[173] A contributing factor found to hasten the loss of situational awareness was a lack of adequate pilot knowledge in understanding the consequences of selecting particular auto flight modes (such as the selection of the altitude "hold" mode in the Asiana accident, or TOGA mode selection during the China Airlines Flight), or climbing in vertical speed mode under autopilot control at higher altitudes.[174] High pilot reliability on systems without cross-verification, in addition to the failure to recognize autopilot

[169] *Ibid* at 15.
[170] *See* discussion of Asiana 214 accident, *supra* at 37-39.
[171] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 50 (citing Veillette, P.R., "Differences in aircrew manual skills in automated and conventional flight decks," *Transportation Research Record*, (1995) 1480, 43–50.).
[172] *Ibid* at 48.
[173] *Ibid*.
[174] *Ibid* at 50.

or auto throttle disengagement, or inability to maintain target speed, heading or altitude also contributed to a lack of control.[175]

A third problem identified by the Working Group was the insufficiency of current training methods and devices related to advanced automation, the time allotted for such training, and adequacy of training content to provide nascent flight crews with the knowledge, skills and overall judgment necessary to successfully manage fully-automated FMS.[176] The Working Group also concluded that insufficient training methods were another contributing factor to the aforementioned degradation of manual piloting skills and over-reliance on automated systems.

A specific study concluded in 1995 by Veillette et. al., and cited by the FAA report found statistical support for the FAA's findings regarding insufficient training, by tracking significant differences in manual control inputs by pilots in less automated aircraft, in contrast to inputs made by pilots in more automated planes — particularly during abnormal operations.[177] Because of recent increased emphasis in pilot training on the use of automated systems, the Working Group found that, without the time and opportunity to develop extensive manual flying skills outside the context of commercial pilot training, pilots may not ever be able to practice and acquire such skills.[178] The Working Group additionally found that recurrent training and checking schemes are insufficient to promote or test retention of manual handling skills[179] — a conclusion reiterated by pilot trainers interviewed for the Report. Trainers were specifically quoted as often observing trainee pilots learning to use automated systems by "watching things

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175 *Ibid*.
176 *Ibid* at 16.
177 *Ibid* at 45. More specifically, the Veillette Report found significant statistical increases in pilot inputs in older, less automated aircraft, in contrast to the dearth of inputs made by pilots in newer, more automated planes.
178 *Ibid*.
179 *Ibid*.

happen" in fixed-base trainers and simulators, creating the same expectation for pilots hand flying to watch things happen and then react — as opposed to encouraging proactive piloting skills and control of automation while in actual flight.[180] As part of the report, the Working Group cautions that this particular training approach could become even more widespread due to demands of new complex airspace control procedures requiring navigational precision beyond that which is realistically achievable during manual flight.[181] Lastly, the FAA identified significant variations in flight deck equipment and design in varying types of aircraft as contributing to the loss of situational awareness and automation dependency — especially with regards to the design of flight crew interfaces and system functionality.[182]

To address the specific deficiencies identified in the PARC/CAST report, the Working Group made a number of recommendations in both pilot training and system design to be implemented as soon as practically possible by the commercial aviation industry. The first recommendation was for the development and implementation of standards and guidance for maintaining and improving pilot knowledge and operating skills for manual flight operations, including providing pilots specific opportunities to refine such knowledge and practical skills[183] — a solution the FAA PARC/CAST found especially important, given the looming implementation of precise navigational path systems requiring constant use of autopilot and auto thrust controls.[184] Thus, according to the FAA, all training and checking policies must be altered

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[180] *Ibid.*
[181] *See* "RVSM Airspace" discussed *infra* in Chapter 3 at 85–86. Because the level of precision required by such new airspace control procedures would be extremely exacting in order to maintain proposed spacing of aircraft, manual flight in such scenarios would essentially be rendered impractical, obsolete, or out right dangerous due to inherent risks of flight path deviation; *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 50.
[182] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 16.
[183] *Ibid* at 45.
[184] *Ibid.*

to directly address the topic of advanced automation in the cockpit and the threat of automation dependency,[185] making sure that operators' policies for flight path management is both consistent and supports sufficient pilot training and practice in each particular aircraft type.[186]

The second recommendation was to require plane manufacturers to design flight deck systems so as to render them more understandable from the flight crew's perspective by utilizing human-centered design processes.[187] A third recommendation was to require airlines to develop guidance for flight crew strategies and procedures for malfunctions for which there is no specific procedure required.[188] This suggestion was born out of the realization that, despite robust failure modes testing by manufacturers, the highly integrated nature of advanced automated systems makes it more difficult for manufacturers to test all potential failures or combinations of failure modes, and subsequently identify all detailed procedures to assist pilots should such failures occur. Because the Working Group found that current abnormal procedures and training programs do not adequately address partial failures and uncertain situations — especially when combined with pilot over-reliance on automated checklist systems — the deficiencies in such programs could lead to future difficulties for pilots when managing unspecified failures or failure combinations under abnormal circumstances.[189]

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[185] Although the level at which these issues have been addressed by airlines can widely vary, some airlines, in particular American Airlines has tackled automation issues head on, creating specific training modules and manual flight programs that expressly combat the dangers presented by automation dependence and other particular modern pilot vices. *See* Reinig, Neil, "Children of the Magenta" (28 December, 2014), online: YouTube <www.youtube.com/watch?v=pN41LvuSz10>.

[186] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 18.

[187] *Ibid* at 19. "Human-centered design" is a creative approach to problem solving that begins the design process by considering the people by which the design will be utilized and ends with the tailoring of design solutions to meet those using the design's needs. *See* "What is Human-Centered Design?" *DesignToolkit*, online: < www.designkit.org/human-centered-design>.

[188] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 19.

[189] *Ibid* at 47.

With regards to legal and regulatory recommendations specifically applicable in the United States, the Working Group advised that FAA Advisory Circular (AC) 120-71A should be updated to include recommended practices for design standards of procedure (SOP) based directly on manufacturer procedures, continuous feedback from airline operational experience, and pilots' lessons learned. [190] The FAA included that such guidance should be updated regularly to reflect operational experience and third party research findings on a recurring basis. For long-term solutions, manufacturers should conduct additional research to understand and address when and why SOPs were not followed in particular scenarios, with such research and updates placing particular emphasis on monitoring of pilot cross verification, and on appropriate allocation of tasks between the Pilot Flying and the Pilot Monitoring.[191] The FAA also emphasized the importance of manufacturers and designers to ensure that human factors expertise is integrated into future flight deck design processes in partnership with other disciplines, with the goal of contributing to or achieving human-centered designs. [192] Such goals should be achieved by documentation of designer assumptions early in the design process on how equipment should be used in operation.[193]

Another regulatory recommendation made by the FAA was the revision as necessary of initial and recurrent pilot training and qualification requirements, as well as developmental

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[190] *Ibid;* Advisory Circular (AC) 120-71A is a specific regulation promulgated by the Federal Aviation Administration that establishes standard operating procedures for flight deck crewmembers in commercial aircraft.

[191] *See* Advisory Circular (AC) 120-71A*, supra* n 190 at 20.

[192] "Human factors" is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. *See* Clinical Human Factors Group, "What is Human Factors?," online: <http://chfg.org/what-is-human-factors>.

[193] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 21.

guidance and maintenance of improved knowledge and skills for successful flight path management — specifically by the implementation and improvement of laws overseeing carrier oversight promulgated under Title 14 of the U.S. Code of Federal Regulations.[194] The Working Group also called for the improvement of regulatory processes, and for guidance regarding aircraft certification and operational approvals — especially for new technologies and operations[195] — so as to develop new standards to encourage consistency in flight crew interfaces over time. The Working Group also postulated that standards establishing consistency of system functionality should be developed specifically from the airspace operations perspective for those operations deemed necessary for current and future airspace operations.[196]

IV Automation dependency as fertile grounds for accident litigation

[194] *Ibid*; for the definition and application of Part 142 training centers in the United States *see* 14 CFR Vol. 3 General Technical Administration, Ch. 54 Part 142 "Training Centers: 3—4332" (19 August, 2011) ("Prior to the implementation of part 142, regulations did not permit organizations other than certificated air carriers to use qualified simulators or flight training devices (FTD) to conduct the training, checking, or testing to qualify flight crewmembers. To acknowledge the advantages of modern simulation technology, the FAA issued various regulatory exemptions to training organizations that enabled them to conduct required training, checking, or testing in flight simulation devices. In 1996, part 142 was implemented and provided the regulatory basis to enable certificated training centers to use approved curriculums, qualified instructors, and authorized evaluators to conduct the training, testing, and checking of airmen in qualified simulators and FTDs. The certification of part 142 training centers also made additional resources available to air operators to enable them to enter into agreements with a training center to conduct ground and simulator flight training and checking for their crewmembers. With approval of the operator's principal operations inspector (POI), an operator may use a training center to conduct portions of the operator's approved training program. This provision has enabled certificated training centers under 14 C.F.R. part 142 to provide a valuable service to operators who would otherwise not have the benefit of using flight simulation training devices (FSTD) to use in their crewmember training curriculums.").

[195] *See* FAA Operational Flight Path Systems Report, *supra* n 52 at 16.

[196] *Ibid* at 21.

In short, the implementation of automation in aviation has presented a double-edged sword for airlines and other members of the aviation industry. Birthed into existence by economic realities brought to pass by airline deregulation and technical advances necessitated by pubic demands for cleaner, safer planes, aircraft automation has been touted universally as the newfound panacea for every airline and pilot malaise. However, the unanticipated side effects of automation — such as pilot dependency, system alienation, loss of situational awareness and lapses in attention span — have taken an undeniable toll on the industry as witnessed by several incidents and accidents directly related to the unknown consequences of heavy automation use.

One of the most destructive consequences not covered in the FAA PARC/CAST report, however, is the effect such issues have had on aviation law and accident litigation. Because the call for improved training and more stringent regulations made by regulatory authorities has yet to be implemented, problems with pilot competency and automation dependency have negatively affected the industry greatly as airplanes grow more complex. If nothing is done, automation dependency and overreliance will likely continue to perennially instigate lawsuits brought under private international air law or products liability law, and thus, become another major threat to an industry already plagued by legal challenges and weakened by large monetary settlements. Without any plausible and realistic rectification of these problems now or in the near future, automation — and the incidents and accidents resulting therefrom —is, and will continue to be a ticking time bomb until these issues are resolved.

CHAPTER THREE:
The Impact of Advanced Automation/Over-Dependency on the Determination of Liability in Catastrophic Tort Litigation: Who Is at Fault?

Although the technology and capability of automated systems in modern aircraft has benefitted the airlines, their pilots, and the flying public in multiple ways, what is missing, however, are proper design principles, crew guidelines and definitive flight rules to establish an appropriate relationship between advanced automated technology and the humans who operate it.[197] It is the exact absence of such guidelines that can be blamed for the increase in automation-related accidents and incidents in the last two decades since the introduction of these systems on modern commercial planes. The *raison d'être* of advanced automation is to use computers to solve common problems in a way that simulates the human reasoning process. Or in other words — to think for pilots, and to make decisions for them using a logical approach to problem solving based upon expert experience and design.[198] However, as demonstrated by several accidents and incidents such as China Airlines 140, Air France 447, and Asiana 214, these advanced cockpit technologies can also be, "silent, surprising, and unpredictable."[199] According to an anonymous pilot queried by Systems Management expert Liu Kuo Kuang, "[Automation] has greatly improved [pilots'] ability to understand flying from a big picture perspective. At the same time, it has lowered our awareness of problems that become apparent upon the failure of a major Electronic Flight Instrument System (EFIS)[200] or Flight Management System (FMS)[201]

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[197] Liu, Kuo Kuang, "The Highly Automated Airplane: It's Impact on Aviation Safety and an Analysis of Training Philsophy" (1997), 47 (citing Edward H. Phillips, "Pilots, Human Factors Specialists Urge Better Man-Machine Cockpit Interface," *Aviation Week & Space Technology*, 23 March, 1993, 67).
[198] *Ibid* at 25.
[199] *Ibid* at 55.
[200] For more information on EFIS *see* Skybrary.com, "Electronic Flight Instrument System," online: <www.skybrary.aero/index.php/Electronic_Flight_Instrument_System>.
[201] *See* definition of Flight Management System (FMS), *supra* in Chapter 1 n 17.

component, [because pilots] tend to depend too much on the electronic displays of our situation rather than keeping up on the analog (brain) functions."[202]

It has been suggested that newly-trained pilots are especially prone to such vulnerabilities, unlike their older counterparts who were trained on less sophisticated systems, and thus are more apt to question sources of information and better prepared to respond to potential system malfunctions, should any occur.[203] A 2011 report presented by the Royal Aeronautical Society asserted that flight crews best able to respond to such failures or other unfamiliar situations were either military-trained or employed by an airline with more than the legal minimum recurrent training programs, thus suggesting that standard pilot training is insufficient to provide modern pilots with the resilience required to manage modern cockpit challenges.[204] These deficiencies are thus opening up airlines to liability for passenger claims brought in law suits resulting from physical injuries encountered as a result of such lapses in pilot training.[205]

To make matters worse, conclusions made in crash investigation reports following events such as Air France 447 exposed even greater deficiencies in training related to pilot responses to automation, including the lack of basic stall recovery techniques, manual handling, and changes in flight characteristics associated with differentiations in altitude.[206] To be more exact,

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[202] *See* Kuang, *supra* n 197 at 45.
[203] *See* "Automation in Aircraft: The Changing Role of the Pilot," online: *HubPages* <http://flyingvet.hubpages.com/hub/Automation-in-aircraft-the-changing-role-of-the-pilot>.
[204] *See generally,* Richard Champion de Crespigny, FRAeS, "*Resilience* — Recovering pilots' lost flying skills," *Aerospace: The monthly flagship magazine of the Royal Aeronautical Society* (June 2015) at 31–26; for more differences between modern pilots and those of previous generations, *see also* Max Scheck, "Training and Management of Pilots across Generations," *International Journal of Business and Social Science* (February 2012) 3:3 at 137.
[205] *See* de Crespigny, *supra* n 204.
[206] *See* Chapter 2, *supra* at 36.

investigations into Air France training protocols in the wake of the Air France 447 tragedy revealed that stall recovery as generally taught in simulator exercises emphasized recovery with minimum height loss. This meant that pilots were tending to move away from general stall recovery techniques taught early on as part of basic flight training in light aircraft — ignoring standard procedure to counteract the stall with definite nose-down movement. Instead, pilots were reacting with a tendency to avoid height loss at all costs. After further investigation, it was in fact concluded that Air France did not include either stall recovery or manual handling at high altitude techniques at all in its training program.[207] Stall recovery technique is generally included in all basic initial flight-training syllabi for both private and commercial student pilots.[208] Although Air France and other flight training organizations have begun to introduce flight upset recovery techniques into their basic training modules after the Flight 447 investigation findings went public, some experts argue that basic training still has yet to adequately address the importance of instilling situational awareness and correct recovery procedures for automation failures in young pilots, especially at an early training stage.[209]

