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Fight for Flight: The Narratives of Human Versus Machine Following Two Aviation Tragedies

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Abstract

This study provides insight into the relationship between human and machine in the professional aviation community following the 737 MAX accidents. Content analysis was conducted on a discussion forum for professional pilots to identify the major topics emerging in discussion of the accidents. A subsequent narrative analysis reveals dominant arguments of human versus machine as zero-sum, surrender to machines, and an epidemic of mistrust. Results are discussed in the context of current issues in human-machine communication, and we discuss what other quickly automating industries can learn from aviation's experience.

Keywords: human-machine communication, aviation, narrative, automation, qualitative

Introduction

At 37,000 feet over the West Coast of Australia, a First Officer is returning to the flightdeck after a regularly scheduled break in the passenger cabin. As is customary, the Captain asks, "How is it back there?" The expected response is probably something like "good," but a pilot hardly expects to hear "It's carnage out there!" But, that is exactly what occurred on the Qantas Flight 72 (Flight 72) on October 7, 2008 (O'Sullivan, 2017). Just prior, the plane had suffered two sudden dives, all 303 people aboard the aircraft experienced momentary roller

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coaster-like conditions, from +1g to −0.8g and back again and again. Thrown into ceilings and galleys, 9 of 12 cabin crew members were seriously injured or unconscious. Countless passengers littered the cabin along with broken glass, ceiling panels, oxygen masks, and anything that was not tied down during the harrowing episode. Was it an exceptional bout of turbulence, an accidental control input, a structural failure? Fortunately, quick thinking by the crew allowed them to identify the offender—the flight control computer—or in other words, the autopilot. The same machine which had controlled over 20,000 hours of safe flight over the plane's lifetime was now violently throwing the plane into a dive. The Captain, attempting to control the aircraft later recounted, "I'm in a knife-fight with this plane. It isn't a fair fight; knife-fights never are" (Sullivan, 2019, p. 2).

Fortunately, the crew of Flight 72 successfully landed the aircraft and all aboard survived. However, just over 10 years later a similar situation ended in tragedy aboard Lion Air Flight 610 (Flight 610). The accident, also involving an automated system that pitched the airplane toward the ground, featured an epic struggle between human and machine lasting nearly 10 minutes (KMKT, 2019). Just months later, a nearly identical accident took place outside Addis Ababa on Ethiopian Airlines Flight 302 (Flight 302). Though Flight 302's pilots had received special training following Flight 610's demise, the crew were still unable to compensate for the commands made by the plane's automated systems. The accidents led to the global grounding of the aircraft involved, the new 737 MAX, which had entered service just over a year earlier (Helmore, 2019).

The resultant accident investigations, legal proceedings, and debates among engineers and pilots are having a profound impact on the aviation profession. Besides the usual suspects such as manufacturers, airlines, and regulators, the professional pilot community is also grappling with the meaning of the incidents. Though the debate about automation on the flightdeck has been active for decades prior, the 737 MAX accidents' visceral, physical battle between human and machine is causing long-held animosity toward automation to boil over; but also the uncomfortable acknowledgment by some that the gradual erosion of human authority in favor of machines is necessary. The longstanding debate in aviation is reflective of the tension between professionals and machines in a growing number of industries, including journalism (Carlson, 2015), surgical care (Ruskin et al., 2020) and pharmacy (Piercy & Gist-Mackey, 2021). Machines are also assuming more control in everyday life. From "robo-advisors" managing finances to autonomous cars transporting us, the tension between human and machine agency is becoming more salient each day. As a profession on the frontlines of the human-machine interface, this watershed moment offers an opportunity to see how the meaning of concepts like authority, skill, and agency are challenged by machines both in aviation and beyond.

In this paper, we investigate the emergent narratives in the professional aviation community as they process the meaning of the crashes, redefine profession and purpose, and reconcile human and machine on the flightdeck. First, we review aviation's relationship with automation over time and note parallels to key issues in human-machine communication. Next, we briefly summarize the accidents in question and conduct a content-narrative analysis on the world's preeminent professional pilot forum as they discuss the accidents. Results have implications for future debates that will inevitably occur in human-machine communication as machines replace humans.

