Technology in the Aviation Industry

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Abstract

Technology is one of largest disruptors of modern society, and it is without a doubt it has made its mark in the aviation industry. New technological additions impact different actors within the industry differently and these disruptions can be analyzed using an Actor-Network Theory approach. Technology also has major effects on the mental models of employees within the aviation industry, sometimes even affecting the overall safety of flying. This thesis will analyze more in depth the various effects technology has on the aviation industry as a whole, first using Actor-Network Theory to analyze the differing effects technology has on all actors, and then narrowing in on employees with a Cognitive Science framework and analyzing how mental models of employees can be broken through the introduction of technology. A case study will be performed on the recent Boeing 737 MAX disaster and see how the tragedy occurred due to a breach of both Actor-Network Theory and Cognitive Science models of the pilots. The thesis will also briefly discuss how culture may also affect the mental models of aviation industry employees before finally providing examples of recent technological solutions to ensure safety of the skies for future generations.

Technology in the Aviation Industry

Introduction

Technology is one of the largest disruptors of the modern era. As society continues to move into the digital era, technology will continue to have major effects across a variety of industries from making human work easier to increasing profits to also adding new complications to processes where humans historically never had to worry about such change. Simultaneously, in recent years, one of the fastest growing and most important industries in the world is aviation. Without aviation, the millions of people who need to get from continent to continent for business, tourism, etc. would not be able to. Currently, around the world, aviation supports 65.5 million jobs all over the world, spread out between private sector jobs such as with airlines or airports to the public sector, with examples such as in civil air navigation services ("Economic Growth"). In addition to jobs, the industry alone has a GDP of $2.7 trillion, meaning if it was a country, it would rank close to Switzerland and Argentina ("Economic Growth"). By 2036, the aviation industry is expected to contribute $5.7 trillion to the global economy, supporting 97.8 million global jobs ("Economic Growth"). An industry as important as the aviation industry that is also growing at the same time as the technological boom is bound to heavily integrate technology into its growth. However, just as technology has disrupted our society as a whole, it also has had a significant impact on the aviation industry. This thesis will aim to provide insight into the human effects of technology's addition to the aviation industry. First, an Actor-Network Theory analysis will be used to analyze how technology impacts the various actors within the aviation industry. Afterwards, a Cognitive Science framework will be used to further analyze the mental impacts technology will have on specific actors within the

industry, closing out with one very recent case study of what happened with the Boeing 737 MAX tragedies in Indonesia and Ethiopia.

Actor-Network Theory

There are many influential actors within the network that is the commercial aviation industry. The core of the network lies with airlines, who supply the planes, staff, and the capability for the network to actually take off. This actor can further be broken down into the corporate office and flight crew, who each may have differing goals, especially demonstrated during times of pilot or flight attendant strikes. Another important actor in this network is paying customers, who provide the revenue for airlines to operate. This is also the actor that airlines must serve and appease in order to continue to be able to fly. Lastly, are the employees of the aviation industry. This spans from air traffic controllers, the people who ensure that all air traffic safely makes its way to its destination, to pilots, to airport workers. A brief summary of some of the varying effects technology can have on these different actors can be seen in Fig. 1.