Thus, the Air France accident exposed a specific aspect of the automation dependency issue in pilots that both exacerbates and perpetuates the problem: the factor that airlines are entirely in charge as to how and how much to train their pilots on advanced automation systems and their responses to them in the commercial planes they will be flying. Nevertheless, the

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[207] *See* "Automation in Aircraft, *supra* n 203.
[208] *See* Joseph Bourque, "The Spin Debate" (November 2003) *Smithsonian Air & Space* online: <www.airspacemag.com/flight-today/the-spin-debate-3571421/?page=2>.
[209] *See* Interview with William H. Voss on 10 July, 2015. Mr. Voss is the President and CEO of the Flight Safety Foundation, and former Director of the Air Navigation Bureau in the International Civil Aviation Organization. Prior to joining ICAO, Mr. Voss assumed many executive positions over a long career at the U.S. Federal Aviation Association and is also licensed as an Airline Transport Pilot and Aircraft Mechanic. For more information on Mr. Voss *see* www.aviationtoday.com/william_voss_bio/.

process of becoming a commercial pilot takes a long time. According to FAA requirements, the minimum number of flight hours required to acquire an Airline Transport Pilot Certificate is 1500, which requires either an airplane category multiengine class rating, or a certificate issued concurrently with an airplane type rating, in addition to training in aerodynamics, adverse weather conditions, air carrier operations, transport airplane performance, professionalism, leadership and development.[210] European requirements for an Airline Transport Pilot License (ATPL) are similar in that they require completion of either a Multi-Crew Pilot License (MPL) or a Commercial Pilot License (CPL) with an additional Multi-Engine Instrument Rating.[211]

Alternatively, under the FAA Advanced Qualification Program (AQP), pilots may achieve certification outside of the traditional requirements established by 14 C.F.R. Parts 121 and 135 via participating carriers, who are granted significant freedom in curriculum design, as long as such programs incorporate data collection strategies capable of testing trainees' cognitive and technical skills.[212] As such, AQP participating airlines can modify and determine what is in each training module, with each cycle lasting anywhere from 9 to 18 months. [213] Although such programs are typically subject to general training recommendations made by the U.S. National

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[210] *See* FAA "Pilot Training ATP Certificate" online: <https://www.faa.gov/pilots/training/atp/> (based upon pilot certification requirements as stated in Title 14 of the Code of Federal Regulations to operate as a domestic, flag and supplemental carrier (Part 121), commuter and on demand carrier (Part 135), or as a flight instructor (Part 142).

[211] For information on completion requirements for either a Multi-Crew Pilot License (MPL) program endorsed by ICAO or a Commercial Pilot License (CPL) in Europe *see* British Civil Aviation Authority (CAA), "CAP 804: Flight Crew Licensing: Mandatory Requirements, Policy and Guidance" *Safety Regulation Group* (15 October 2013) Parts D and E, online: <www.caa.co.uk/docs/33/CAA_CAP%20804.pdf>.

[212] *See* FAA "Advanced Qualification Program," online: <https://www.faa.gov/training_testing/training/aqp/more/>.

[213] Interview with Dr. Katherine Wilson on November 17, 2015. Ms. Wilson currently works as an accident investigator for the U.S. National Transportation Safety Board and has taken part in the investigations of several incidents and accidents attributed to issues related to advanced automation systems in modern airplanes and automation dependency in commercial pilots.

Transportation Safety Board (NTSB), ultimately it is up to the discretion of the participating airline to determine how to accomplish pilot training up to the standards of the airline while also remaining within the original footprint of the AQP philosophy.[214] As a result, pilot training on manual flying skills and advanced automation can vary wildly, depending on the specific requirements of each airline.

Although the outcomes of accidents such as Air France 447 have emphasized the need to improve automation training and maintenance of manual flying skills throughout a pilot's career, the high costs of uniform training initiatives, both in actual price and opportunity costs in the form of pilot time (in simulators and in flight), render airlines resistant to additional training beyond that required to meet regulatory requirements.[215] Therefore, if private airlines were to incorporate additional training on such issues, they will most probably do so only if required as part of an amendment in the laws governing training programs, or as part of a colossal shift in commercial aviation culture, requiring the replacement of profitability with safety as the airline industry's number one stated concern.[216]

However, the probability of such a definitive shift in priorities — especially considering the potential effect such actions could have on industry profits, both long and short term — is slim. One major reason for this outcome is the fact that commercial aviation is, and has never been more extremely safe. According to the NTSB, the accident rate per 100,000 flight hours in

[214] *Ibid*.
[215] *Ibid*.
[216] *Ibid*. Although some may argue that safety is already the aviation industry's number one concern, the potential threat of shortcomings recently identified in pilot automation training and manual flight skills has yet to be addressed by AQP programs in any significant way — leading aviation safety proponents to speculate that the aviation industry is, indeed, prioritizing profits over safety. *See* interview with William H. Voss, *supra* n 209.

2014 was 6.74, with a fatal accident rate of 1.40.[217] These rates were only marginally worse than the rates published in 2013 — 6.26 and 1.12, respectively, making 2013 the safest year in aviation since its inception 110 years before.[218] Despite these figures, however, Boeing has also reported that between 2003 and 2012, the loss of control inflight, runway excursions and controlled flight into terrain (CFIT) accounted for a little more than two-thirds of all fatal accidents — with the first two categories indicating a decline in manual flying skills, and all three confirming that additional training is required.[219] Despite the overall increase in safety however, these statistics beg the question of whether the increase in safety perceived by increases in automation are actually greater than the decrease in safety due to automation's role in hastening the decline of manual piloting skills.[220]

One problem not currently accounted for in overall aviation safety statistics is the vulnerability of automated systems to computing errors or pilot close calls, and the potential effects such errors could have on aircraft were they to suffer such errors in flight — underscoring the importance of manual flying skills should such problems occur. Because of the continued increase of modern aircraft with advanced automation systems in use every year, safety experts agree that automation presents a potential safety risk that must be accounted for and eventually acknowledged in accident statistics. [221] As a result of such risks, some airlines, such as Emirates

[217] National Transportation Safety Board (NTSB), "2014 Preliminary Aviation Statistics," online: <www.ntsb.gov/investigations/data/pages/aviation_stats.aspx>.
[218] *Ibid*.
[219] *See* de Crespigny, *supra* n 204 at 32.
[220] *Ibid*.
[221] *See* Interview with Katherine Wilson, *supra* n 213. One such incident, the uncontrolled decent in mid-flight of Qantas Flight 72, an Airbus A330-300 on its way to Perth, Australia, when a computer fault in algorithmic data used for processing angle of attack data occurred, requiring a total system shut down and reversion to manual flying skills. 110 out of the 303 passengers were injured. *See* Australian Transport Safety Bureau (TSB) Aviation Occurrence Investigation AO-

has voluntarily increased manual flight time training, despite the majority of other operators' reticence to do so because of the perceived impact on operating costs. [222] Either way, despite variations in governmental and airline approaches to such issues, specific shortcomings in pilot training and the fallibility of advanced systems have rendered airlines, airplane manufacturers and airplane sub-component parts manufacturers vulnerable to legal challenges resulting from the unintended consequences and unforeseen challenges associated with advanced automation in modern planes.

I. Airline and Manufacturer Liability for Injuries Resulting from Automation Over-Dependence, and the Role of Both the Warsaw and Montreal Conventions in Limiting Such Claims

i. Airline liability

Because automation dependency and training deficiencies in manual flight skills have exposed affected airlines to liability for accidents and injuries emanating therefrom, many lawsuits have been brought around the world for passenger injuries and property loss. For cases brought against airlines for losses experienced during international flights, such lawsuits fall within the jurisdiction of both the Convention for the Unification of certain rules relating to international carriage by air, also known as the Warsaw Convention of 1929, and the Convention for the Unification of Certain Rules for International Carriage by Air, also known as the Montreal Convention of 1999.

The Warsaw and subsequently the Montreal Convention are multilateral treaties adopted by Member States to the International Civil Aviation Organization (ICAO) establishing airline liability for death, injury or delay to passengers, or in cases of delay, damage or loss of baggage

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2008-070, "In-flight upset 154 km west of Learmonth, WA 7 October 2008 VH-QPA Airbus A330-303," 213, online: <https://www.atsb.gov.au/media/3532398/ao2008070.pdf>.

[222] *See* interview with William H. Voss, *supra* n 209.

and cargo occurring during the course of international flights.[223] However, neither the Warsaw nor the Montreal Conventions apply to claims brought against non-airline defendants, the claims against which will conversely be covered by less demanding and exacting standards set by state and federal laws in the countries where such claims are filed.[224] The Montreal Convention was promulgated as a modernized version of the Warsaw Convention, which began as a single, universal treaty to govern airline liability around the world.[225] For those countries that have not become contracting parties to either Convention, however (about 116 of the 191 ICAO Member

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[223] *Convention for the Unification of Certain Rules Relating to International Carriage by Air* (Warsaw Convention) 137 LNTS 11 (entered into force 13 February, 1933); *Convention for the Unification of Certain Rules for International Carriage by Air (*Montreal Convention*)* 2242 UNTS 309 at 106-45 (entered into force 4 November, 2003). Although both treaties establish a single, unified standard of liability for all affected airlines domiciled in member states, unless specifically mentioned otherwise, this thesis will refer to the standards of liability promulgated by the Montreal Convention, as it shares a good deal of the same standards and rules originally promulgated by the Warsaw Convention of 1929, and presents the most current expression of unified liability standards in force today for airlines around the world. Currently, 152 parties have signed onto the Warsaw Convention, while 116 parties have signed onto the Montreal Convention of 1999. *See* "Current lists of parties to multilateral air law treaties," *International Civil Aviation Organization* (ICAO), online: <www.icao.int/secretariat/legal/lists/current%20lists%20of%20parties/allitems.aspx>.

[224] *See* David L. Fiol, "The Legal Landscape Created by Asiana 214,"(2013) *Brent, Fiol & Pratt, LLP,* online: www.bfnlaw.com/resources/the-legal-landscape-created-by-asiana-flight-214.html The scope of applicability of the Montreal Convention is defined in Article 1(2), which states:

> For the purposes of this Convention, the expression *international carriage* means any carriage in which, according to the agreement between the parties, the place of departure and the place of destination, whether or not there be a break in the carriage or a transhipment, are situated either within the territories of two States Parties, or within the territory of a single State Party if there is an agreed stopping place within the territory of another State, even if that State is not a State Party. Carriage between two points within the territory of a single State Party without an agreed stopping place within the territory of another State is not international carriage for the purposes of this Convention.

[225] "The Montreal Convention 1999 (MC99)," *International Airline Transport Association*, online: < https://www.iata.org/policy/pages/mc99.aspx>.

States) — including many fast-growing aviation markets in Asia, like Thailand, Indonesia, Vietnam and Russia — a patchwork of other liability regimes applicable to aviation accidents controls. For those Member States that have signed on to either treaty, aviation cases against airlines brought under legal jurisdiction of member countries — including all those brought in the United States[226] — will be governed by either the Warsaw or Montreal regime as the sole and exclusive legal basis for suing an airline for injuries suffered in the course of an international flight.[227]

Under Article 21(1) of the Montreal Convention, an airline is liable without proof of fault for damages suffered by a passenger of up to 113,100 "Special Drawing Rights" (or SDRs), currently valued at approximately $171,000 U.S.[228] For those claims of damages that exceed 113,100 SDRs, the carrier is not liable for damages arising from passenger injuries if the carrier can prove that such damage was not the result of negligence or other wrongful act or omission of the carrier or its agents, or the damage was solely due to the negligence or other wrongful act or omission of a third party.[229] Therefore, the airline will be held liable for all of the plaintiff's damages unless the airline proves that it was completely without fault, or that the accident was caused solely by the fault of a third party.

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[226] *See* Fiol, *supra* n 224 (citing *El Al Airways v. Tseng*, 525 U.S. 155 (1999) (establishing Montreal Convention of 1999 as exclusive remedy for cases brought in the United States against airlines for accidents or incidents occurring during international flights).
[227] *See* Article 1, Montreal Convention, *supra* n 223 at 106-45. The question of which treaty applies in each case is determined by ratification of either the Warsaw or Montreal Convention by the origin and destination state listed on the flight itinerary of the passenger damaged in each case.
[228] An S.D.R. is defined as an international reserve asset utilized by the International Monetary Fund, the value of which is based upon a basket of four key international currencies: The European Euro, the Japanese Yen, the British Pound Sterling and the U.S. Dollar. *See* International Monetary Fund, online: http://www.imf.org/external/np/exr/facts/sdr.htm.
[229] *See* Montreal Convention, *supra* n 223 at Article 21.

Unlike most laws that place the burden on the plaintiff to prove his or her claim, the Convention imposes on the airline the duty to prove its lack of fault, and an airline will be held liable in every instance in which an accident occurred.[230]According to Article 17 of the Montreal Convention, airlines may only be held liable for damages under the terms of Article 21 for damage sustained to passengers in the case of death or bodily injury, upon condition only that the "accident" which caused the death or injury took place on board the aircraft or in the course of any of the operations of embarking or disembarking the airplane.[231] The term "accident" has been interpreted by various jurisdictions, with courts in the United States specifically requiring the "event or happening" causing a passenger's injury to be "abnormal, unexpected or unusual and external to the passenger, meaning, the injury is not a result of the passenger's own 'internal reaction' to normal flight operations."[232] Additionally, "injury" has been interpreted as those damages that are physical in nature only, and do not extend to purely mental conditions.[233]

Therefore, for cases in which passengers were injured on international flights due to accidents arising from issues with automation training, dependency, or lack of manual handling skills, airline liability automatically arises and damages will be determined under the Warsaw or

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[230] *See* Fiol, *supra* n 224.
[231] *See* Montreal Convention, *supra* n 223 at Article 17.
[232] *See Air France v. Saks*, 470 U.S. 392, 393 (1985) (U.S. Supreme Court case decided before implementation of the Montreal Convention interpreting "accident" as defined in Article 17 of the Warsaw Convention. One of the drafters of the *Montreal Convention* has stated that the wording of Article 29 of the Montreal Convention is virtually identical to that of the corresponding article in the Warsaw Convention, in order to maintain the relevance of the jurisprudence rendered under the Warsaw System to cases determined under the Montreal regime. *See* George N. Tompkins Jr., "Are the Objectives of the 1999 Montreal Convention in Danger of Failure?" (2014) 39: 3 Air & Space L 203 at 204-207. at § 12.8).
[233] *See Jack v. Trans World Airlines, Inc.,* 854 F. Supp. 654, 665 (N.D. Cal. 1994) (citing *Eastern Airlines, Inc. v. Floyd,* 499 U.S. 530, 552. In *Floyd*, The Court concluded that the Warsaw Convention did not allow recovery for purely mental injuries because mental injuries were not encompassed by the term "bodily injury" in the text of Article 17.).