Automation in Aviation

The image of a pilot struggling with the controls, battling swirling winds, and dodging clouds is no doubt compelling. But such a depiction is closer to Hollywood than the flightdeck of a modern commercial airliner. Stepping into the modern cockpit presents the uninitiated viewer with a kaleidoscope of lights and colorful displays. The lack of *old-fashioned* analogue dials and gauges is a marketing point for manufacturers. The industry-speak for a modern flightdeck presages the dominating role of electronics: they are known as "glass cockpits" (Farvre, 1994). On aircraft from one major manufacturer, the role of the human seems especially diminished; instead of a T-shaped control yoke in front of the pilots' seats, control has been relegated to a small joystick that looks more at home on an Atari than an aircraft.

Piloting an aircraft is a task that lends itself to automation—long, monotonous hours in cruise are simple for a machine to monitor but a monumental task of concentration for humans. Over the course of decades, more automated systems have been added to planes. As such, the broad term *flightdeck automation*—though standard industry jargon—encompasses an ecosystem of various technologies which incorporate everything from robotics to artificial intelligence (AI). For example, while monitoring automation such as a speed-warning system only requires a sensor and display, control automation like the autopilot requires calculation/judgment and robotic control. Recent advances, such as in-flight weather forecasting and automatic route-modification, combine all three—sensors, judgment, and control—with AI. Thus, the modern flightdeck is a quintessential example of the "cluster" of technologies and processes that define modern workplaces where human-machine communication takes place (Fortunati & Edwards, 2021, p. 22). With control automation just now becoming common in production cars, it is indicative of aviation's long history with automation that Tesla's well-known implementation is marketed as *autopilot*.

The increasing capability and presence of automation on the flightdeck has not always been welcomed by pilots. Like other industries such as pharmacy and finance, new technology at times caused *automation anxieties* as the working environment and job scope changed. For example, increasing automation in pharmacy work can lead pharmacists to worry about losing their jobs to machines (Piercy & Gist-Mackey, 2021). This parallels a current controversy in aviation where—citing the capability of automation on the latest jet models—airlines are currently seeking approval for single pilot operation of commercial aircraft (Frost, 2021), a move that has not been received well by pilots and industry groups (Driskill, 2021). In addition to anxieties for aviators, more machines controlling the plane meant pilots felt an increasing "distance" from the aircraft (Tsang & Vidulich, 2002). Several high-profile accidents caused by a pilot's failure to understand complex automation modes, or the inability of pilots to recover when automation failed, led to calls for a new paradigm of "human-centred" automation (Billings, 1996). That proponents chose to call it "human-centred" says both what they wish for and also their view of current technology: indifferent machines designed for an automation first, human second, era.

Agency

The introduction of the Airbus A320 into revenue service in 1988 was a pivotal moment. The new plane was equipped with automatic systems designed to keep the aircraft in the *flight envelope* (i.e., controllable state). Unlike other aircraft that would simply warn pilots when flying at the edges of this envelope, the Airbus computers would override the pilots. Airbus also chose to do away with mechanical connections between the controls and the control surfaces—replaced with electronic signals that humans may initiate, but only machines could approve (Farvre, 1994). It was not tacit but outright acknowledgment that ultimate authority over safe flight was best left to a machine; regardless of the truth it was understandably offensive to many pilots (Ibsen, 2009; Sarter & Woods, 1997).

Airbus's decision illustrates how the negotiation of human and machine agency can build new organizational and social structures (Gibbs et al., 2021). In the Airbus structure, humans were symbolically placed in a fenced area, overseen by machines in watchtowers. But, the structure of Boeing's philosophy remained traditional: trust and ultimate control authority remained with the pilots. The rift between the world's two major aircraft manufacturers has endured ever since the A320 flew in 1988, and perhaps the reputation of Boeing as being the *pilot's aircraft* has added to the significance of the 737 MAX incidents studied here. This wasn't *supposed* to happen on a Boeing where human agency is paramount. How could it be that a rogue machine could fight the pilots and win—had Boeing thrown in the towel and silently abandoned their philosophy? With their pride in question, professional aviators anxiously awaited word from investigators. What ultimately emerged tells a complex tale of corporate, regulator, human, and machine failure; we summarize below.