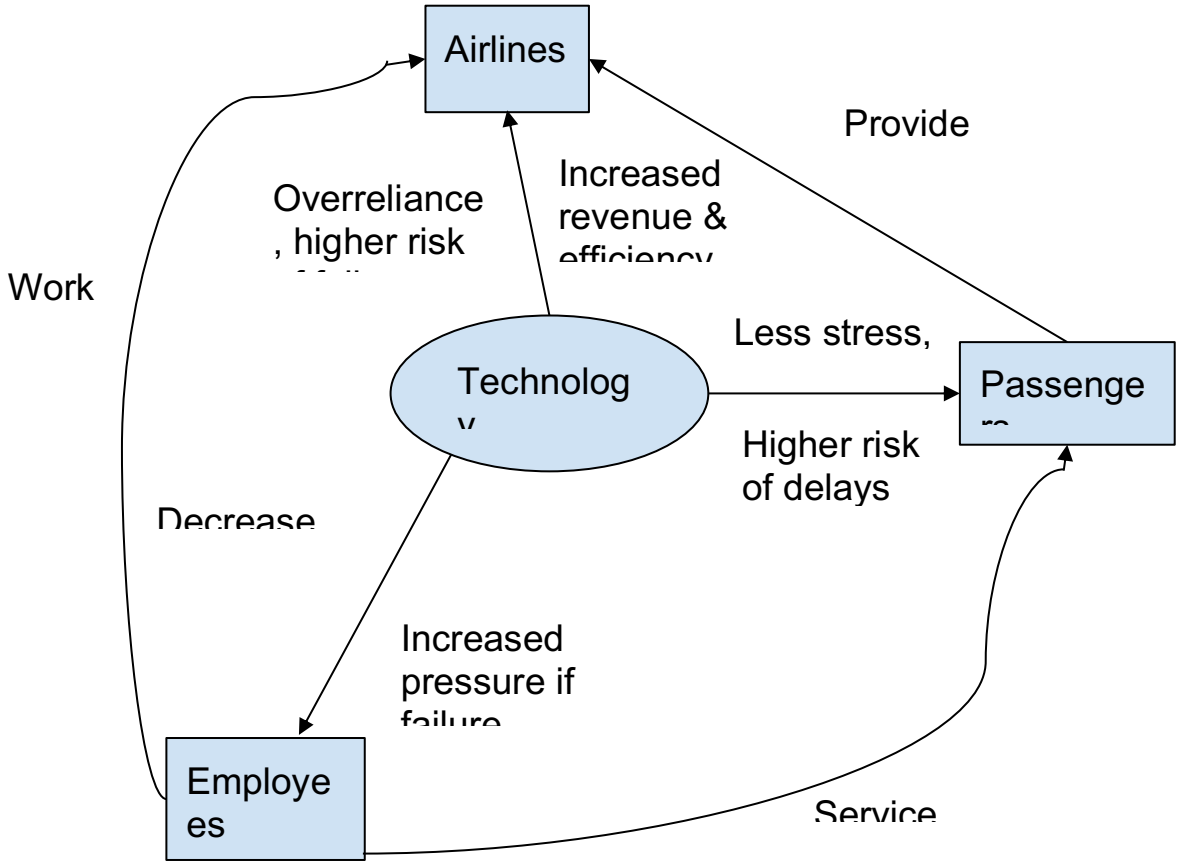

Fig. 1. Actor Network Theory framework summary

Firstly, technology has been very quickly adopted by airlines in recent years to help speed up many processes. Over the years, many airlines have digitized their entire system, using IT systems to manage many everyday tasks, from customer management, such as check-in, flight reservation, baggage handling, etc., to internal managerial tasks like crew management and providing flight information to civil air navigation services, such as the Federal Aviation Administration (FAA) in the United States ("Information on Airline IT Outages", 2019). Having IT systems manage all of these tasks greatly reduces the work that airlines have to do. No longer do they need to have people order and plan schedules and flight routes, manage customer information manually, etc.. All the data only needs to be inputted into a system and a computer program would automatically take care of it, lowering the workload for many of the airlines' employees. Many airlines even outsource their IT systems to third party IT providers who can

better specialize in the operation and maintenance of these important systems ("Information on Airline IT Outages", 2019). All this may allow them to eliminate some employee roles, helping to lower their cost of operation. On the flip side, it also frees up employees to handle other more complex tasks that computers cannot, helping to increase efficiency. Many of these IT systems also directly interface with travel booking sites, other airlines, and the FAA, forming a very important part of the communication network for the airline and the many other important nodes within the industry ("Information on Airline IT Outages", 2019). With the heavy amount of data airlines can collect from IT systems, they can also shift to digital merchandising and retailing to better serve their customers, increasing airlines' own revenues ("Information on Airline IT Outages", 2019). Thus, technology can accomplish a lot for airlines, helping them to increase their revenue and efficiency while simultaneously lowering their costs.