Montreal Conventions (whichever one is applicable) in every case in which an "accident" occurs and passengers are "injured" within the meaning of Article 17.[234] In the case of Asiana 214 for instance, airline liability is attributed from the accident occurring due to the pilots' actions in misinterpreting the actions of the auto throttle, and flying the aircraft significantly below the minimum safe speed for its approach to the threshold of the runway — spurring numerous cases to be filed against Asiana by passengers both inside and out of the United States.[235] Similarly, in the Air France case, Air France was held liable for its failure to properly train pilots to recognize and react to situations in which airspeed information is temporarily lost, and to both avoid and properly react, if necessary, to control loss due to high speed, high altitude stalls.[236] Air France is also liable for the behavior of Captain Marc Dubois, for his failure to both return to the cockpit in a timely manner from his mandated break and resume control of the aircraft in a timely manner from the junior pilots flying prior to the crash.[237]

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[234] "Accident" as defined for purposes of determining carrier liability is determined in Article 17 for both the Warsaw and Montreal Conventions. *See also Horvath v. Deutsche Lufthansa AG*, 2004 WL 241671 * 2 (S.D.N.Y. 2004) (negligence analysis by trial court to determine whether crew actions could be considered "accidental" as defined under Article 17 of the Warsaw Convention was improper. "Airline negligence that either precipitates or exacerbates a passenger's internal reaction to normal airplane operations may not qualify as an "accident."). 2004 WL 241671 * 6. However, under Article 29 of the Montreal Convention, the treaty does not govern "who are the persons who have the right to bring suit and what are their respective rights." Stated more simply, under the terms of the Convention, the courts where cases are tried under the Convention must use their own rules to determine who is entitled to sue and what kinds of damages they may seek. For instance, in the U.S., either local laws or the laws of the passenger's domicile, or permanent place of residence typically govern these issues. *See* Fiol, *supra* n 224.

[235] *See In re; Air Crash at San Francisco, California on July 6, 2013*, 4:13-md-02497-YGR (N.D. Cal.)(filed 13 December, 2013) (compilation of over 63 multi-district lawsuits filed against Asiana Airlines under the U.S. Multidistrict Litigation Act, 28 U.S.C. § 1407 (2011)).

[236] *In re: Air Crash Over the Mid-Atlantic on June 1, 2009*, MDL Docket No. 10-2144-CRB (N.D. Cal.) (filed 10 May, 2010).

[237] *Ibid*.

Although no reported court cases appear to exist in either the U.S. or Europe from the crash of China Airlines 140, China Airlines was held liable for insufficient pilot training in advanced auto throttle modes, contributing to the pilots' failure to recognize the immediate consequences of inadvertent selection of Take Off/ Go Around Mode in the Airbus A300, and the pilots' manual attempts to avoid the go around.[238] In the Überlingin disaster, Bashkirian Airlines was similarly held liable for the Russian pilots' failure to recognize, and follow established procedures for TCAS resolution advisories as advised by international aviation safety protocol.[239]

For automation dependency accidents resulting from travel on domestic flights, court cases have also been filed against airlines in state and local courts, both in the U.S. and abroad. One such case occurred in France, when Air France was held liable for the first-ever accident involving its advanced automated "fly-by-wire" system after the crash of Air France Flight 296. The crash occurred in 1988 at the Mulhouse-Habsheiem Airshow during the public debut of the Airbus A320. More specifically, Air France was held liable for Captain Michel Asseline's failure to comprehensively understand and appropriately react to the limitations of the Airbus' all-new fly-by-wire flight control system, preventing him from properly executing a pre-planned fly-over

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[238] Interview with Andrew J. Harakas, Esq. on June 12, 2015. Mr. Harakas is an attorney with Clyde & Co., one of the firms who handled claims from China Airlines 140 in the United States. Mr. Harakas stated that although some cases were brought against China Airlines in the wake of the crash, all or most of them were either settled or subsequently dropped. For more on Mr. Harakas *see* http://www.clydeco.com/people/profile/andrewharakas.

[239] *See* Giuseppe Contissa et al., "Liabilities and automation in aviation," (Paper delivered at Second *SESAR* Innovation Days Conference, 27–29 November, 2012), 3–4, online: <http://www.sesarinnovationdays.eu/files/SIDs/2012/SID%202012-36.pdf>; Federal Aviation Association, *Introduction to TCAS II — Version 7.1* (28 February, 2011), online: <www.faa.gov/documentLibrary/media/Advisory_Circular/TCAS%20II%20V7.1%20Intro%20booklet.pdf> at 29. This was in spite of evidence of conflicting procedures issued by ICAO at the time. *But see* Chapter 2 at 40–41.

as part of the airshow display — subsequently causing the plane to crash into the woods trailing the end of the runway.[240] Another well-publicized regional case occurred after the crash of Colgan Air Flight 3407, a commuter flight being performed by a propeller-driven Bombardier Dash 8 Q400, which crashed while on an instrument approach into Buffalo-Niagra International Airport on February 12, 2009. Fifty people, including 45 passengers, two pilots, two flight attendants and one person on the ground, were killed.[241] Colgan Air — a regional carrier engaged in a Capacity Purchase Agreement with larger airline Continental at the time of the crash — admitted to negligence on the part of its pilot and co-pilot, after the accident report revealed that both pilots, who were fighting the effects of extreme fatigue, had inappropriately reacted to a stick shaker warning indicating an impending stall. [242] The stall warning and subsequent crash was later determined to have been due to the loss of airspeed in iced conditions, and the pilots' negligent and inappropriate reactions to the stick shaker during flight.[243] As is typical for many cases brought in state courts for domestic flights, the plaintiffs in the Colgan

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[240] *See* Interview with Andrew J. Harakas, *supra* n 238.
[241] *See* NTSB, "Loss of Control on Approach, Colgan Air, Inc., Operating as Continental Connect Flight 3407, Bombardier DHC 8 400, N200WQ," AAR-10-01 PB2010-910401 (20 February, 2010), 80, online: <www.ntsb.gov/investigations/AccidentReports/Pages/AAR1001.aspx>.
[242] *Ibid; See Matter of Air Crash near Clarence Center, New York on February 12, 2009*, 2014 N.Y. Slip. Op. 24435 (Sup. Ct. of N.Y., Erie County) at * 1. Under a Capacity Purchase Agreement ("CPA") or a "fixed-fee arrangement, part, or all of a regional airline's seat capacity is purchased by a major airline partner. The regional airline then operates flights on behalf of the major airline, and is generally paid a fixed-fee for each block hour of flight time completed. The major airline thus incurs expenses for such services as ground handling and operating expenses, including airport use and fuel. However, the CPA also determines regional airline pricing, scheduling, ticketing and seat inventory variables, while the regional airline remains responsible for labor expenses, aircraft maintenance and aircraft rent (also known as "controllable cost items"). Thus, a CPA is useful in that it protects regional airlines from variations in passenger loads, as well as fluctuations in aircraft fuel and airline ticket prices. *See* Davide Pavone, "Regional Airlines: Challenging Investor Perceptions," *Seeking Alpha* (1 June, 2010), online: <http://seekingalpha.com/article/207801-regional-airlines-challenging-investor-perceptions>.
[243] *See* NTSB Loss of Control Report, *supra* n 241 at 84.

Air case alleged claims of general negligence against the airline (in this case Continental) and its agents (mostly pilots, and at times also crew), negligent hiring practices, and general liability for Colgan Air's failure to do more to prevent against passenger injuries and deaths.[244] All of the plaintiffs' claims in these cases were most certainly supported by additional evidence of inappropriate pilot training and erroneous responses to automation revealed later in each respective accident report.

One advantage plaintiffs suing airlines for incidents on domestic flights enjoy is the absence of limitations on potential damages and the requirement for actual physical damages as required in Article 17 in both the Warsaw and Montreal Conventions. However, additional advantages to suing airlines for damages sustained during domestic air travel are few and far between. One major drawback for suing outside the confines of the international liability regimes is the loss of automatic liability assumed on the part of the airline upon condition that the damage sustained by the passenger (either injury or death) occurred on board the aircraft or in the course of any operations of embarking or disembarking as required in Article 17.[245] For cases normally within the scope of either the Warsaw or Montreal conventions, an injured passenger need not prove fault on behalf of the carrier for an airline to assume liability,[246] making a negligence analysis unnecessary for carriers to be held labile for injuries sustained during international flights. Conversely in domestic aviation accident cases, the burden to prove negligence on account of the airline remains on the plaintiff, as the reverse burden of proof in

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[244] *See* Interview with A. Harakas, *supra* n 238.
[245] *See* Montreal Convention, *supra* n 223 at Article 17.
[246] *See Air France v. Saks*, 470 U.S. 392 (1985) at n 9. ("Questions of negligence are not implicated or even relevant; instead the focus of the inquiry is on "the nature of the event which caused the injury rather than the care taken by the airline to avert the injury.").

Article 17 would not apply.[247] The additional requirement of expert opinions and extensive evidence to prove airline culpability in negligence cases can be an expensive and intimidating proposition, especially for plaintiffs acting alone. However, a majority of negligence cases — especially those brought as a result of egregious pilot errors — often settle early in the litigation process, avoiding such costs.[248]

One significant and often overlooked advantage for potential plaintiffs looking to sue outside of the international treaties however, is the ability to sue airlines for psychological injuries, mostly resulting from Post Traumatic Stress Disorder (PTSD) or other forms of mental distress. Although the issue has been hotly debated throughout the aviation industry, the general consensus has been that any such injuries remain outside the scope of Article 17 of the Warsaw or Montreal Conventions, [249] rendering suits asserting claims for non-physical damages null and void per the "exclusivity provision" of Article 29 of the Montreal Convention.[250] For domestic

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[247] *See* Montreal Convention, *supra* n 223 at Article 17.

[248] Interview with Kenneth Quinn, Esq. on October 7, 2015. Mr. Quinn is a partner at Pillsbury, Winthrop, Shaw, Pitman, LLP practicing aviation, transportation and aerospace law, and also serves as General Counsel and Secretary of the Flight Safety Foundation. He has litigated several seminal aviation crash litigation cases and also acts as regulatory counsel to several airlines and airplane manufacturers around the world. For more on Mr. Quinn *see* http://www.pillsburylaw.com/kenneth-quinn.

[249] *See Thibodeau v Air Canada*, 2014 SCC 67 (Sup. Ct. Canada 2014) at ¶ 19 (failure of Air Canada to offer services in both English and French during flight as required by Canadian Official Languages Act (RSC 1985, c 31 (4th Supp), s 22(b)) did not constitute injury as defined within Article 17 and, as such, was properly dismissed under Article 29 of the Montreal Convention); *see also Stott v Thomas Cook Tour Operators Limited*, [2014] UKSC 15 at para 58 (affirmed); *But see Ehrlich v. American Airlines*, 360 F. 3d 366 (2004)(recovery for emotional distress recoverable only to the extent that it flows from the bodily injury); *Weaver v. Delta Airlines*, 56 F.Supp.2d 1190 (1999) ("bodily injury" for PTSD in the form of physical evidence of actual trauma of brain cell structures is compensable).

[250] Article 29 states that in relation to claims falling under the scope of the Montreal Convention, "any action for damages, however founded" may only be brought "subject to the conditions and such limits of liability as are set out in this Convention." (emphasis added). A similar exclusivity provision applicable to the Warsaw regime is established in Article 24 of the Warsaw Convention.

flight cases brought in U.S. state or federal courts, however, such limitations on recovery for psychological injuries do not apply. Domestic air crash cases also allow for contemplation of exemplary and punitive damages, which are normally excluded under liability ceilings established in Articles 22 and 21 of both the Warsaw and Montreal Conventions, respectively.[251] The potential award of such damage oftentimes incentivizes plaintiffs to pursue lawsuits in cases of domestic air crashes, as well. Because of the potential increase in automation dependency-related lawsuits as more modern aircraft enter service every day, airline liability for such events also increases, both within the scope of the Warsaw or Montreal Conventions, or under more traditional tort regimes.[252] However, the reality of such cases — especially those in which airline liability is either admitted or easy to prove — is that defendants often quickly settle with plaintiffs instead of engaging in litigation to refute accusations against airlines for negligence or other torts.[253] Instead of risking potential public relations issues related to pilot training shortcomings — even when admitted in some cases — it is easier for airlines to just settle with plaintiffs, while also demanding non-disclosure agreements preventing plaintiffs from publically discussing their claims.[254]

ii. Manufacturer liability

Although airline liability for accidents is almost always pursued by plaintiffs in all actions brought as a result of an aviation incident or crash, the possibility of strict limitations on

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[251] *See* Montreal Convention, *supra* n 223 at Article 21.
[252] *Ibid.*
[253] As a direct result, such settlements often cause airline insurance costs to rise. *See* Section III, *infra* at 89.
[254] Interview with Stephan Eriksson on August 8, 2015. Mr. Eriksson is a specialized aviation mass tort litigator and has worked on several aviation automation-related mass disaster accidents, including the Überlingin disaster and Air France 447. For more on Mr. Eriksson *see* http://www.advokatfirmaneriksson.se/en/home.html.

recovery and a two-year period of limitations for claims brought under jurisdiction of either the Warsaw or Montreal Conventions incentivizes plaintiffs to search out, and name additional parties to their claims — especially since many suits originating from aviation accidents often cannot come to fruition until decisive evidence determining actual and proximate cause is issued by investigating authorities many years after the crash.[255] Claims brought as a result of automation-dependency accidents are no different, and typically assert additional claims against airplane and sub-component part manufacturers, under the pretense of strict or traditional products liability.

In general, aircraft manufacturers can be held liable in most modern legal systems in a number of ways for the production of products determined to be dangerous or defective in some way. Coming a long way from initial application of *caveat emptor* to early product liability claims, manufacturer exposure helps to make mass-produced products safer for consumers all over the world.[256] With regards to modern strict products liability claims, aircraft manufacturers

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[255] *See* Montreal Convention, *supra* n 223 at Article 35 ("The right to damages shall be extinguished if an action is not brought within a period of two years, reckoned from the date of arrival at the destination, or from the date on which the aircraft ought to have arrived, or from the date on which the carriage stopped.").