Flight 610 and 302

Both Flight 610 and 302 took off from their respective airports normally in excellent flying weather. But, shortly after take-off and with the plane still at low altitude, both flights experienced sudden pitches downward. On the flightdeck, a cacophony of warnings sounded, including a stall warning (suggesting the plane was flying too slow), and the overspeed warning (suggesting it is flying too fast). Bewildered at this impossible situation, both crews counteracted the pitch down by *pulling up* with the controls. Seconds later, another inexplicable pitch down. Flight 610 continued for several minutes, oscillating up and down as the machine pitched down and pilots pitched up. Aboard Flight 302, the pilots used all their strength to pull on the controls but only managed to maintain roughly level flight for a few minutes. In the end, both flights eventually became uncontrollable and impacted the ground at high speed, leaving only small pieces of debris.

Invisible Machines

The 737 MAX is a modernized version of a much older aircraft that originally entered service in the 1960s. Over many iterations, changes to the length of the plane, fuel capacity, and engine types required minor tweaks on the flightdeck, but by and large the pilot of a 1960s 737 could fly a 2020 version and vice versa. The 737 MAX however incorporated exceptionally large engines that made a substantial change to the way the aircraft handled. In order to spare airlines the cost of a pilot retraining program for a new aircraft, Boeing needed to find a way to comply with regulations stating the new plane must handle like the old one. Boeing's solution was to implement the Maneuvering Characteristics Augmentation System (MCAS), a system that automatically made control inputs to make the plane *feel* like previous models. Boeing seemingly did not want many questions about MCAS. Besides ensuring it had a forgettable name and bland acronym, Boeing declined to include information about MCAS in the official pilot training documents for the MAX. And, in the 1,600-page pilot's manual, MCAS was virtually anonymous, mentioned just once.

Silent Malfunctions

The pilots aboard Flight 610 likely had no idea MCAS existed or how to identify its operation. But this was the system that malfunctioned aboard both flights and began thrusting the plane toward the ground. Compounding matters, Boeing had omitted any aural or visual alert of MCAS activation on the flightdeck. And, MCAS had been programmed to move control surfaces faster than the human pilots could (Gates, 2019). The pilots of Flight 302, benefitting from the preliminary investigations of Flight 610, had been briefed on the existence of MCAS, but Boeing had revealed little information about the obscure system and the operational properties of MCAS were still a mystery to the crew on their fateful flight. In sum, the pilots were fighting against a silent machine which was faster, stronger, and ultimately victorious.

Reactions

In the aviation industry, reaction to the crashes has been understandably mixed, with blame placed on everyone from the original designers of the 737 to manufacturers of flight simulators (Helmore, 2019). As more information continues to be revealed in the ongoing investigations, blame has gradually shifted away from the pilots and onto Boeing. Many pilots, having an affinity for Boeing due to their design philosophy, have found this an uncomfortable position to take. In truth, there were a set of actions the pilots could have taken to save the plane, but this sequence is only obvious in hindsight. To gain an understanding of how the professional aviation community is coming to terms with the accidents, we visit the largest online community forum for aviation professionals. Our investigation is driven by three research questions:

> **RQ1:** What are the main points of discussion in the professional aviation community regarding the 737 MAX accidents?
>
> **RQ2:** How do the 737 MAX crashes challenge or reinforce existing narratives of human and machine in aviation?
>
> **RQ3:** What narratives emerge from the 737 MAX debate and what do they tell us about the relationship between human and machine in industries beyond aviation?

Methodology

The Professional Pilots Rumour Network (PPRuNe) is a global forum community where professional pilots discuss prominent aviation news. At the time of analysis, the forum required a registration process that verifies all members are aviation professionals (e.g., pilot, mechanic, cabin crew member). One research assistant gained access to the forum because she was an Air Force pilot trainee. Although the forum requires membership to utilize functions like search and thread bookmarking, all posts on the forum are publicly accessible, indexed by all major search engines, and require no special permission to view. After consulting the Internet Research: Ethical Guidelines 3.0 (Franzke et al., 2020) and the accompanying materials, we determined this to be a low-risk forum (Moreno et al., 2013). Though authors post with no expectation of privacy, and may post behind pseudonyms, we have lightly edited quotes to reduce discoverability. We downloaded discussion threads relevant to the 737 MAX incidents. Upon inspection, the vast majority of discussion took place in the "Ethiopian Airliner Down in Africa" thread. There were 5,124[1] discussion posts from March 10 to May 8, 2019, when the thread was formally closed by moderators. The thread spanned the moment the second crash occurred all the way through the release of preliminary reports from investigation agencies.