However, with almost all aspects of an airline's daily tasks delegated to an IT system, any technological issue that arises with the system can have catastrophic effects for the airline and even the rest of the industry. In June 2018, American Airline's subsidiary, PSA Airlines, experienced an IT issue that led to the cancellation of around 3,000 flights over the following week and ended up costing American Airlines an estimated $35 million ("Information on Airline IT Outages", 2019). Another incident took place two years earlier in 2016 when an outage in the system that Delta Air Lines uses to check in and board passengers occurred, resulting in the cancellation of 2,300 flights over the course of three days and cost Delta $150 million ("Information on Airline IT Outages", 2019). All these delays not only cost airlines a huge amount of money, but also have repercussions around the world. Many airlines operate out of major hub airports where much of their traffic connects through. Delays and cancellations of flights at one hub airport would thus have a ripple effect worldwide, resulting in missed

connections all over the world. At this point, airlines would need to reach out to aviation regulators to figure out logistics related to new flight paths for the delayed flights or partner airlines to transfer passengers to, affecting many new actors within the industry. IT systems also operate in an extremely dynamic, data-intensive environment that demands around-the-clock availability since major airlines have flights in the sky 24/7 ("Information on Airline IT Outages", 2019). This makes it extremely difficult for airlines to be able to take their systems offline at any point to perform routine maintenance or even replace old, vulnerable software ("Information on Airline IT Outages", 2019). All in all, the usage of technology introduces many new costs and issues that airlines now have to deal with. Ultimately, however, it comes down to weighing the benefits and the costs from such systems and technology that they provide to airlines and as technology continues to develop and improve, most airlines have chosen the path of integrating more technology for their added benefit at the cost of once in a while catastrophic technology failures.

The next group of major actors within the aviation industry are the paying passengers, whose money keeps the industry aloft. Increased usage of technology are designed to streamline passenger experience when flying. On top of all the additions that airlines have introduced, airports themselves have added many technological features to make the airport experience smoother for passengers. Many airports are transitioning away from “Airport 2.0”, which focused on self-service and process efficiency to “Airport 3.0”, which emphasizes using digital technology to optimize flow monitoring and passenger processing (Jarrell, 2018). The power of cloud computing enables airports to more easily simulate and analyze passenger flow data, allowing them to better know when and where to allocate resources to adapt to changes in demand between peak and off hours (Jarrell, 2018). Automation and self-service have also

helped make passenger processing easier. One of the newest examples include self-service bag-drops. They allow passengers to quickly drop off their bags at their own convenience, helping relieve congestion during peak hours at the check-in desk and improving passenger flow through the airport ("Why airports are investing in automation", 2019). All this new technology speeds up the entire airport process, from the check-in desk to security to the boarding process, reducing lines and crowds at each location. Simplifying the process overall makes the whole process much more stress free for all passengers, making the airport experience much more enjoyable. With less crowds and lines, passengers also save a lot of time and do not need to arrive hours in advance before their flight departs. In summary, technology serves to alleviate stress from passengers and also to help them save time, all very healthy benefits overall.

However, just like for airlines, technology failures can cause severe headaches for passengers. The overreliance on IT systems on airlines' part can lead to extreme delays and cancellations, severely impacting passengers' plans, whether they be tourists with a schedule to follow or a businessman flying to an important meeting. Such incidents can lead to passengers having to make out-of-pocket expenses for these sudden changes ("Information on Airline IT Outages", 2019). Moreover, there is not much protection provided to passengers in these circumstances, with compensation differing from airline to airline, creating very unequal compensation for different passengers ("Information on Airline IT Outages", 2019). Some airlines even treat IT outages as an "act of God", meaning they do not need to provide the full compensation that they would have needed to provide for other mechanical issues ("Information on Airline IT Outages", 2019). The burden technology failure can place on passengers to find travel alternatives and comb through long, confusing airline obligations to figure out what rights

they are entitled to is a new stress that they are susceptible to face now thanks to these new additions.

The last set of actors in the aviation industry to be analyzed are the employees of the industry, more specifically those involved in the actual flying of planes, such as pilots and air traffic controllers (ATC). Technology can provide many new resources for the industry to make flying more efficient and safe. Many airports have introduced a virtual control tower, which uses video sensors to replicate the view and tracking capabilities of a traditional control tower ("Three digital technologies that are about to reshape aviation", 2016). Newer technology has also enabled satellite-based tracking systems, which allows both traffic controllers as well as other pilots to track nearby aircrafts twice every second without the need of conventional radar ("New Air Traffic Control Technology Improving Safety"). Such new features greatly increase the safety of flying as now both ATC and pilots are able to better track planes as well as current weather conditions to more safely plan efficient flight routes and traffic. The automation of much of this technology also lowers the workload for many of these employees as much of the more manual work can be performed through automation.