[256] The legal precept of *caveat emptor* (or "may the buyer beware") stems from traditional notions of contract law protecting manufacturers from liability for dangerous or defective goods before the Industrial Revolution. Justification for such protections were sourced from cases in which usually the potential purchaser had a direct relationship with the manufacturer, thus allowing him or her the chance to inspect items before purchase, and also creating privity of contract between purchasers and manufacturers upon initiation of product sales. This gave purchasers the chance to rectify product issues with manufacturers directly, or at least provided manufacturers a defense against such claims if purchasers had been put on notice of the dangerous or defective qualities of the manufacturer's goods before they had been acquired. As the Industrial Revolution raged on, however, and consumer products were sold in greater numbers to more people due to the mass-production of goods, the relationship between manufacturer and purchaser became less personal, thus creating the need for widespread consumer protection imposed through law. *See also Greenman v. Yuba Power Products*, 59 Cal. 2d 57, 63 (Sup. Ct. Cal. 1963). Eventually, the traditional protections afforded by breaches in tort or contract law became insufficient to adequately hold complex manufacturers accountable for

may be held liable under either contract law or in torts, as well as under traditional notions of negligence including *res ipsa loquitor*.[257] More specifically, products liability claims often allege elements of breach of express or implied warranty, defective manufacturing and/or faulty design. In the U.S., the most well accepted summation of strict products liability law is presented by Section 402A of the Second Restatement of Torts. According to the Restatement, "One who sells any product in a defective condition unreasonably dangerous to the user or consumer or his property is subject to liability for physical harm thereby caused to the ultimate user or consumer, or his property, if: (a) the seller is engaged in the business of selling such a product, and; (b) it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold.[258]

How a product is determined to be "unreasonably dangerous" is usually based upon variations in U.S. state laws,[259] however, in most cases, the presence of a defect is sometimes detected by variations of the "Consumer Expectation Test" advocated by the Second Restatement of Torts, which turns upon whether the product is more dangerous than it needs to be and whether the consumer can expect the product to present such risks.[260] Other U.S. states use a

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the value and quality of their goods. As a result, court systems began to hold manufacturers liable strictly based upon the placement of such products on the market for sale. *See* Paul S. Dempsey, *Private International Air Law: Cases and Materials* (Montreal, Canada, McGill University, Institute of Air and Space Law: 2007) at § 3.01–3.10.

[257] *Res Ipsa Loquitor* (or "the thing speaks for itself") is a theory of negligence in which the very presence of a defective good or condition causing damages suggests negligence on account of the party being sued. In cases asserting *res ipsa loquitor* claims, negligence is automatically assumed, thus switching the burden of proof from that of the plaintiff to the defendant, who must then prove the absence of negligence to successfully defend against the claim. *See Fosbroke-Hobbes v. Airwork Ltd., and British American Air Services, Ltd.,* [1937] 1 All ER 108.

[258] *See also Yuba Power Products*, *supra* n 256 at 59.

[259] *See* Mark A. Swartz, "The Concepts of 'Defective Condition' and 'Unreasonably Dangerous' in Products Liability Law" (1983) 66:280 Marquette L Rev at 282.

[260] *See Restatement (Second) of Torts* § 402A, cmt. B (1965). In Europe, strict products liability is established by the Council Directive 85/374/EEC of 25 July 1985 on the approximation of the

"risk-benefit" analysis advocated by the Third Restatement of Torts, in which a jury must decide if the design of the product outweighs its benefits — and in most aviation claims, whether there is also a feasible, alternative design that could have been implemented by the manufacturer at the time the product was sold.[261]

In strict product liability cases, the plaintiff has the burden of proving the product was in a defective condition at the time it left the seller's hands.[262] A seller can be any manufacturer, wholesaler, or retailer of the product found to be within the chain of production of goods.[263] Before placing the product on the market, the manufacturer has an obligation to inspect the product to a reasonable degree to ensure it is safe and free from defects.[264] The product manufacturer also has a duty of care under the Third Restatement of Torts to ensure that the product is safe. If the design is found to be defective, all products further down the line are considered defective as well.[265] The product manufacturer also has a duty of care to prevent manufacturing defects, which is met by inspections during the assembly line and product testing when product assembly is complete.[266] The more complex a product is, the more complex accompanying instructions should be, as adequate warnings for complex products are required

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laws, regulations and administrative provisions of the Member States concerning liability for defective products, [1985] OJ, L210, 07/08/1985 at 29–33. Although the main purpose and philosophy for the Directive remains the same as that promulgated by the Second Restatement of Torts, one major difference between the two laws is the Directive's reliance on the "Civil Law Consumer Expectations Test," which defines a defective product as "unreasonably dangerous" when it does not present safety which the consumer is entitled to expect. *See* 85/374/EEC at Article 6.

[261] *See Restatement (Third) of Torts, Product Liability* § 2(b) (1998). For a list of U.S. states utilizing the "risk-benefit" approach *see ibid* at cmt D.

[262] *Ibid* at § 2.

[263] *Ibid* at § 1.

[264] *Ibid* at § 2.

[265] *Ibid*.

[266] *Bruce v. Martin-Marietta Corp*, 544 F. 2d 442, 448 (10th Cir. 1976) (interpreting Restatement (Second) of Torts § 402A).

by law.[267] For complex products warranting instructions and adequate warnings and sold without them, the manufacturer will be held automatically liable for such products if the consumer was not adequately warned.[268] However, warnings solely are not enough to absolve a manufacturer of responsibility — particularly for complex products and parts, such as aircraft.

Manufacturers of complex products, such as airplanes, also have a duty to perform product observation — meaning the manufacturer must keep all products in use under observation, formulating a client registry for which clients employing the product are asked to remain in contact with the manufacturer, so as to inform them of any safety incidents and to enable the manufacturer to distribute regular service bulletins to its clients.[269] There is an inherent duty to inform operators of the limitations and risks associated with aircraft as manufactured products, as manufacturers are responsible not only for the aircraft as a whole but for *every aircraft component as well.*[270]

Although major commercial aircraft manufacturers such as Boeing and Airbus have been held directly and indirectly accountable for product defects countless of times in innumerable products liability suits, several cases stand out based upon issues or defects with advanced automation technology in use on modern planes. One such case was against Boeing for the February 25, 2009 crash of Turkish Airlines 195 — a Boeing 737-800 manufactured in 2002 (line number 1065) at Amsterdam Schlipol Airport.[271] In the aftermath of the Flight 1951 crash, over twenty plaintiffs sued Boeing asserting several claims, including negligence, strict products

[267] *See Restatement (Third) of Torts*, *supra* n 261 at § 2.
[268] *Ibid*.
[269] *Ibid*.
[270] *Ibid* (emphasis added).
[271] *See* "Accident Description — Turkish Airlines Flight 1951," *Aviation Safety Network*, online: <http://aviation-safety.net/database/record.php?id=20090225-0>.

liability, wilful/wanton conduct on the part of Boeing, and wrongful death.[272] The plaintiffs alleged that Boeing was liable for designing, manufacturing, assembling, testing, selling and servicing the 737-800 at issue, which included various faulty or defective components. [273] Such components included the failed radio altimeter determined to be mainly responsible for the Turkish Airlines crash, and the autopilot/auto throttle function and flight control computers that were designed to function in such a way as to force the pilots to rely solely upon information received from the faulty altimeter. The plaintiffs also asserted that the flight displays failed to both adequately alert the pilots and incorporate a comparator function to warn them of discrepancies in altimeter heights, resulting in the subsequent loss of airspeed.[274]

The plaintiffs also sued Boeing for inadequate warnings and pilot instruction related to the faulty altimeter, and the potential effects it had on the autopilot and other advanced automated systems without proper pilot monitoring of airspeed.[275] Lastly, plaintiffs asserted that Boeing's failure to properly train pilots on radio altimeter failures, and its decision to exclude both a low airspeed/low energy warning and notification of radio altimeter malfunction as part of its automated cockpit notification system was a wilful and wanton disregard of pilot and passenger safety — thus becoming the proximate causation of the pilots' and passengers' wrongful deaths.[276] Because Boeing was the sole inspector and maintenance provider for the aircraft at issue, the plaintiffs argued Boeing was additionally liable for failing to adequately identify and fix the problematic radio altimeter, which had reportedly failed on the same aircraft

[272] *See Yancgo et al v. The Boeing Company*, Case 1:10-cv-06622 (N.D. Ill. 2010) Doc. 1-1; *Kaya v. The Boeing Company*, Case 1:10-cv-06617 (N.D. Ill. 2010) Doc. 1-1.
[273] *Kaya*, *supra* n 272 Doc. 1-1 at 3–6.
[274] *Ibid*.
[275] *Ibid*.
[276] *Ibid* at 15–17.

numerous times.[277] Although the cases were ultimately settled out of court, plaintiffs asserted claims against Turkish Airlines for damages related to compensable damages, as well as passengers' loss of enjoyment of life, pain and suffering, punitive damages, and wrongful death — recovery for which normally resides outside the limits of recoverable damages from airlines within both the Warsaw and Montreal regimes. [278]

i. Sub-component manufacturer liability

In addition to aircraft manufacturers, plaintiffs have also sued sub-component manufacturers for problematic equipment determined to have created or contributed to a crash. After the loss of Air France 447 in 2009, a litany of cases was filed against Airbus and several other sub-component manufacturers determined to have designed or installed specific microchip processors responsible for controlling the advanced flight management systems on the ill-fated flight.[279] Strict products liability and negligence claims were filed against Airbus as the general manufacturer of the A330, and negligence and strict products liability claims were also filed against Thales, as the manufacturer of the faulty pitot tubes, Motorola and CT Corporation as the manufacturers of the microprocessors used in the Air Data Inertial Reference Unit (ADIRU)[280] and flight control computers; Intel, Corporation as the designer of the microprocessor chips used in the ADIRUs and the flight control computers; Hamilton Sundstrand Corp. as the designer and manufacturer of the side-stick control; Rosemount Systems as the design and manufacturer of the

[277] *Ibid* at 16.
[278] *See* Interview with Andrew J. Harakas, *supra* n 238.
[279] *See* Interview with Kenneth Quinn, *supra* n 248.
[280] For more information on ADIRUs *see* JustABoutFlying, "Could the ADIRU failure bring the plane down?" *AskCaptainlim.com*, online: www.askcaptainlim.com/-air-safety-aviation-35/25-could-the-adiru-failure-bring-the-plane-down.html (detailed explanation of the ADIRU system and how it functions as part of advanced FMS on modern commercial planes).

airplane's angle-of-attack sensors and in-flight ice detection systems; Dupont, and Tyco Electronics, which both manufactured and sold wiring products for the airplane; and Honeywell International, as the manufacturer of the ADIRUs. [281]

Other relevant claims, *inter alia* were that the side stick controls in the A330 provided inaccurate information to the flight control computers; [282] the flight control computers were such that they did not prevent dangerous, erroneous and unauthorized flight control movements, and that on-board software installed on flight control computers, ADIRUs and other components failed to adequately filter out inaccurate data, thus providing erroneous information to the pilots.[283] Plaintiffs also claimed that the microprocessors used in the flight control computers, ADIRUs and other components prevented the installed software from functioning properly and created inaccurate data.[284] Claims against Dupont and Tyco alleged that the aircraft wiring was subject to wet and dry arcing, chafing, cracking, hydrolysis and pyrolization of insulation, which resulted in inaccurate information being sent to both the ADIRUs and flight control computers, in addition to other aircraft components lacking sufficient protection from electromagnetic interference.[285]

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[281] *See Dos Santos v. Airbus S.A.S et al*, Case 3:11-cv-00558-CRB (S.D. Cal. 2010) Doc. 1, 8.
[282] One defining characteristic of all Airbus commercial planes is the use of "side-sticks" in place of traditional yokes as control columns in its planes. It is a key feature of Airbus cockpit design philosophy and was mentioned as a small contributing factor in the Air France 447 disaster. Unlike Boeing aircraft, which utilize a traditional larger yoke designed to move each column in unison with input movements of the other, the side sticks on Airbus aircraft are smaller, and operator independently of one another, allowing for potential conflicting inputs by pilots flying. *See* Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civil (BEA), *Final Report on the accident on 1st June 2009 to the Airbus A330-203 registered F-GZCP operated by Air France flight AF 447 Rio de Janeiro — Paris* (July 2012), 173, online: <www.bea.aero/en/enquetes/flight.af.447/rapport.final.en.php>.
[283] *See Dos Santos*, *supra* n 281 at Doc. 1,
[284] *Ibid*.
[285] *Ibid* at 9.

The plaintiffs also sued Airbus for failing to provide A330 pilots sufficient manual flight training and testing during initial qualification for the aircraft, and for not taking sufficient steps to ensure that A330 pilots remained proficient in flying the aircraft manually.[286] They also alleged that Airbus was otherwise negligent in manufacturing and maintaining an aircraft that was unable to adequately or safely recover from unusual attitudes, and that the aircraft and its component parts were therefore defectively designed and or manufactured.[287]

In addition to compensatory damages, the plaintiffs sued for pain and suffering prior to death, mental anguish suffered by survivors, beneficiaries and heirs to the decedents, loss of consortium and companionship, pecuniary losses, loss of inheritance and net accumulations, lost value of life, funeral expenses and any and all other applicable damages.[288]Although a number of cases included in the consortium settled out-of-court, those that did proceed as part of the *Dos Santos* action were eventually dismissed from U.S. federal court in the Northern District of California based on *forum non conveniens*.[289]

Because of the increasing usage and complexity of advanced automation systems in commercial airliners constructed of thousands of customized parts manufactured by a bevy of sub-component manufacturers, liability for dangerous or defective products in these systems will

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[286] *Ibid*. at 11. Although plaintiffs fail to allege exactly how Airbus could be held directly responsible for maintaining the manual flying proficiency of A330 airline pilots, the claim was contained in the complaint, nonetheless.
[287] *Ibid*.
[288] *Ibid.* at 12–13.
[289] *In re Air Crash Over the Mid-Atlantic on June 1, 2009*, 760 F. Supp. 2d 832, 832 (N.D. Cal. 2010). *Forum non conveniens* is a legal concept allowing dismissal of a case to another court better suited to hear it. The dismissal does not prevent a plaintiff from refilling his or her case in the more appropriate court. *See* Black's Law Dictionary, *sub verbo* "forum non conveniens," online: <http://thelawdictionary.org/search2/?cx=partner-pub-4620319056007131%3A7293005414&cof=FORID%3A11&ie=UTF-8&q=forum+non+conveniens&x=0&y=0>.

continue to increase. The bigger and more complex modern aircraft become, so too will the risks associated with flying such advanced planes. As automation dependency incidents continue to occur — as these cases prove — inevitably so too will the lawsuits, settlements, and insurance payouts augmenting already high airline operating costs.[290]

II. Government Liability and Exposure for Shortcomings in Oversight and Regulatory Framework Related to the Incorporation and Use of Advanced Automation in Modern Aircraft