Content Analysis

To answer our first research question, we elected to conduct a content analysis of all posts in the thread. Our content analysis method specifies the following steps: (1) initial determination of potential themes, (2) identifying and condensing meaning units, (3) coding process, (4) categorization process (5), relation to emergent themes, and (6) tally count of occurrence frequencies (Erlingsson & Brysiewicz, 2017; Neuendorf, 2002). We performed the content analysis manually using spreadsheet software to inventory and count codes.

Initial Coding Scheme

Our initial coding scheme was developed by reviewing the literature related to aviation and automation. This is an admittedly vast body of research and spans both traditional academic journals and trade journals focused on the aviation industry and human factors. Our initial coding scheme simply served as a guide to guide our initial exploration of the forum postings. After familiarization, our emergent coding scheme took precedence and guided the remainder of our analysis.

Emergent Coding Scheme

Discussion posts were read thoroughly to ensure consistency and comprehensiveness in the identification of meaning units within the thread. Relevant posts were then divided into meaning units which succinctly conveys the essential meaning of the text. Identified units were further condensed while keeping the central meaning intact as demonstrated in Tables 1–3.

1. Discrepancies between the number of discussion posts seen in the thread and featured within this research may exist due to deletion by users or restoration of deleted responses after the thread was closed.

TABLE 1 Example—Condensation for #1335
Meaning Unit
"What I want is for the aeroplanes I travel in to be managed safely by pilots of the minimum allowable skill. Not every flight deck will be occupied by superhero pilots"
Condensed Meaning Unit
Aircraft systems should be designed for pilots of low skill

TABLE 2 Example—Condensation for #2396
Meaning Unit
"Reliance on just a single sensor driving a system that was not known and that could take over command is sheer madness"
Condensed Meaning Unit
Faulty design to trust a sensor; Lack of pilot authority

TABLE 3 Example—Condensation for #2894
Meaning Unit
"I actually welcomed the computers to help us to pilot the ships, but increasingly we're only operators and the computers are controlling us"
Condensed Meaning Unit
Automation should assist, but now it replaces; Lack of pilot authority

The next step of the content analysis process is to assign descriptive labels to each condensed meaning unit to assist with the identification of relationships between relevant units as demonstrated in Tables 4–6. Additionally, simple codes were generated to aid in the process. At least two thirds of the posts were checked by two independent coders to ensure agreement. Next, codes were placed into broader categories allowing for the identification of overarching themes.

TABLE 4 Example—Coding for #1335	
Condensed Meaning Unit	
Aircraft systems should be designed for pilots of minimum allowable skill	
Codes	
Low Skill	Simple Design

TABLE 5 Example—Coding for #2396		
Condensed Meaning Unit		
Overreliance affects structural integrity; Pilots should always be in command		
Codes		
Design Flaws	Trust of Machines	Command over Automation

TABLE 6 Example—Coding for #2894	
Condensed Meaning Unit	
Automation should assist but not replace; Lack of pilot authority over automation	
Codes	
Assistance for Aircrew	Command over Automation

Finally, we grouped related codes into categories. We aimed for 10 major categories to clearly summarize the contents of the discussion thread as it relates to our research question. Results are summarized in Table 7 [see appendix for all codes]. Overall, we find that the topics of automation design and human skill dominate the discussion, including how automation should be designed (e.g., redundancy) and what it should communicate (e.g., the human factors of a surprise automation malfunction). Although this is predictable given industry history, we were surprised to see discussions of Boeing's corporate behavior so prevalent. While we would expect topics of corporate culture to be at home on a forum for business managers, its presence here indicates the desire of pilots to understand if the traditional Boeing value of *pilots first* has disappeared. We also see a considerable amount of discussion about what pilots are expected to know and what should be part of pilot training. These topics are clearly related to automation: If modern pilots are no longer trusted to fly, then should pilot training be more akin to an IT professional or should training still focus on manual flying skills? Finally, we note that while human versus machine topics dominated discussion, rarely were both entities talked about in a collaborative frame. In light of the accidents, at least, it was more natural to discuss human and machine working in *opposition* rather than working together.