Unfortunately, just like the previous actors, there are many downsides that technology also brings to this set of actors. One of the biggest fears that many employees in this industry have is being replaced by technology. Many wonder if it is possible that in the near future computer programs will be able to perform all the work that ATC does, completely eliminating the need for this position. Similarly, the role of a pilot in recent years has already been transformed from commanding the plane to something more of a troubleshooter (Wendover Productions, 2018). Besides being replaced, automation also increases the workload and knowledge that aviation employees need to know. On top of the basic mechanics of flying,

employees now need proper training on what to do with technology if it should fail (Baker, 2018). Moreover, if the technology does fail, employees will now be tasked with both trying to perform their regular duties with the addition of handling the technical issue, placing a lot more pressure onto their shoulders. Technology can do a lot to make aviation employees' jobs easier but can also be an additional source of stress for them.

Cognitive Science Framework

A further analysis can be conducted on how technology affects the mental state of the employee actor group using a cognitive science framework. One of the biggest effects that technology has on the aviation industry's employees is a decrease in their situational awareness, especially for air traffic controllers, who now have diminished roles. Situational awareness is a vital trait that ATC must possess as they need to extract differing information from various screens, comprehend the information they have extracted, and extrapolate as to what that information may imply for future conditions in the sky (Nunes, 2003). However, it is believed that while such visual aids that are commonly used as predictive aids for ATC do reduce effort and increase performance, it may reduce long-term retention of knowledge, which can have serious implications for problem-solving skills, something vital to an ATC's role (Nunes, 2003). This decrease in long-term cognitive performance is believed to arise from the fact that the predictive aid performs most of the complex thinking for ATC workers. In a study conducted by Ashley Nunes of the University of Illinois at Urbana Champaign, ATC workers were split into two groups, one receiving predictive assistance and the other not. The study showed that those who did not receive the aid first had to understand the problem on their own terms, then problem solve over time, generating their own strategies as they progressed, improving with each new

challenge presented (Nunes 2003). On the other hand, the group given the aid did not develop this method of critical thinking, resulting in constant scores throughout the entire study (Nunes 2003). All this group was doing was relaying information generated by the aid to pilots and other relevant actors, meaning they had no part in the actual mental processing and generation of the solutions.

For these reasons, it is very important for designers of aid technology for ATC to ensure their systems do not decrease the cognitive demand for controllers. One recent example of such technology is integrating advanced display information onto ATC displays. New technology, such as Free Flight, gives pilots the freedom to route their own aircrafts as long as they maintain safe separation distances (Endsley, Sollenberger, Nakata, & Stein, 2000). Like many predictive aids, this completely reduces the role of ATC to only stepping in on the rare occasion when they notice two planes that are too close (Endsley, Sollenberger, Nakata, & Stein, 2000). Thus, ATC workers have no active role in the navigation of planes anymore, resulting in them completely lacking situational awareness of the skies they are in charge of. Advanced display information on the screen hopes to mitigate this by communicating in advance information to ATC workers. In the case of Free Flight, these displays would tell ATC when pilots intend to change their flight routes and display all relevant information such as the plane's heading, altitude, etc. (Endsley, Sollenberger, Nakata, & Stein, 2000). From Endsley et. al.'s study of these displays, it was shown that they dramatically increased ATC employee's situational awareness of all the things happening in the skies they are in charge of (2000). More technology like the advanced displays used in Endsley et. al.'s study should be implemented and tested to ensure they do not interfere with the mental models of ATC workers, ensuring they are prepared to face the challenges of aviation safety.

Another fear that many have with increased technology in the aviation industry is an increased mental burden on employees, both in ATC and pilots. For example, while the advanced displays studies by Endsley et. al. work to help increase ATC's situational awareness, there are also fears that they may bombard ATC with too much information, which would end up being a mental distraction rather than provide a cognitive boost (2000). On the pilots side, technology has given them much more freedom in choosing their own routes. Systems such as Free Flight or satellite-based tracking grant pilots much more freedom to choose their own paths since they have all the relevant information to safely make such decisions. However, just like with ATC, there are many concerns that presenting all this data to pilots overloads them with too much information while they are in the air (Gui, et al., 2015). The issue with overburdening pilots is that it will affect their mental state while they are flying, hindering their decision-making, attention skills, and spatial orientation (Gui, et al., 2015). All three are extremely important for plane safety. In the ever-changing condition of the sky that planes fly through, pilots are tasked with making very important, sudden decisions to maintain plane safety. Simultaneously, in order to do so, they must be paying very close attention to all their instruments to gather the right data of where they are and what conditions may be coming up. Oversaturating pilots with information will slow them down in making sudden decisions and also interfere with them paying attention to the right data they need at that moment, which could become very dangerous for the plane. Thus, it is very important that technology does not interfere with these mental models of pilots and ATC to ensure safety in the skies.