Another significant legal impact of issues related to advanced automation in aviation is the liability of national governments for failure to adequately regulate such technology in airplanes independently certified for commercial use. In the U.S., the Federal Aviation Administration may only be held liable for issues related to airplane certification if a plaintiff meets three specific requirements: (1) the government official at issue must be a salaried government agent or employee, either appointed or assigned to a specific role; (2) the official must have inflicted a tort or delict[291] on a private party while exercising the functions or requirements of his or her job; and (3) the official must have completed his or her functions without discretion or misrepresentation.[292]

Discretion on account of the federal government is determined to exist based upon the nature of the activity — mainly when it involves a policy-based decision versus a non-policy based decision — known in U.S. administrative legal jurisprudence as the "discretionary

[290] *See* Interview with Ken Quinn, *supra* note 248. *See also* Section III *infra* at 89.
[291] According to Black's Law Dictionary, a "delict" is a wrong or injury, usually in the form of either a violation of public or private duty or offense. *Black's Law Dictionary*, online, *sub verbo* "delict," online: <http://thelawdictionary.org/delict/>.
[292] *See Leone v. United States,* 910 F.2d 46, ¶ 11 (2nd Cir. 1965).

function exception."[293] According to controlling case law, the entire FAA inspection and certification process is protected by the discretionary function exception because the FAA exercises statutorily-granted discretion every time it certifies an aircraft, leaving no personal discretion to specific regulators.[294]

The discretionary function exception was explored in *United States v. Varig Airlines*, in which the plaintiffs sued the FAA after a fire broke out in the aft lavatory of a Boeing 707 flying from Rio de Janeiro to Paris.[295] The fire produced a thick, black smoke throughout the cabin, and although the airplane landed safety, most of the passengers on board succumbed to asphyxiation or the latent effects of toxic gas inhalation produced before they could exit the plane. The plaintiff sued the FAA under the U.S. Federal Tort Claims Act,[296] alleging that the Civil Aeronautics Agency (as the precursor to FAA) was negligent for its decision to issue a type certificate to the Boeing 707. More specifically, the plaintiff alleged the design of the aft lavatory trash receptacle in the plane did not satisfy applicable safety regulations, and that additionally, the CAA's decision to issue a supplemental type certificate for the installation of a non-compliant gasoline-burning cabin heater did not comply with FAA regulations — thus

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[293] *See Berkovitz v. United States,* 486 U.S. 531, 535–39 (1988) (defining discretionary function exception to government liability as precluding liability for any and all acts arising out of federal agencies' regulatory programs, but insulating from liability only those governmental actions and decisions that involved an element of judgment or choice, and that are based on public policy considerations).
[294] *See United States v. Varig Airlines,* 467 U.S. 797, 798 (1984).
[295] *Ibid*.
[296] The U.S. Federal Tort Claims Act (FTCA), 28 U.S.C. § 1346(b) is a federal statute that permits private parties to sue the United States in federal court for most torts committed by persons acting on behalf of the United States. The FTCA allows for a limited waiver of federal sovereign immunity established in U.S. jurisprudence (s*ee Price v. United States*, 174 U.S. 373, 375–76 (1899)) and state sovereign immunity established by the 11th Amendment of the U.S. Constitution.

contributing to the crash.[297] The U.S. Supreme Court held that the FAA's actions in granting the supplemental type certification for the gasoline stove were covered by the discretionary function exception of the FTCA — as judicial intervention, in the form of a private tort suit would "second guess" the political, social, and economic judgments of the FAA.[298] The Supreme Court

[297] The Federal Aviation Act of 1958, 49 U.S.C. § 1301 et seq., directs the Secretary of Transportation to promote safety in air transportation by promulgating reasonable rules and regulations governing the inspection, servicing and overhaul of civil aircraft. The Secretary, in his or her discretion, may prescribe the manner in which such inspection, servicing and overhaul shall be made. In exercise of this discretion, the FAA, as the Secretary's designee, has devised a system of compliance review that involves certification of aircraft design and manufacture. Under this certification process, the duty to ensure that an aircraft conforms to FAA safety regulations lies with the manufacturer and operator, while the FAA retains responsibility for policing compliance. Thus, the manufacturer is required to develop the plans and specifications and perform the inspections and tests necessary to establish that an aircraft design comports with U.S. federal regulations. The FAA then reviews the data by conducting a "spot check" of the manufacturer's work to ensure inspected aircraft comply. Part of the FAA compliance procedure involves certification, whereby the FAA — if it finds that a proposed new type of aircraft comports with minimum safety standards — signifies its approval by issuing a type certificate. If an already certificated aircraft's design undergoes a major change, the FAA — if it approves the change — issues a supplemental type certificate. *See Varig*, *supra* n 294 at 797. Should the FAA later discover un unsafe condition exists in the aircraft, or is likely to develop in other products of the same type design after original type certification is granted, the FAA may issue a legally-enforceable "Airworthiness Directive," which specifies inspections to be carried out, conditions and limitations with which airlines and manufacturers must comply, and any additional actions that must be taken to resolve the unsafe condition. *See* 14 C.F.R. § 39. The process for aircraft type certification in Europe by the European Aviation Safety Agency (EASA) and other aviation regulatory agencies across the world is similar to that employed in the U.S., in that the manufacturer of the potential aircraft to be certified conducts the majority of requisite certification tests necessary to prove to the applicable regulatory agency that the aircraft is safe and compliant with all safety requirements, with representatives of the regulatory agency periodically verifying compliance with safety, and other regulatory standards before type certification is issued. *See* "Aircraft Certification," *European Aviation Safety Agency* (EASA), online: <https://easa.europa.eu/easa-and-you/aircraft-products/aircraft-certification> (explaining the overall purpose, processes and legal basis of aircraft type certification as employed by EASA). EASA also has a similar process for the issuance and verification of manufacturer and airline compliance with affected product airworthiness directives, as well. *See* "Airworthiness Directives," *European Aviation Safety Agency*, online: <http://easa.europa.eu/easa-and-you/aircraft-products/airworthiness-directives-ad> (citing EC 1702/2003, Part 21A.3B, OJ L240, 7/09/2002, pg. 1).

[298] *Varig*, *supra* note 294 at 807–21.

also held that the FAA's discretionary authority to establish a spot-checking program for aircraft compliance was the best way to accommodate the goal of air transportation safety while also considering the reality of finite agency resources.[299] Therefore, under the reasoning of *Varig,* there would most likely be no government liability for certification of advanced automation systems, even if the design of such systems is challenged as ultimately flawed because such certification would be part of the FAA's discretionary function to certify aircraft.

These issues related to FAA liability have potentially come into play after the Asiana 214 accident, after several Boeing 777 pilots exposed recurrent issues with mode change awareness in the Boeing 777. More specifically, 777 pilots complained about a design feature in the 777 that caused the auto throttle system to automatically switch to a "hold" mode upon disconnection of the autopilot — a mode which did not control or automatically maintain airspeed.[300] Although the NTSB noted in its report that complex auto throttle and flight director systems were inadequately described in Boeing's documentation (and Asiana's pilot training),[301] the FAA ultimately could not be held liable for its initial certification of the auto throttle system, since overall, it was exercising its discretionary function during the certification process of the airplane when determining whether such systems were found to be generally safe.[302]

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[299] *Ibid*.
[300] *See* "NTSB report on July 2013 crash of an Asiana Airlines 777 in San Francisco," *AirSafe.com News* (25 June, 2014), online: <www.airsafenews.com/2014/06/ntsb-report-on-july-2013-crash-of.html>.
[301] John Croft, "FAA 'Strongly Encouraged' Autothrottle Change," *Aviation Week Network* (31 March, 2014), online: <http://aviationweek.com/regulatory-safety/faa-strongly-encouraged-autothrottle-change>
[302] *See Varig*, *supra* n 294. In order to achieve type certification, a new aircraft must meet all airworthiness requirements stated in Title 14 of the U.S. Code of Federal Regulations, and any "other airworthiness criteria [the FAA] find[s] appropriate and applicable to the [aircraft's] specific design and intended use [while] provid[ing] a level of safety acceptable to the FAA." 14 C.F.R. § 21.17(f)(1). For flight guidance systems and auto throttle controls to be considered "safe" within the meaning of Title 14, such system functions, controls, indications and alerts

Similarly, in Europe the European Aviation Safety Authority would be immune to governmental challenges because the aircraft certification process is one with which the government promotes safety — however, it is by no means a way to guarantee it. Therefore, in Europe, the duty to certify or to observe certification exists solely towards the general public as a public function. It is not owed to the individual.[303] Even after EASA authorities determined the susceptibility of all Thales Avionics series P/N C16195AA pitot tubes installed on Airbus A330 and 340 airplanes to develop high-altitude ice crystals in inclement weather as witnessed in the Air France 447 disaster, EASA issued Airworthiness Directive 2009-0195 requiring all affected pitot tubes to be replaced within a period of four months.[304] Because EASA's certification duty is owed solely to the public as a means to promote safety, but not guarantee it, EASA cannot be held liable for individual failures or lapses in safety resulting in accidents or passenger deaths.[305]

i. Shortcomings in Oversight and Regulatory Framework

Although government regulatory agencies may not be legally liable for discretionary functions employed in initial certification of a plane and its parts, continued political pressure

must be designed to minimize flight crew errors and confusion concerning the behavior and operation of the flight guidance system, and means must be provided to indicate the current mode of operation, including any armed modes, transitions, and reversions. 14 C.F.R. § 25.1329(i). Following disengagement of the auto thrust function, a caution must be provided to each pilot. 14 C.F.R. § 25.1329(l). Although the FAA acknowledged issues existed with shortcomings in flight manual coverage and explanations of the complex intricacies of the auto throttle system after the Asiana accident, no government liability was determined to exist because the FAA, in its discretion, determined that the design of the system itself met all overall requirements for original type certification as required by Section 25.1329. *See generally,* U.S. Dept. of Transportation Federal Aviation Administration Type Certificate Data Sheet No. T00001SE Revision 38 (October 27, 2015) (held by the Boeing Company for all Boeing 777-200, -300, -300ER, -200LR and 777F series aircraft).

[303] *See SNIS et CAMAT c. Etat Francais,* 205 AQ 236 S.N.I.A.S. 1981–83 (1994).

[304] 31 August, 2009.

[305] *See SNIS*, *supra* note 303 at 1981–83.

and the FAA's regulatory mandate requires the agency to enforce high regulatory standards in the wake of high-profile air disasters, which motivates the agency nonetheless to re-evaluate system design and manufacturing processes to identify and correct any identified faults. One way in which the agency is allowed to require acknowledgement and rectification of design errors or safety faults is by way of federal airworthiness directives, which, upon issuance, require aircraft manufacturers to correct problems from which safety issues could exist. If the manufacturer fails to implement the changes mandated in all federal airworthiness directives it may be held in violation of 14 C.F.R. § 39.9 and prosecuted accordingly.

Another way the U.S. Federal Aviation Administration regulates safety is by requiring air carriers (including foreign air carriers like Asiana, when landing in the United States) to purchase ample liability insurance for each applicable flight,[306] so that there will be more than enough coverage to fully compensate all affected passengers should something go wrong. However, because the FAA has very little authority to force airlines to change practices determined to be a safety threat, but are otherwise compliant with government regulations, and because affected airlines are often covered by liability insurance for accidents nonetheless, there is little impetus for airlines to change such policies immediately or down the road.[307] One such problematic issue is pilot certification, both in Europe and the United States. As discussed *supra* all that is required of performance-based pilot training programs — especially those certified under the AQP framework discussed on page 54 — is for basic regulatory standards to be met. The FAA and other certification authorities do not specifically state how pilots must be trained to meet AQP standards. The sole expectation for pilots graduating from such programs is to pass

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[306] *See* Section III, *infra* at 89.
[307] *See* interview with William H. Voss, *supra* n 209.

the check ride — regardless of whether pilot check rides actually entail evaluations of specific piloting skills. For this reason, check rides and the philosophy behind them have been accused as lacking by industry experts, since they fail to include evaluation requirements to assess pilot cognitive ability to "predict" aircraft behavior, as needed to adequately respond to automation errors should they occur.[308] Such "visualization" techniques are crucial to automation error recovery, however, there is no current way for check ride evaluators to observe or confirm that a pilot is capable of incorporating and utilizing such skills.[309]

One potential way to ensure pilots learn these additional skills is implementation of the operational versus skill-based training approach.[310] Knowledge-based training — as exemplified in the context of FMS training — is focused upon teaching pilots to know how the automation works and thus adequately predict the computer's behavior, instead of focusing solely on obtaining an end result with automation commands.[311] In practice this would entail teaching each pilot to know the programming logic employed behind the aircraft's automated processes, instead of solely focusing upon what key should be punched to command the plane to perform a certain function.[312]

This "top-down" approach of knowledge-based FMS training thus varies greatly from the "bottom up" approach typically employed in basic training programs all over the world. Although the "bottom up" training approach is designed to enable pilots to learn appropriate protocol for making FMS work in standard training situations, it does little to help pilots learn to

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[308] *Ibid*.
[309] *Ibid*.

[310] *See* Kuo Kuang, *supra* n 197 at 16-18.

[311] *Ibid*.
[312] *Ibid* at 43.

operate in novel or unexpected situations encountered while flying the line, or to understand aircraft FMS as a whole.[313] The standard skill-based approach is utilized by several manufacturers and airlines — including United, Airbus Industrie and Air Canada[314] — while a standardized mandatory knowledge-based approach has yet to be developed by the airline industry, EASA, or the FAA.[315] The necessity for knowledge-based training originates from evidence gathered from recent accidents and incidents revealing common reoccurrences of pilot input errors to FMS systems — especially when pilots are under severe time constraints — which, when coupled with high workloads and high stress situations, can become a severe problem yielding disastrous results.[316]

A second issue is lack of specific regulations and ambiguity surrounding what is referred to in the U.S. as "phase II pilot training."[317] In the United States, airline pilot training requirements are divided into two parts: the first part, referred to as the "basic flying skill training" phase gives student pilots their airline pilot rating in fulfillment of the basic

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[313] *Ibid* at 44 (citing John A. Wise, *et al*, *Automation in Corporate Aviation: Human Factors Issues*, Federal Aviation Administration (Washington D.C.: 1993), 18).

[314] *Ibid*.

[315] *Ibid*.

[316] *Ibid* at 43. One accident resulting from a pilot input error was the crash of American Airlines Flight 965, a Boeing 757-200 that crashed while on approach to Cali, Columbia. The accident was ruled to be a "controlled flight into terrain (CFIT), due to the crew's erroneous programming of the FMS to include an incorrect navigational waypoint as part of a VMH omnidirectional range (VOR) non-precision approach utilizing only a radio localizer at night. As a result, the airplane flew into the surrounding mountainside, killing 159 out of 163 passengers and crew. *See* "Accident Description, American Airlines Flight 965," Aviation Safety.Net, online: <http://aviation-safety.net/database/record.php?id=19951220-1>.