TABLE 7 Summary Categories

Number	Category	N	Percent
1	Automation Design: Human-Machine Interaction	458	31.87
2	Human Skill	278	19.34
3	Corporate Silence and Disregard of Safety	256	17.81
4	Automation Design: Hardware and Software Redundancy	138	9.60
5	Regulators and Aircraft Certification Process	91	6.33
6	Human Factors	54	3.75
7	Expectations for Aircrew Knowledge	47	3.27
8	Limitations of Automation and Inappropriate Uses	45	3.13
9	Aircrew Training and Airline Training Philosophy	41	2.85
10	Human-Automation Teaming	29	2.01
	Total	**1437**	**100.0**

Narrative Analysis

Our chosen content analysis method assumes the analysis in step 5 (relation to emergent themes) involves the identification of larger concepts at a higher level of abstraction than content codes. Given the nature of our third research question, we felt it was best to approach this thematic analysis process as a narrative analysis. Although differences between the methods are slight and subjective, narrative analysis is suited to an issue with a long history like humans versus machines in aviation. By "focusing on the *telling* of a story," (Smith, 2016) we look beyond the minutia of technical debates and observe the dominant frames used by pilots to reconcile the events aboard Flight 610 and 302 with personal and professional identity (Black, 2008).

We first identified the posts which were relevant to our research question and excluded posts that were irrelevant, such as news links, technical clarifications, or posts that only included images/emoticons. There were 4,098 discussion posts deemed to be irrelevant, leaving 1,025 posts for narrative analysis. The study team then independently read all relevant posts and met to discuss preliminary narratives. This process was repeated a second time; after the second meeting a research assistant discussed the emergent narratives with two professional pilots with thousands of hours of flying experience for a major international airline. Upon confirmation that our narratives were appropriate, the study team met again to settle on three encompassing narratives.

Human Versus Machine as a Zero-Sum Game

In a zero-sum game, there is no *win-win*. Ideally, automation would be designed in a way that helps human pilots, allowing both parties to leverage their respective strengths to ensure safe operation. For example, humans can use their senses and experience to discern what is the actual state of the aircraft when malfunctioning sensors are sending conflicting messages. Instead, the conflicting inputs on the 737 MAX flights led the machine to essentially pick one as being true and take action. In reality, neither were true. With the proliferation of automation in aviation over the past several decades, one would expect automation designed with human-machine "teaming" in mind (Battiste et al., 2018; Calhoun, 2021). But the narrative emerging from the discussion of the 737 MAX is that the introduction of automation on the flightdeck is associated with *losses* for humans rather than gains. One user comments, "Automation denies skill." Another says, "I think producing pilots capable of hand flying with confidence is an essential skill—it requires a change of culture. Some airlines already do this just by encouraging turning off the automation." The user goes on to recount an interaction with a senior pilot following a tenuous manual landing, " . . . what would the passengers rather have, a perfectly flown approach by the autopilot every time or a pilot who can confidently fly if the situation requires it?" Whereas the first statement suggests physical skills are lost by reliance on automation, both statements acknowledge a psychological skill, *confidence*, is lost as well. One user suggests that automation is preventing the proper training of pilots, "You just need to select and train pilots as it used to be when automation was basic . . . " and another user describes losing touch with the aircraft, "Today, the artificial manual feedback stuff is degrading the primary flight control ergonomics, and distracting and stressing the crew." The commenter starts by saying "today," indicating that it *used to be* different in the past, like the previous user discussing training. Thus, we see that while new narratives are emerging, the long-running industry narrative about the gradual erosion of human skill is perpetuated in the conversation regarding the 737 MAX.

An important sub-narrative that invites the framing of gains/losses is the characterization of machines as *adversaries*. One user discusses Flight 610, "On [their] last fateful flight, MCAS compounded the crisis by faithfully following its mandated duty—executing a NOSE DOWN infinite loop." The user's anthropomorphising of the machine as a "faithful follower" is attention-grabbing, but the user does not answer the question of who or what issued the "mandate." However, it matters little, the point is not who it was but who it *was not:* the pilots. Another user describes MCAS as one would a maniacal movie villain, "[It is] idiotic that the computers would happily perform a manoeuvre of such violence."