Boeing 737 MAX

One case of where the introduction of technology led to a terrible disaster is with the recent Boeing 737 MAX disaster. The fourth generation of the Boeing 737, the 737 MAX took its maiden flight in January 2016, entering passenger service in Malaysia in May 2017 ("Boeing 737 MAX", 2020; German, 2020). However, within two years, two fatal crashes would occur, one in Indonesia and another in Ethiopia, leading to a worldwide grounding of Boeing's newest project. One of the biggest changes to the plane were new, larger, and more efficient engines that allowed it to fly farther and carry more passengers (Ghilarducci, 2019; German, 2020). However, the drawback to these engines was that since they were bigger and Boeing wanted the 737 MAX to service smaller airports with limited equipment, they had to move the engines slightly forward and higher under the wing (German, 2020). This change disrupted the aerodynamic balance of the plane, causing the nose to pitch up more often in flight, increasing the risk of a stalling (Ghilarducci, 2019; German, 2020). To compensate for this, Boeing included a new software in the plane to automatically push the nose back down should it rise too high, called the Maneuvering Characteristics Augmentation System (MCAS) (Ghilarducci, 2019). It was this new technological addition that would lead to the tragedies in Indonesia and Ethiopia. Both Indonesian and Ethiopian aviation safety agencies heavily placed blame on the MCAS system that led to the two crashes (German, 2020). The Indonesian final report for the Lion Air Flight 610 crash found that the only sensor MCAS relied on had a fault and flight crews were inadequately trained to use it, leading to improper maintenance and cockpit confusion moments before the crash (German, 2020). The Ethiopian analysis for its crash led to similar results as the Indonesians, citing flaws with the MCAS sensor system as well (German, 2020). Another major flaw that both reports cited was the lack of training and guidance on the MCAS system in flight

manuals or flight crew training, which was in the form of an hour's worth of an iPad-based course that barely mentioned MCAS (German, 2020). Similar pilot complaints came from pilots on the other side of the world, with Southwest Airlines and American Airlines pilots in the United States making similar complaints after the initial Indonesian crash (German, 2020). The primary reason for this lack of training was to minimize the cost and time of certifying pilots to fly this newer model of plane (German, 2020). For this reason, Boeing had asked the FAA for support to consider the MAX as just another model of the 737 despite all the new changes that were added, limiting the amount of training necessary to fly the MAX (German, 2020). This lack of training, subsequently led to pilots not knowing how to react when MCAS engaged, resulting in conflicting actions taken between flight crew and the plane's autopilot, leading to the two tragedies (Baker, February 2020).

There are many significant issues that this case raises, especially from Boeing's actions. Leaks of internal documents showed that many Boeing employees already knew of issues with the MCAS system years before the two crashes. Text messages from two of the company's top pilots from all the way in 2016 complained of the MCAS's habit of self-engaging, calling it "egregious" (German, 2020). Similar emails from 2018 showed similar sentiments from other Boeing employees. "I still haven't been forgiven by God for the covering up I did last year," one employee wrote (German, 2020)."This airplane is designed by clowns who in turn are supervised by monkeys," another employee wrote (German, 2020). Beyond these internal leaks, there were also times when Boeing's public responses were questionable. For example, after the Lion Air crash in Indonesia, Boeing's only response was for pilots to simply turn off MCAS should they find themselves in a similar situation to Lion Air Flight 610 (German, 2020). That is a terrible response as not only do they not address or fix the issue, they are essentially asking pilots to turn