[317] *See* 14 C.F.R.§ 61.153 ("Airplane rating: Aeronautical Knowledge").

requirements for airliner pilot knowledge and flying skills.[318] However, the FAA does not specifically define the second phase of airline pilot training relating to airline pilot training on automation.[319] Therefore, it is left up to the airlines as to how to complete such training, the details of which airlines are often allowed to keep classified.[320]

EASA also has a similar approach. Although following an evaluation of current European aviation regulations European regulators concluded that the European aviation system is already globally well protected against flight crew automation issues, EASA nevertheless made several recommendations for the development of specific airline automation policies to better protect against flight crew automation issues. EASA then published its recommendations in its "Automation Policy" developed by the EASA Internal Group on Personnel Training (IGPT) in 2013.[321] Of those recommendations, several included the improvement of basic airmanship skills, improvement of recurrent training and testing practices with regards to automation management, improvement of better Crew Resource Management, Competence Based Training (CBT)[322] and Evidence Based Training programs (EBT),[323] and improvement of

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[318] *See* Kuo Kuang, *supra* n 197 at 36 (citing 14 C.F.R. §§ 61.151, 153, 155 and 157).
[319] *Ibid*.
[320] *Ibid* at 69.
[321] *See* EASp Action EME4.4 (28 May, 2015), 6, online: <http://easa.europa.eu/system/files/dfu/sms-docs-EASp-SYS5.6---Automation-Policy---28-May-2013.pdf>.
[322] CBT is a means of training that places emphasis on achieving benchmarked standards of performance, so as to focus on achievement of skills specifically required in the workplace after completion of a program of training designed to help participants achieve such skills. *See* Capt. Gary Morrison, "Competence-Based Training Solutions, The Time Is Now!" International Civil Aviation Organization (ICAO) *Next Generation of Aviation Professionals Program (NGAP)*(March 2010), 9, online: <www.icao.int/Meetings/AMC/NGAP/Documentation/CompetencyBased%20Training%20Solutions.pdf>.
[323] EBT is a process that allows operators to restructure their training programs to target current risks of operation — such as automation dependency — instead of spending valuable training time and resources on outdated training models originating from the Twentieth Century. It

the IATA Multi-crew License (MPL) program[324] to better address automation management.[325] ICAO has also recommended similar recommendations for implementation on a global scale.[326]

Although regulatory bodies and aviation safety agencies have already identified and acknowledged major shortcomings in automation training, surveys of pilots and other aviation professionals — such as that performed by Embry Riddle University in the Kuo Kuang paper — confirm that a shortage of phase II training still exists.[327] In some cases, it has additionally been indicated by surveyed pilots that the training they received on automation was minimal, if non-existent — with some pilots claiming that the training they received equated to being handed a manual on computer automation over a weekend, or gaining experience while on the job.[328] Although attitudes regarding automation in the industry have changed in the years proceeding the Embry Riddle survey, which was performed in 1997, the issue still remains that no specific structured automation training has since been put in place by any major regulatory agency. As

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utilizes real-time data collected from flight data reports, over 9,000 line operations safety audit observations, 1,000 pilot surveys, and several thousand advanced pilot qualification program reports to make these changes. It has been incorporated into ICAO Standards and Recommended Practices and endorsed by organizations such as the Royal Aeronautical Society, the International Airline Transport Association (IATA) and airline manufacturers such as Airbus and Boeing. *See* William H. Voss, "Evidence-Based Training," AeroSafety World (November 2012), online: <http://flightsafety.org/aerosafety-world-magazine/nov-2012/evidence-based-training>.

[324] The IATA MPL is the first airline-dedicated professional pilot license, adopted by ICAO as part of Annex 1 of the Procedures for Air Navigation Services. *See* ICAO *Procedures for Air Navigation Services*, ICAO doc 4444 –ATM/501, 15th Edition (2007).

[325] *See* EASA IGBT Automation Report, *supra* n 321 at 9.

[326] *See* ICAO, *Procedures for Air Navigation Services — Manual of Evidence-Based Training,* ICAO Doc 9995 (2013).

[327] *See* Kuo Kuang, *supra* n 197 at 18.

[328] *Ibid* at 69 ("My initial training involved myself on the ground with a manual sitting in a powered up electronic system. Then I went on a trip and was given instruction on the way. This is very typical. Some [instructor] pilots don't even have the desire to sit in the aircraft on the first trip.").

with other aspects of pilot training, the only standardized aspect at this time, especially in the United States is the training check ride.[329]

Moreover, as stated above, neither EASA nor the FAA has an actual regulatory mandate to write such rules, since opponents argue that these issues have not significantly impacted safety according to current aviation statistics. Because of recent data publicized establishing accident and incident rates at near historic lows,[330] there also is a lack of justification for regulatory agencies to incur extra costs associated with the promulgation of new rules.[331] Conversely, however, EASA and the FAA's roles in requiring expansion of automation use continue to be growing. With the implementation of Reversed Vertical Separation Minimum (RVSM) airspace, the minimum required separation between aircraft at cruising altitude (above flight level 290 (29,000 feet)) has recently been reduced from 2,000 to 1,000 feet.[332] With the implementation of RVSM airspace, airlines are now required by law to use automation anytime an aircraft is above 24,000 feet (Flight level 290). Hand flying at this stage is prohibited, so as to reduce the chance for human error, which could be catastrophic considering the reduced separation minimum

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329 *See* FAA Flight Standards Service, Washington DC 20591, "Airline Transport Pilot and Aircraft Type Rating Practical Test Standards for Airplane," FAA-S-8081-5F, online: <https://www.faa.gov/training_testing/testing/test_standards/media/atp_pts.pdf>.

330 *See* National Safety Council, "Injury Facts 2015," online: <www.nsc.org/learn/safety-knowledge/Pages/injury-facts.aspx>. Indeed, the current odds of dying in an aviation or space transport incident in 2015 are 1 in 8,015 — significantly less than the chance of dying in a motor vehicle crash (1 in 112) or a motorcycle accident (1 in 911).

331 *See* Interview with William H. Voss, *supra* n 209.

332 RVSM airspace was implemented to reduce the vertical separation above flight level (FL) 290 from 2000-ft minimum to 1000-ft minimum. It allows aircraft to safely fly more optimum profiles, gain fuel savings and increase airspace capacity. *See* FAA, "Reduced Vertical Separation Minimum (RVSM)," online: <https://www.faa.gov/air_traffic/separation_standards/rvsm/>. RVSM airspace was implemented as a means to increase airspace capacity and access to more fuel-efficient flight levels, and was adopted by ICAO and its Member States beginning in March 1997. *See* "Reduced Vertical Separation Minimum (RVSM)," *CSSI.Inc*, online: <www.cssiinc.com/industries/aviation/reduced-vertical-separation-minimum-rvsm>.

requirements between cruising flights.[333] With the implementation of RVSM airspace, the average amount of time commercial pilots spend collectively operating an advanced automated airplane by hand — such as the Boeing 777 — from take-off to landing has been reduced to less than seven minutes per flight.[334] Therefore, partially due to the implementation of RVSM airspace, opportunities for pilot improvement of manual handling skills have been reduced even further during actual flight —contributing to rapid deterioration of basic airmanship and piloting skills.[335]

i. Air Traffic Control Liability

Another significant, but often overlooked factor in assessing the effect advanced automation has had on legal liability of the aviation industry is the determination of air traffic controller liability for accidents caused directly or indirectly by errors in the administration of air traffic control. According to current global liability models, air traffic liability is normally divided up into three distinct categories: (1) Those services wholly owned or administrated by the government, which would normally be immune to liability due to the concept of sovereign immunity;[336] (2) air traffic control services provided by a public body as part of a separate corporate entity set up by special legislation (and usually expressly excluded from sovereign

[333] *See* Interview with William H. Voss, *supra* n 209.
[334] *See* John Markoff, "Planes Without Pilots," *The New York Times* (6 April, 2015), online: <www.nytimes.com/2015/04/07/science/planes-without-pilots.html?_r=0>.
[335] *See* Interview with William H. Voss, *supra* n 209.
[336] For a complete discussion of sovereign immunity as it relates to government liability for aviation incidents and accidents *see* Section II, *supra* at 75. The U.S. Federal Aviation Administration Air Traffic Control Services is an example of air traffic control services entirely administrated by the government. *See* FAA, "Air Traffic," online: <https://www.faa.gov/air_traffic/>.

immunity);[337] and (3) services provided entirely by a private company managed under private law business principles, but wholly owned by the government — thus allowing such services to remain totally under government control and allowing some challenges to sovereign immunity — depending on the case.

Air traffic control liability as related to pilot issues with advanced automation was highlighted by the Überlingin disaster in Germany.[338] That mid-air collision between a Bashkirian Airlines Tupolev TU 154 and a DHL Boeing 757-200 resulting from conflicting resolution results issued by both aircrafts' Traffic Collision Avoidance System (TCAS) and a lone, overworked air traffic controller at Swiss controller Skyguide overseeing the airspace at that time. [339] The accident resulted from the Russian pilots' choice to follow instructions given by Skyguide, while the DHL crew complied with TCAS resolution commands.[340] The state of international regulation at the time of the accident was unclear as to which resolution source had priority: TCAS or air traffic control.

Skyguide is a joint-stock company established under Swiss law to provide air traffic management of Swiss civil and military airspace.[341] Despite attempts to hold both Skyguide and Bashkirian Airlines jointly and severally liable without limitation for the accident, regardless of

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[337] For example, *see* NavCanada. Nav Canada is a separate corporate entity established by Canadian federal regulations that administers air traffic control services throughout Canada. *See* Nav Canada "About Us," online: <www.navcanada.ca/en/about-us/pages/who-we-are.aspx>.
[338] The Überlingin Disaster is discussed at length in Chapter 2 at 39–41.
[339] *See See* Giuseppe Contissa et al., "Liabilities and automation in aviation," (Paper delivered at Second *SESAR* Innovation Days Conference, 27–29 November, 2012), 3, online: <http://www.sesarinnovationdays.eu/files/SIDs/2012/SID%202012-36.pdf>
[340] "Investigation Report AX001-1-2," *German Federal Bureau of Aircraft Accidents Investigation* (2 May, 2004), 111–13, online: <www.bfu-web.de/EN/Publications/Investigation%20Report/2002/Report_02_AX001-1-2_Ueberlingen_Report.pdf?__blob=publicationFile>.
[341] *See* "People and Organization," Skyguide, online: <www.skyguide.ch/en/company/people-organ/>.

Skyguide's potential immunity as a private entity under Swiss government control, the Swiss Court dismissed all claims[342] — a decision later upheld by the Supreme Court of Madrid, Spain.[343] Notwithstanding the suit's dismissal, Skyguide established the largest compensation fund in European history between 2003 and 2004 to pay amounts agreed upon by most of the victims' families, including members of the flight crew.[344] Attempts to increase the amount of compensation, however, were rejected in 2011 by the Federal Court in Berne, Switzerland.[345]

Ultimately, liability for the Baskirian crew's failure to correctly interpret and interface with TCAS commands and Skyguide's failure to adequately manage and adhere to formal air traffic control management policies was split evenly amongst the two defendants.[346] Honeywell International — the manufacturer of the TCAS system — was also sued for its failure to provide appropriate information on the use of the TCAS system. Honeywell was also sued for failure of the TCAS Pilot's Guide to clearly set forth priorities of TCAS advisories over conflicting orders from air traffic control.[347] Two other alleged defect claims — a fault in the resolution advisory system, and Honeywell's failure to implement a newer version of TCAS software — were subsequently dismissed.[348]

III. <u>The Effect of Automation Over-Dependence on the Aviation Insurance Industry</u>

The final, but perhaps most lasting legal effect advanced automation accidents could have, however, is the potential to drive up the costs of the commercial aviation insurance market

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342 *See* Contissa et al., *supra* n 339.
343 *Ibid* (citing *Judgment* 564 (18 July, 2011).
344 *See* Contissa et al., *supra* n 339 at 4.
345 *Ibid* (citing Judgment 2C_287/2010 of 28 April, 2011).
346 *Ibid*.
347 *Ibid* (citing Case 5. First Instance Court N.34 of Barcelona, Spain).
348 *Ibid*.

— and, as a result, the cost of passenger ticket prices. On average, a commercial airliner takes off every second of every day with 65 passengers and flight crew on board, with an average hull value valued at $27 million USD.[349] Collectively, the world's fleet of aircraft has been valued at around $570 billion USD.[350] Because the potential liability for airlines and aircraft manufacturers for any partial or complete hull loss is so large, airlines are required to present proof of adequate liability coverage as part of the certification process for commercial carriers.[351] Many aircraft manufacturers choose to carry insurance policies to protect themselves from accident litigation, as well.[352]

The need for aviation liability insurance was then again drastically underscored by the events of September 11, 2001. Although the frequency of total losses has gradually decreased over the years — mostly due to greater engine reliability and advanced cockpit technology — the advancement of aviation technology manifested in the employment of bigger and more valuable planes by the industry — such as the Airbus A380 — and the continued increase in passenger traffic per year presents a large risk to the entire aviation industry should a potential loss occur.[353] Normally, legal insurability limits for each aircraft range from USD $250 million to

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[349] *See* Swiss Re, "The true value of aviation insurance," *Technical publishing — Aviation*, 6, online: < http://media.swissre.com/documents/the_true_value_of_aviation_insurance_en.pdf>.
[350] *Ibid.*
[351] In the U.S., all carriers applying for a commercial air operations certificate under Part 121 of Title 14 U.S.C. (Domestic, Flag, and Supplemental Operations) must prove a schedule of insurance coverage in effect on the operator's current balance sheet showing insurance companies, policy numbers, types, amounts, period of coverage and special conditions, exclusions and limitations. *See* 14 U.S.C. § 119.36(e)(7). In Europe, insurance requirements for most commercial airline operators are established as part of the Air Operator's Certificate (AOC) mandated by the Civil Aviation Authority (CAA). *See* Civil Aviation Authority (CAA), "Guidelines for airline operators and staff," online: <https://www.caa.co.uk/default.aspx/default.aspx?catid=2327>.
[352] *See* Interview with Kenneth Quinn, *supra* n 248.
[353] *See* SwissRe, *supra* n 349 at 8 and 11.