All these excerpts feature a narrative of humans in conflict with machines. Such a narrative is somewhat expected due to the nature of the crashes and the maturity of related narratives in the aviation industry. What is unexpected is the framing of humans losing to machines. And it isn't only skill being lost, machines are causing humans to be stressed, distracted, and lose confidence while the machines are "happy" and "faithful" even as they command the plane toward its doom. One user sums up the narrative, "As an overall improvement we need either reduced reliance on automation enabling greater experience, or improved automation." The user gives no option for experience *and* improved automation, it is *either* humans *or* machines, a zero-sum game.

Surrender to Machines

Another important narrative functions in part as a counter-theme to humans needing to gain control back from the machines. Some pilots eschew the belligerent framing and instead suggest that the battle is already lost. One user asks early in the thread, "Have we passed the point in modern aviation where it is not possible to (quickly) switch off all these pilot and performance aids and fly manually?" Another user poses a question in a whimsical way as to suggest the answer is obvious, but unpleasant, "How does a crew really get back to an old-fashioned 'hands on' configuration of controls, instruments, and sensors (where all of the automation and fancy gadgets are completely isolated from involvement) these days?" Other users suggest that humans are no longer a solution to machines' problems, "Actually I agree with [other user] and concur that the inevitable and unstoppable answer to imperfect automation is improved automation."

Though this narrative is prevalent, it is clearly controversial and virtually every post expressing the view is quickly met with retorts from other users. One user calls his opinion "humble," as if it may be embarrassing to say, "I don't have humble opinions, but the one I do have favours intelligent acceptance of the inevitable AI, not the expensive step in the wrong direction of trying to make new pilots more like the old ones." One wonders about the author's use of "expensive," it appears to carry meaning beyond just money; investing in humans will *cost* safety. Other users are more forthright, "Systems must no longer use human intervention as part of their safety case; we are too unpredictable. Safety critical systems must get smarter; garbage in, garbage out is not an option, neither is giving up and disconnecting."

The narrative of surrender shares similar beginning chapters to the narrative of zero-sum. Both pit mortal versus machine, but the two narratives diverge at the current moment. For zero-sum subscribers, the conflict is escalating and the final chapters are yet to be written. But surrender suggests that the battle is over. One user suggests human skill is itself mortal, "Hand flying is an essential skill. But it is a dying one. The tide, my fellow artful flyers, has turned against us. Were it any other way, we would not be having this discussion." Perhaps the sensitivity of the topic owes to the profound challenge that surrender poses to pilots' professional identity. The symbolism of brass wings and epaulettes is associated with authority and respect, not with mere observers. Nevertheless, some users urge their colleagues toward the realization, the "humble" user quoted above concluded his post with the candid replacement of the word *fly*, "Driving airplanes is not what it used to be, nor should it be."

Epidemic of Distrust

Granting a pilot with control of an aircraft conveys trust from manufacturer, airline, and passenger that the pilot is capable. Aviation has seen numerous episodes involving the distrust (and mistrust) of both humans and machines, but this distrust has typically been limited to specific systems or circumstances. However, the debate about the 737 reveals that distrust has permeated the entire aviation industry. And, though historically supportive of Boeing's stated philosophy placing pilots at the fore, the apparent unravelling of this philosophy leaves pilots dubious toward all industry actors from regulators to airline leadership.

The concept of authority is conceptually related to responsibility; however, we were surprised to see no references to the maxim that pilots have ultimate responsibility for safe operation. Nor was the finger pointed at MCAS alone, instead responsibility was diffused upon many actors. One commenter acknowledged the complexity of the situation but singled out Boeing, "There are many layers of responsibility here, the first being Boeing's insistence on polishing-off a 50+ year-old aircraft . . . bringing questionable stability, and mitigating it all with a poorly thought-through safety system." Another commenter expressed the same sentiment and was doubly sure to spare the individual human engineers and instead implicate management, "I am not sure the blame sits with whoever designed MCAS," because, "I suspect they were backed into a corner constrained by schedule."