off a security feature that they placed into the 737 MAX themselves. In addition, after both crashes occurred, there seemed to be a war of words between pilots and Boeing executives. After the Lion Air crash, American Airlines' pilot union approached Boeing, asking for more information on a system that had a capability of killing their pilots (Baker, May 2019). One of Boeing's vice presidents responded by saying they did not want to overload crews with "information [about MCAS] that was unnecessary", which was clearly false as MCAS had already crashed Lion Air Flight 610 (Baker, May 2019). Similarly, after the Ethiopian Airlines crash, Boeing's CEO placed blame for the crash on the pilots, saying they failed to follow Boeing's emergency procedures, a point in direct contradiction to results from crash investigators (Baker, April 2019). These are all examples of a shift in Boeing's culture from one focused on pilots to one that favors money and profit. Traditionally, Boeing had always been the planemaker that shunned automation, instead trusting pilot skill, something that in turn led to much respect from pilots (Baker, April 2020). Thus, many pilots felt betrayed by Boeing when they found out they were completely left in the dark about MCAS, a system that many felt violated the trust that used to exist between Boeing and pilots (Baker, April 2020). Boeing had violated this philosophy of trusting pilots and keeping them in the loop ultimately, for money (Ghilarducci, 2019). Such a breach of its own philosophy may stem from a change in the culture at Boeing. Many of Boeing's oldest employees say the culture shift began after the McDonnell Douglas (MD) Merger in the late 1990s (Chakrabarti & Tatter, 2020). When Harry Stonecipher, then CEO of MD, became CEO of Boeing in 2004, he made it explicit that he wanted Boeing to be "run like a business rather than a great engineering [firm]" (Chakrabarti & Tatter, 2020). Finance people became the dominant people in the company, and bit by bit, this drive for shareholder value above everything else trickled-down from management, changing the entire

culture of Boeing (Chakrabarti & Tatter, 2020). Such a change has a dramatic effect on employees, completely changing their mental models as they continue to work in Boeing. Instead of caring about Boeing's old philosophy of good engineering and trust in pilots, employees are now in a mental culture that is profit-driven, throwing the old philosophy completely out the door.

An in-depth analysis of what happened with the 737 MAX unfortunately showed that the tragedies in Indonesia and Ethiopia were unavoidable. While the 737 MAX was supposed to be a more efficient and cost-saving plane, when Boeing introduced this new technology to the aviation network, they failed to fully educate one of the key actors of the network: the pilots. Pilots were completely left in the dark about the MCAS, leaving them helpless in the situation when it failed. Boeing had ignored Actor-Network Theory but trying to implement new technology but not ensuring that all actors within the network were fully educated on the addition. Similarly, there were also many cognitive science failures that Boeing exhibited. Leaving pilots in the dark completely ignores the mental model of pilots while in the air. Airline pilots are trained to be able to safely fly in many extreme circumstances, but all this requires accurate information on conditions around them as well as knowledge of all the equipment in the cockpit (German, 2020). By not providing full training to pilots on MCAS, Boeing broke this mental model of pilots for safe flying, ultimately ending in disaster and the loss of over 300 lives.

Conclusion

Technology has greatly changed the aviation industry in the past couple of years. Its introduction has greatly disrupted the many actors within the industry, generating profit and

increasing efficiency, but also adding stress and creating an overreliance for the industry as a whole. Technology can also create major disruptions for the cognitive models of many of the employees in the industry, resulting in a loss of situational awareness and also impacting the safety of flying. The importance of maintaining these frameworks when introducing technology is evident by the Boeing 737 MAX disaster. Boeing had failed to keep an entire actor in the network, pilots, in mind when introducing new technology to the 737 MAX, leading to a severe disruption in the mental model of the pilots while they were flying, ultimately resulting in tragedy. The case of the 737 MAX also exemplifies the importance of a moral company mental culture. There is strong evidence supporting that a shift in company values from good engineering to profit resonated through all of Boeing, and when employees work under such a profit driven mental model, ethical engineering exits the picture.

Automation and new technology will not be going away anytime soon. Both Boeing and Airbus are reportedly designing new systems with younger pilots in mind (Pasztor & Tangel, 2019). Airbus has even unveiled an idea of placing touchscreens inside of its A350 cockpits (Pasztor & Tangel, 2019). "Automation can help by verifying that pilots are doing the right things, and then helping them all the way through an incident," said Kevin Hiatt, a former airline captain and industry safety executive (Pasztor & Tangel, 2019). Ultimately, the goal of implementing new technology is to improve the safety of flying. As long as engineers keep all actors of the aviation industry in mind when designing new technology for the industry, it is possible for both automation and safe flying to coexist, helping to keep safe the growing number of millions each year flying across the planet.

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