USD $2 billion.[354] Although some carriers will be subject to limitations in legal liability credited to international airline liability regimes such as the Warsaw and Montreal Conventions and the IATA Inter-Carrier Agreement,[355] a great deal of insurance claims originate from domestic and international flights not subject to liability limitations on such flights.[356] Despite significant improvements in aviation safety statistics (largely attributed to advanced automation systems), total insurance awards have continued to increase, especially in Europe and North America — the two largest employers of "fourth generation" large commercial jets.[357]

Although aviation insurance is a prerequisite to airline operation certification in most countries, and can potentially pay out millions or even billions of dollars in potential carrier claims, the actual total cost of insurance, on average, is less than 2% of the operator's total budget — a cost factor considered to be small enough that it is often left out of most carrier financial reports.[358] Thus, when compared with total potential carrier liability exposure in the

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[354] *Ibid* at 6.

[355] The IATA Intercarrier Agreement of 1996 was a contractual agreement undertaken amongst all signatory airlines to increase the original liability limits of the Warsaw Convention of 1929, which were found to be mostly outdated and insufficient in comparison to modern-day standards at the time for damages awards for other types of cases outside of the international aviation liability regime. *See* International Air Transport Association, Intercarrier Agreement on Passenger Liability, *open for signature* Oct. 31, 1995, online: <https://www.iata.org/whatwedo/workgroups/Documents/legal/intercarrier-agreement-passenger-liability-feb09.doc.>; *see also* Andrea L. Buff, "Reforming the Liability Provisions in the Warsaw Convention: Does the IATA Intercarrier Agreement Eliminate the Need to Amend the Convention?" (1997) 20:5 Fordham LJ 1768 at 1825.

[356] *Ibid* at 11. For a discussion of airline liability for events outside the scope of international limited liability regimes *see* Section I(a) *supra* at 66.

[357] A "Fourth generation" commercial aircraft is considered to be any commercial plane manufactured after 1988 that includes "fly-by-wire" technology and advanced flight envelope protection. *See* Airbus, "Commercial Aviation Accidents 1958–2013 A Statistical Analysis," 8, online: <http://asndata.aviation-safety.net/industry-reports/Airbus-Commercial-Aviation-Accidents-1958-2013.pdf>.

[358] *See* Swiss Re, *supra* note 349 at 17.

case of a major incident or accident, the cost of insurance, or re-insurance, is relatively small.[359] Because the insurance market tends to be reactive as opposed to proactive, the cost of insurance is determined by a number of separate factors considered by underwriters when pricing policy costs. Such factors considered include the airlines' historical experience of attrition, and major, partial, and total hull losses experienced in a year.[360] Insurers also use exposure-oriented models and predictive threat scenarios to project future losses for single accidents, collisions of various aircraft on the ground or in the air, and natural catastrophes — which could damage aircraft at risk at a particular location.[361] Underwriters also consider calculations of overall loss versus the risk of potential loss, requiring a statistical knowledge of expected and unexpected losses and calculation of a host of commercial aviation volatility factors — such as losses incurred as a result of automation dependency, and other advanced technological factors.[362]

Thus, the actual and potential cost of incidents and accidents encountered by carriers related to issues with advanced automation must be considered equally by both insurers and carriers when assessing carrier policy costs.[363] Indeed, as with most insurance, the more claims an insured makes against its policy the more costly insurance premiums will be.[364] Thus, as the number of modern aircraft with advanced automation systems entering into commercial air service continues to increase, so will the potential for automation related incidents and accidents as the cause for carrier claims. Although carriers could potentially be liable for major accidents totaling anywhere from millions to hundreds of millions of dollars for the complete loss of a

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[359] *Ibid.*
[360] *Ibid* at 19.
[361] *Ibid*.
[362] *Ibid* at 20.
[363] Interview with Philip Crystal, Senior Claims Expert and Director of Claims Corporate Solutions, SwissReinsurance Company, Ltd., on November 19, 2015.
[364] *Ibid*.

wide-body airplane, the airline will mostly likely be able to recover, as the cost of a loss of such magnitude will ultimately be absorbed by the industry as a whole[365] — increasing already large operation costs, and eventually driving up potential passenger fares.[366]

An even more concerning risk is the potential effect a major loss of an ultra wide-body airplane — such as an Airbus A380 — could have on the entire aviation insurance system as a whole. Such a loss could theoretically bankrupt most major airlines and their insurance and re-insurance carriers due to potential multi-billion dollar claims.[367] However, such a loss may be mitigated by the aviation insurance market's ability to eventually fold such losses back into premium costs, due mostly to the extremely slow pace of aircraft accident litigation — even those cases moving through U.S. federal courts.[368]

Therefore, because of the ubiquitous impact advanced automation and automation dependency issues have had, and will continue to have on carriers, manufacturers, governmental regulatory agencies, air traffic control operations and aviation liability insurance costs, in addition to inevitable increases in risk due to the continued employment of such advanced systems in commercial planes, these problems can no longer be ignored.

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[365] *See Husserl v. Swiss Air Transport Co.,* 351 F. Supp. 702, 707 (S.D.N.Y. 1972) (according to judicial philosophies expressed in the interpretation of the Warsaw Convention and similar treaties, it is the primary function of such limited liability regimes to redistribute the costs involved in air transportation directly to air carriers, as they are best qualified to initially develop defensive mechanisms (such as the purchase of applicable insurance policies) to both avoid and address such costs.

[366] *See* Interview with Philip Crystal, *supra* n 363.

[367] *Ibid*.

[368] *Ibid.* Insurers are gradually able to fold the costs of large losses into carrier premiums and into aviation industry costs in general due to the extremely slow pace of litigation resulting from air crash accidents, especially in the U.S. The settlement or dismissal of such cases oftentimes takes several years, allowing carriers and other industry members a significant amount of time to spread out liability for major accidents and resulting settlement costs. *See* Interview with Phillip Crystal, *supra* n 363.

CHAPTER FOUR/CONCLUSION:
Who Will, and How Should the Aviation Industry Respond?

When considering private industry and government liability in the wake of any major revelation related to consumer safety and products liability law, consumer advocate Ralph Nader said it best when referring to corporate responsibility to rectify problems identified as inevitable safety risks:

> What's the solution? Well, you look at the objective. Let's say you want a safety law; you want a company to do something different. You say, what has to be done? Well, the first step is to make people aware of the problem. If they aren't aware their friends were killed because of a defective design, they're not going to be interested in your solution.[369]

Although it has been proven that the aviation industry is extremely safe — especially when compared with other modes of transportation — industry recognition of pilot automation intimidation and dependency issues is the first step of many required to evaluate and eventually eradicate such risks. Regardless of automation proponents' claims that integration of advanced automated systems in modern aircraft is crucial for continued safety, studies such as the aforementioned U.S. Federal Aviation Administration (FAA) report on the Operational Use of Flight Path Management Systems, the European Aviation Safety Administration (EASA) Automation Policy, and the 2011 Royal Aeronautical Society Pilot Automation review conversely prove that the unbridled use of automation without specific training and regulation can yield dangerous results. Although the industry may go several years in between major

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[369] John T. Halliday, "Air France 447: A Cockpit China Syndrome" (25 May, 2011), Huffington Post Tech, online: <www.huffingtonpost.com/john-t-halliday/air-france-447-a-cockpit_b_304737.html> (citing Ralph Nader, "Unsafe at Any Speed," Time Magazine (24 December, 1965.)

accidents, major events such as the Air France 447 disaster, Asiana 214, China Airlines 140 and many others, as well as the potential risk of future mishaps prove the industry needs to remain vigilant when addressing the "dark side" of automation.[370] Although no single solution exists to this incredibly complex and multi-faceted problem, there are several changes the industry must consider when formulating a plan to successfully combat, and eventually eradicate automation dependency and intimidation risks. Such changes should include: (1) amendments to government regulation to include specific requirements for pilot automation training; (2) standardizations of cockpit automated systems and uniform applications of ergonomic design concepts; (3) re-evaluation of both public and private industry attitudes towards pilot training and certification goals; (4) evolution of public information gathering processes and statistical aviation safety analysis; (5) and a total, industry-wide re-evaluation as to the appropriate purpose and aim for advanced automation utilization in commercial aircraft during flight. Because a final solution can only be achieved if global regulatory bodies and private industry come together to solve the automation problem, it will continue unabated until the industry prioritizes the problem as commercial aviation's biggest safety threat.

Although some specific aspects of advanced automation are admittedly more problematic than others, one of the most specifically dangerous issues is the lack of uniformity and standardization of cockpit automation design, which has proven to be especially dangerous in certain, specific scenarios.[371] To solve this problem, both carriers and manufacturers must be

[370] *See* Chapter 2, *supra* at 26.
[371] Interview with Dr. Katherine Wilson on November 17, 2015. Ms. Wilson currently works as an investigator for the U.S. National Transportation Safety Board and has taken part in the investigations of several incidents and accidents attributed to issues related to advanced automation systems in modern airplanes and automation dependency in commercial pilots. According to Dr. Wilson, lack of cockpit automation design uniformity and standardization was found to be a contributing factor in the Asiana 214 accident (*see* Chapter 2, *infra* n 101 at 96),

willing to unify cockpit automation design by incorporating the use of scientific research concerning "human factors," also known as ergonomics,[372] which establishes best practices for the deliberate interfacing between man and machine. [373]

One question standing in the way of complete integration of uniform ergonomic concepts, however, is the persistence of different manufacturer design philosophies, and emphasis on whether final control authority of the aircraft should be granted to either the pilot or the machine.[374] Since no "correct" design philosophy has yet to be established as the safest method through which pilots must interact with their planes, the aviation industry and it regulators are left to ponder the correct approach. Regardless, ergonomics and also Cockpit Resource Management (CRM)[375] have been identified as two crucial methods to improve advanced human interfacing with aircraft automation notwithstanding preferences in final control authority. If incorporated into the final automation solution, both concepts must ensure pilots remain positively integrated into automated processes, ensuring pilots remain engaged with the computer flying the aircraft, instead of interfacing with the machine solely as automation monitors — a role which has been proven to encourage boredom, automation dependency, and loss of situational awareness during flight.[376]

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the Air France 447 disaster (*see* Chapter 2, *infra* n 93 at 210) and the China Airlines Flight 140 loss (*see* Chapter 2, *infra* at 19–20).

[372] *See* Chapter 1, *infra* at 12.

[373] *Ibid*. For a prior explanation on human factors and how they effect commercial aviation *see* Chapter 2 n 192.

[374] For prior discussion on differing manufacturer design philosophies and the effect they have on pilot authority *see* Chapter 2 at 13–14.

[375] Cockpit Resource Management (CRM) is defined in Chapter 2 n 38.

[376] *See* Air crash Investigation/Mayday, "Who's In Control?," (28 February, 2011), online: <https://www.youtube.com/results?search_query=turkish+airlines+1951>. For a complete analysis of the perils of exclusive human monitoring of advanced automation processes *see* Chapter 2 at 15.

A second critical change must modify how carriers and pilot training programs currently train commercial pilots to appropriately respond to automation threats. Accident reports for seminal automation dependency cases such as Asiana 214 and Air France 447 have proven a definitive lack of stick and rudder skills exists amongst current commercial pilots.[377] However, because of the statistical improvement in aviation safety as a whole and the potential effect additional manual flight training may add to overall training program footprints, there is little to no current economic incentive for additional airline emphasis on manual flight skills — especially at a time when airline economics depend heavily upon meeting passenger demands for cheap seats.[378] Thus, in order to realistically measure the actual impact automation threats have on flight safety risks, the way statistical data is gathered and analyzed to determine current aviation accident rates must be changed to include specific inclusion of reported automation issues, incidents and near-misses — thousands of which are reported every year on almost a daily basis.[379] Only then will carriers and other industry members be publically forced to report the true risk that aircraft automation presents to the flying public, the fallout from which will most certainly motivate the industry to take a more proactive approach.

A third change emphasized by the FAA PARC/CAST,[380] EASA[381] and RAS reports[382] is the demand for modification of flight training to include distinct modules on cockpit automation

[377] *See* Chapter 2 at 34–37 for a full discussion of both the Air France and Asiana flight accident investigations and the conclusions reached thereby.
[378] *See* Chapter 2 at 20–21 for a brief discussion of current airline economics, Low Cost Carriers (LCCs) and passenger demands for low carrier fairs.
[379] Andy Pasztor, "Pilots Rely Too Much on Automation, Panel Says," *The Wall Street Journal* (17 November, 2013), online: <www.wsj.com/articles/SB10001424052702304439804579204202526288042>.
[380] *See* Chapter 2 at 33, 43, 46 and 50.
[381] *See* Chapter 3 at 83–84.
[382] *See* Chapter 2 at 52 and Chapter 3 at 84.

such as integrated FMS, auto pilot and auto throttle systems, and the proper role pilot discipline must play with regards to the use of automated systems from the earliest stages of training. Because of the nature of piloting (and current manufacturers' preferences to retain the human pilot's role in automation oversight), until otherwise, pilots will always have to aviate, navigate and communicate as part of their baseline responsibilities,[383] but now in the automated age they must also learn to manage the various resources available to automate and simplify those responsibilities.[384] It is not enough for pilots to be able to monitor these systems, they must also be able to understand the logic and the parameters within which these systems operate the aircraft.[385] Therefore, knowledge-based training and visualization techniques must be incorporated into all levels of commercial airline pilot training to allow pilots to know and fully understand all automated processes, which would allow pilots to anticipate predictive behaviors of the airplanes they are flying, and educate them as to when these same processes may be leading them astray. In order to make flying safer, these new concepts must replace current methods of pilot training and certification methods based solely upon the successful completion of required check lists and check airman rides.[386]

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383 "Aviate, Navigate, Communicate" (A-N-C), is a phrase that has been used by pilots for many years. It is a reminder of Pilot In Command priorities during emergency situations, and can be used as a guide to create training scenarios. *See* FAA Activities, Courses, Seminars and Webinars, "ALCContent," online: <https://www.faasafety.gov/gslac/ALC/course_content.aspx?cID=40>.

384 Dan Mannigham, "The Cockpit: A Brief History" (1997) 80 No. 6 Business & Commercial Aviation, 61.

385 Liu, Kuo Kuang, "The Highly Automated Airplane: It's Impact on Aviation Safety and an Analysis of Training Philosophy" (1997), 36 (citing John A. Wise, *et al*, *Automation in Corporate Aviation: Human Factors Issues*, Federal Aviation Administration (Washington D.C.: 1993).

386 *See* analysis of checklist and check airman ride deficiencies in Chapter 2, *infra* 31–32.