Other users reference the Airbus versus Boeing debate, "Boeing went rouge [sic] from their philosophy and instead errantly took a page from Airbus' philosophy, trying to fully automate the plane, and half-assed the entire logic and failed miserably," says one user, "this MCAS system seems criminally designed." Revelations about Boeing's clandestine implementation of MCAS shook pilots, some worrying what else they don't know, "[This all] may have been caused by something else and may be yet another undocumented 'feature' of the MAX." Other users cut into Boeing's press releases, "'To make a safe airplane safer' is just a Coué-method equivalent of 'to make a dangerous airplane a little less dangerous.'" Beyond Boeing, some users have lost faith in the regulatory agencies, "The FAA will undoubtedly approve 'MCAS 2.0', but the evidence shows that there is such a degree of regulator capture that this will be hard to see as an objective evidence-based process." An economic angle is present as well, "In the centuries old battle of profit above all else, safety can only ever come a distant second" laments one user.

In this story of suspicion and doubt, pilots are the clear losers. Machines have no pride to lose, no feelings to hurt, and no concerns of what else may be hidden in the planes they occupy. For some users, fear is palpable. The operation of MCAS is described by various users as "insidious," and "mysterious, ghostly, undocumented." Perhaps envisioning themself in the position of the doomed pilots, a user imagines, "[The crew] were occupied on solving the puzzle and suddenly realized that all this time the ghost in the machine had been busy and still continued incessantly bringing the plane's nose down to the end, it's all too late for them to recover."

Discussion

The 737 MAX incidents offer insight into a profession's struggle to negotiate a shifting identity and purpose as machines play a larger role in the workplace and usurp human agency. For pilots, this workspace is the intimate confines of a commercial aircraft, but this environment is not far different from the hospital operating rooms or car interiors which are being rapidly automated. Unfortunately, the lessons learned from the 737 MAX are the result of a tragic story, but understanding how the professionals on the front lines construct their own narratives may help prevent tragedy in other industries. Additionally, the fallout from the accidents has implications for the field of human-machine communication in general. Machines will inevitably fail, sometimes with tragic consequences. What can these incidents tell us about the human-machine relationship under stress? And, what can aviation's experience teach us about the evolving tension between humans and machines in related industries and transport technologies?

Deskilling Machines

We find it compelling that throughout over 5,000 posts, we never observed the word *skill* being used to describe machines, but the same word is used countless times to describe human capabilities. It's also telling that users often refer to manual flying skills as *hand-flying*. The term almost seems purposefully chosen to exclude a machine from eligibility; only humans have hands. Guzman (2020) identifies a number of ontological boundaries between humans and machines, including emotion, intelligence, and autonomy. It is unclear where the notion of skill may fit in, or perhaps—in the wake of two devastating accidents—pilots recast the meaning of skill to provide a new barrier between human and machine. Additionally, maybe retaining skill as human-only also serves to defend the honor of the profession and pilots' sense of professional competence that they feel is being eroded by manufacturers, regulators, and corporate leadership. Regardless, what is important is to observe how the effects of industry traditions, context, and perhaps a dose of human ego, can lead to the collective drawing of new boundaries between human and machine in unexpected places. This finding raises questions about related transport technologies such as autonomous vehicles (AVs)—will tomorrow's self-driving cars be referred to as skilled in marketing materials or in public discourse? How might the verbiage change following accidents? This is a promising area for future research given the rapid development in AV technology.

Human-Machine Uncommunication

Almost no aspect of the accidents generated more outrage from aviation professionals than the secretive implementation and operation of the MCAS system. The field of human-machine communication assumes that machines act as interlocutors in a number of capacities (i.e., agency, influence, interactivity (Banks & Graaf, 2020)). However, has enough consideration been given to machines that do not communicate? Is a system like MCAS outside the boundaries of the discipline—and if so, how can we participate in the design of better systems in the future? We definitely see a place for human-machine communication research in machines that are not obviously communicative (e.g., the "mute machines" and industrial robots studied by Guzman, 2016) and more research should be directed at uncommunicative machines.

The anger over the silence of the machine is also important to other industry leaders looking to implement automation, especially in other transport technologies like AVs. Perhaps not every action by a machine must be communicated; information overload can be just as harmful as silence. But machine actions that override human inputs should be announced. We see consistently in our results that pilots feel their autonomy is challenged by flightdeck automation. So it is embarrassing enough to humans that a machine may be trusted more to perform certain actions, failure to inform humans of this may cultivate an atmosphere of distrust that destroys relationships between human and machine.

Enduring Tensions

In a recent presentation, Professor Rich Ling highlighted the ongoing tension that exists between human and machine (Ling, 2021). In our study we see it manifest as competition. Remarkably, there is only token mention of human-machine collaboration—on the flightdeck it is a zero-sum game in the battle for agency. We also see the tension manifest between different groups of users: some who see the machines as inevitable and accept their fate, others who maintain that humans are still the ultimate authority. This is a fruitful avenue for future research as machines advance into personal and professional life. Will there be a day where some have ceded control of aspects of their life to machines? After all, some would likely argue we are "already there" when we let Netflix choose our next movie night or Yelp tells us where to eat.

We also witness human-machine tension as pilots negotiate their changing professional identity. The lesson for industry leaders is to pay close attention when implementing machines as they may disrupt employee's sense of pride and purpose, ultimately disrupting communication channels between employees and management and—in aviation—compromising safety. The lesson for human-machine communication scholars is all of the above, but with an emphasis on the need to further study the factors that lead to both the resentment *of* and resignation *to* machines. We end with an encapsulating post:

> These two accidents are a perfect example of a problem that is only going to get worse. You can't make better pilots by putting them in airplanes that fly themselves until the day they don't, then expecting them to fly it out of the fire. The days of good hands and feet flying are never coming back, and this is not news to

those who make the software. The sooner we give up and turn it all over to them the better. You can rest assured they are ready for it, even if the public and the pilots are not. That said, if it was me getting kicked out of the loop they would have to pry my cold dead hands off the controls.

Conclusion

In 2019, two aviation tragedies reignited the long-running debate of human versus machine. In witnessing the professional aviation community make sense of the incidents we see narratives emerge that describe human versus machine as a zero-sum game, as already lost, and as a battle which has poisoned an entire profession with bitterness and distrust. The pilots of Flight 610 and 302 were ultimately unsuccessful against machine in their fight for flight; but their actions have spurred a discussion which offers a window into the future of the complicated relationship between human and machine. A decade from now, we are sure to be witnessing these same tensions in the countless other industries implementing automation. At that time, we may not look back to aviation and think "we've seen this movie before," but we can rest assured that aviation and the 737 MAX incidents provide a sneak preview.

Author Biography

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Appendix: Total Codes Count

Technical Discussions			
#	Code	N	Percent
1	Aircraft Systems	540	13.61
2	MCAS	276	6.96
3	Flight Data Recorder (FDR)	115	2.90
4	Operational Procedures	82	2.07
5	Flight Tracking Software	58	1.46
6	Principles of Flight (POF)	50	1.26
7	Data Analysis	44	1.11
8	Simulators	42	1.06
9	Switch Design	22	0.55
10	Fly-By-Wire (FBW)	16	0.40
	Total	**1,245**	**31.38**

Investigative Discussions			
#	Code	N	Percent
1	Aircrew	409	10.31
2	Corrective Measures	298	7.51
3	Boeing	280	7.06
4	Emergency Grounding	192	4.84
5	Investigation Board	139	3.50
6	Regulators	108	2.72
7	Ethiopian Airlines	76	1.92
8	Lion Air	60	1.51
9	Service Resumption	15	0.38
10	Cancelled Orders	3	0.08
11	Lawsuits	1	0.03
12	Aircraft Registration	1	0.03
	Total	**1,582**	**39.88**

Comparative Discussions			
#	**Code**	**N**	**Percent**
1	Other Incidents	71	1.79
2	Other Manufacturing Companies	32	0.81
3	Other Aircraft	24	0.60
4	Other Airline Companies	13	0.33
	Total	**140**	**3.53**

General Discussions			
#	**Code**	**N**	**Percent**
1	Aviation Industry	17	0.43
2	Thought Experiment	11	0.28
3	Summary of Happenings	4	0.10
	Total	**32**	**0.81**

Miscellaneous Comments			
#	**Code**	**N**	**Percent**
1	Aviation Industry	199	5.02
2	Irrelevant Personal Responses	336	8.47
3	Unrelated Questions	183	4.61
4	Irrelevant Argumentations	89	2.24
5	Expressions of Formality	59	1.49
6	Speculatory Statements	48	1.21
7	External Resources	31	0.78
8	Emotional Responses	12	0.30
9	Repeated Posts	4	0.10
10	Indecipherable Posts	7	0.18
	Total	**968**	**24.40**