An additional effective automation management skill that must be inculcated, tested and trained into pilots is the concept of pilot "resiliency" introduced by Captain Richard de Crespigny in the wake of the Qantas 32 accident[387] as a way for pilots to predict automated behavior by "staying ahead of the airplane" and its automated responses. A classic example of pilot failure to remain resilient and stay ahead of airplane automation is the Air France 447 accident, which will forever remain a tragic reminder of the dangers of unchecked automation dependency if changes to current pilot training is not made.[388] As specifically identified by the FAA PARC/CAST automation study,[389] young pilots are not receiving enough training to recognize inappropriate automation behavior, and not receiving the encouragement they need to build the confidence necessary to intervene if something goes wrong. In fact, some carriers highly discourage pilots from intervening with automated processes at all.[390] This is a distinctive characteristic distinguishing the "Children of the Magenta"[391] from previous pilot generations,

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[387] *See generally,* Richard Champion de Crespigny, FRAeS, "*Resilience* — Recovering pilots' lost flying skills," *Aerospace: The monthly flagship magazine of the Royal Aeronautical Society* (June 2015) Chapter 3 n 204. Qantas 32 was an Airbus A380-800 that experienced an uncontained engine failure while climbing out of Singapore Changi Airport on 4 November, 2010. As a result of shrapnel from the damaged engine entering into, and damaging many advanced FMS located in the avionics bay of the A380, Captain de Crespigny and the four other pilots in the cockpit at the time were forced to turn back to the airport and land the plane with significantly degraded computer systems, relying significantly on all pilots' manual flying skills and what Captain de Crespigny refers to specifically as "pilot resiliency" to work through computer system losses and other logistical problems to the point where pilots can eventually land the plane. Of the 449 passengers and 29 crew members reported on board Qantas 32, not a single injury was reported. As a result, Captain de Crespigny has been hailed as both a hero and a perfect example of how pilots should strive to attain a balance between basic airmanship skills and intimate automated knowledge of advanced aircraft automation. He now tours the world giving lectures on pilot resiliency in the wake of automation error or loss.

[388] For more information on the Air France 447 accident *see* Chapter 2, *infra* at 20–23.

[389] For more information on the FAA PARC/CAST report *see* Chapter 2, *infra* at 18–19, 33–37.

[390] *See* Interview with William H. Voss on 10 July, 2015.

[391] *See* Reinig, Neil, "Children of the Magenta" (28 December, 2014), online: YouTube <www.youtube.com/watch?v=pN41LvuSz10>.

who came of age in older aircraft without the ease and convenience of automation to assist them with piloting tasks.[392] Without appropriate confidence and prudence to know the limitations of advanced automation, airline pilots will remain susceptible to automation dependency, creating unnecessary safety risks to the flying public. Because both carriers and manufacturers have a responsibility to make aviation as safe as possible, at the very least, carriers must change their training programs and incorporate new philosophies and techniques if the automation issue is ever to be resolved.

A fourth crucial change must be made to all applicable regulatory laws and policies governing pilot training and automation interactions to force carriers to implement changes in pilot training and proficiency in advanced automation. Currently, Title 14 of the U.S. Code of Federal Regulations (CFR) Part 61 Sub-part F governs the licensing requirements for Airline Transport Licenses, and lists all basic pilot recruiting requirements. Known as "Phase I Training," all requirements for initial airline pilot training are established in Part 61 Section 135.345 Sub-part F, which includes, *inter alia*, initial training in flight locating procedures, aircraft weight and balance determination, basic meteorology, air traffic control protocol, navigation systems, and communication procedures.[393] A complete review of Part 61 reveals no requirements for pilot automation training or understanding of automation features and limitations. "Phase II Training," as outlined by Part 61 Section 345.347 does allow pilots to begin using automated systems in cockpits, should they so choose, but currently includes no formal requirements for such training.[394]

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[392] For more information on the differences between the current generation of automation-centric pilots and older generations of pilots *see* Chapter 2 at 17–19.
[393] 14 C.F.R. 135.345 (2006).
[394] 14 C.F.R. 345.347 (2006).

Alternatively, pilots may have a chance to gain more automation training through completion of the Advanced Qualification Program (AQP), recently implemented in the U.S. by the FAA.[395] The AQP is a voluntary training initiative offered to qualifying carriers certified under either Parts 121 (commuter airlines) or Part 135 (domestic or legacy airlines) of Title 14 of the U.S. Code of Federal Regulations. It is designed to improve aircrew performance by allowing commercial carriers to opt out of the normal Title 14 training requirements by developing their own training initiatives incorporating the most recent advances in training methods and techniques. [396] Although AQPs could potentially include specific automation training, at this point no formalization of the training is required by the AQP.[397] A similar situation exists for airline pilot training in Europe. [398] Areas such as Southeast Asia, however, are subject to little or no pilot training regulation at all, and are thus given full discretion to develop their own pilot training programs, which are often focused mainly on meeting high pilot production requirements to meet growing economic demands.[399]

Although the aviation industry has yet to respond to earlier calls for expansion and formalization of automation training in a comprehensive manner, one potential response was the

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[395] For more information on the AQP *see* FAA, "Advanced Qualification Program (AQP), online: <https://www.faa.gov/training_testing/training/aqp/>.
[396] Such training techniques include: Cockpit Resource Management (CRM) training and evaluation, Line Operational Simulations (LOS) for both Line Oriented Flight Training (LOfT) and Line Operational Evaluations (LOE) as defined in FAA Advisory Circular 120-35B and any other specialized training for instructors and evaluators determined by the operator as mandatory for inclusion for the AQP. Definition of the AQP itself and other specific requirements are explained at length in Chapter 3 at 54–55.
[397] *See* FAA "Advanced Qualification Program," *supra* Chapter 3 n 212.
[398] *See* CAA airline transport pilot requirements Chapter 3 n 211.
[399] *See* Asian Aviation, "Pilot Training," (9 December, 2012), online: <http://www.asianaviation.com/articles/364/Pilot-Training>. Many of the carriers discouraging pilot interaction with automated systems are often located in Southeast Asia, the training models for which are focused mainly in producing certified pilots as quickly as possible. This may have been a factor in the Asiana 214 accident. *See* Interview with Bill Voss, *supra* n 390.

"Multi-Crew License" (MPL) requirement adopted by the International Civil Aviation Organization (ICAO) in 2012 and subsequently endorsed by both the International Air Transport Association (IATA) and the International Federal of Air Line Pilots' Associations (IFALPA) later that year.[400] The MPL is different from previous licensing requirements in that it adopts competency-based training philosophies designed to assess pilot proficiency based upon actual pilot performance in a range of situations, instead of simply completing an outdated syllabus culminating in a check airman ride.[401] Although this is a step in the right direction, it is not enough to completely eliminate the automation threat.

A fifth change necessitated is the re-evaluation of both public and private industry attitudes towards pilot training. Part of this shift must begin with carrier and manufacturer investment in the expansion of simulator access to pilots — especially for those flying the newest and most automated machines.[402] It is through improved simulator access that carriers can allow pilots to practice and improve upon manual flying skills, however, carriers must also be willing to look the other way and eliminate any inherently punitive cultural expectations should pilots encounter any difficulties while improving their manual flying skills in the simulator.[403] In essence, pilots in training should be allowed to make mistakes, instead of being pressured to

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[400] *See* IATA/IFALPA, "Guidance Material and Best Practices for MPL Implementation," 2 ed. (July 2015), ix, online: <https://www.iata.org/whatwedo/ops-infra/itqi/Documents/guidance-material-and-best-practices-for-mpl-implementation.pdf>.
[401] For more on competency-based training philosophies *see* Chapter 3 at 81.
[402] *See* Kuo Kuang, *supra* n 385 at 69-70.
[403] *See* Interview with William H. Voss, *supra* n 390. ("If we are to allow pilots to use simulator time to really improve upon manual handling skills we have to ensure that such time does not evolve from session time to line checks. If a Captain crashes a simulator while attempting to improve upon his or her manual flying skills, such an exercise cannot and should not have any professional consequences on that pilot's career. Which is not necessarily the state of airline expectations or culture today.").

deliver flawless simulator performances in every check ride — a current attitude that only increases pilot reliance on automation to eliminate the possibility of pilot error.

Re-evaluating training attitudes, however, should not just start in the simulator. General "check ride philosophies" in all situations should be re-evaluated to include new criteria to fit commercial aviation safety needs in highly automated airplanes, requiring pilots to practice recoveries of all types — especially those necessitated from automation errors. This philosophy would replace current industry emphasis on pilot acquisition of only the knowledge necessary to pass their check rides.[404] Thus, check ride philosophies must be altered to incorporate performance-based criteria, such as pilot resiliency to automation errors and visualization techniques mentioned by senior aviators like Richard de Crespigny to ensure pilots can maintain high standards of safety, even during unexpected events. These philosophies should be built into both the front end of training curriculums and tested throughout a pilot's career, and would not have to necessarily increase training footprints if evaluated to specifically replace older, unnecessary training techniques.[405] If airlines were asked to incorporate these concepts in addition to traditional training modules as is, however, the expansion in training would almost undoubtedly be met with reluctance, due to undesirable economic effects additional training would induce. Therefore, an evaluation of all current regulatory pilot training requirements must simultaneously be completed to replace antiquated training requirements with newer rules based upon pilot training in newer, automated machines. Airlines must also make sure to place additional emphasis on junior pilot mentoring programs, so that older pilots with more manual flying experience can pass on their knowledge to younger flight crews. This "human dimension"

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[404] *See* Kuo Kuang, *supra* n 385 at 72.
[405] *Ibid*.

to flight training is crucial to the creating and maintenance of airline safety culture, and must also be a key element to combatting automation dependency issues as training protocols continue to evolve.[406]

Even if such improvements to pilot training and safety culture are adopted in the future, automation advocates will always argue that only a true balance of man and machine can achieve optimum safety results. In tandem with Airbus' 2011 release of its "Flight Operation Briefing Notes"[407] intended to assist pilots in developing the skills and experience necessary to effectively manage fully automated planes, Airbus also advocated for incorporation of the "red button" scenario into commercial aircraft — a concept already in full use by the U.S. military.[408] With this solution, Airbus proposes the utilization of full aircraft automation in "doomsday" scenarios, taking over complete control should the pilots be unable to recover the aircraft.[409]

Although automation opponents may disagree that the solution to automation dependency should not be more automation, Airbus may have a point that for every incident caused by automation, just as many incidents occur in which automation plays a positive role saving passenger lives.[410] This point is supported by incidents such as the U.S. Airways Flight 1549 bird

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[406] *See* Interview with William H. Voss, *supra* n 390.

[407] *See* Airbus Industrie, "Flight Operation Briefing Notes — Standard Operating Procedures, Optimum Use of Automation," online: <www.airbus.com/fileadmin/media_gallery/files/safety_library_items/AirbusSafetyLib_-FLT_OPS_SOP_SEQ02.pdf>.

[408] *See* John Markoff, "Planes Without Pilots," New York Times (6 April, 2015), online: <http://www.nytimes.com/2015/04/07/science/planes-without-pilots.html?_r=0>.

[409] *See* Interview with William H. Voss, *supra* n 390.

[410] One example of positive automation intervention occurred in the case of U.S. Airlines Flight 1549, an Airbus A320-200 en route from New York La Guardia airport to Charlotte, South Carolina. The airplane experienced a double engine failure after suffering a bird strike upon take off. Carrying 150 passengers and five crew, the Pilot In Command — Captain Chesley "Sully" Sullenburger ditched the plane in the Hudson River, saving the lives of all passengers and crew onboard. *See* William Langewiesche, "Anatomy of a Mircacle," *Vanity Fair Magazine* (31 May, 2009), online: <www.vanityfair.com/culture/2009/06/us_airways200906>. Upon investigation of

strike, during which advanced automation in the aircraft was credited for assisting the successful ditching of the Airbus A320 in the Hudson River without a single loss of life. According to senior NTSB investigator Earl F. Weener, the ditching of the Airbus is a testament to just how rugged and resilient modern automated aircraft are actually designed to be,[411] supporting the argument that whatever the final solution to the automation problem is determined to be, it must combine and optimize the positive attributes of both man and machine. While machines can be rugged, predictable and eliminate the risks posed by the repetitive actions and minutia required of commercial pilots, humans are crucial too in that they are capable of problem solving and independent sentient thought. Therefore, an optimization of commercial air safety must come from the combination of these characteristics.

In conclusion, automation in aircraft can be done poorly or it can be done well. Ultimately, it comes down to the philosophy employed by the automation engineers that makes a difference as to how the aviation industry should appropriately respond to the automation over-reliance/dependency issue. Until then, airlines, aircraft manufacturers, and manufacturers of sub-component parts will continue to be liable for accidents attributed to automation problems. The first question asked before crafting a solution is whether the automation is intended to replace or augment the pilot's role. Although some manufacturers have endorsed the possibility in the

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the accident, it was determined that Captain Sullenburger's ditching maneuvers of the A320 were assisted by Airbus flight envelope protections (*see* Chapter 2 at 28–29 for more information on flight envelopes), which kept the aircraft from stalling by reaching auto-pilot limitations on the alpha floor. *See* NTSB "Accident Report — US Airways Flight 1549," NTSB/AAR-10/03 PB2010-910403 (adopted 4, May 2010), 12, online: <www.ntsb.gov/investigations/AccidentReports/Reports/AAR1003.pdf>. For more information on alpha floor protections *see* Airbus, "Flight Control Laws," online: <www.airbusdriver.net/airbus_fltlaws.htm>.

[411] *See* Interview with Earl F. Weener on November 5, 2015. Mr. Weener is a senior investigator with the U.S. National Transportation Safety Board, and was involved with the investigation of U.S. Airways 1549.

future of replacing pilots altogether in commercial cockpits,[412] such a solution would inevitably create a tremendous engineering quagmire by requiring automation engineers to identify, and address all possible scenarios that could exist while piloting a plane. Whether or not this is advisable, or even achievable not only questions the current limitations of computer engineering, but also poses questions as to manufacturer, government and carrier liability should pilots ever truly be eliminated from the equation. It also begs the question: how complicated is too complicated? And if so, who should be accountable if something goes wrong? Could the aviation insurance industry continue to absorb such losses, even if fully-automated airplanes prove to be less safe?

Although aviation technology has evolved to the point where human beings are by far the weakest link in the chain, ironically, pilots also remain aerospace engineering's greatest asset.[413] To achieve maximum levels of safety, aircraft automation systems must straddle the bridge between too much flight automation and not enough reliance on pilots to provide rational judgment in situations when the computer fails. According to A330 pilot, aviation blogger and novelist Karlene Petitt, "This is a new world we face — a battle between automation and proficiency. The real question is: how will we win this war without losing thousands of lives?" And more importantly, can automation ever be considered failsafe against the imperfection of man? Only time will tell.

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[412] *See e.g.*, Paul Thompson, "Airbus Wants to Take the Cockpit Out of the Future," *Jalopnik* (1 July, 2014), online: <flightclub.jalopnik.com/airbus-wants-to-take-the-cockpit-out-of-the-cockpit-of-1598171449>.

[413] Eric Auxier, "Do Commercial Pilots Really 'Suck' at Manual Flying?," *NYC Aviation*, online: <www.nycaviation.com/2013/11/commercial-pilots-really-suck-manual-flying/#.Vln7VoSd7ww>.

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