*Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)*
*Edited by* Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio
 *Published by* Research Publishing, Singapore.
doi: 10.3850/978-981-18-8071-1_P336-cd

# Safe work practice: choosing the right level of flight deck automation.

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Automation in modern aircraft has been a major contributor to increased safety and efficiency in commercial flight operations the last decades. However, complexity of automation can reduce pilots' understanding and control of the aircraft thereby creating dangerous and even fatal situations. The objective of this qualitative study is to expand our understanding of human-automation interaction by examining how airline pilots use automation technology in a social and collaborative context. In-depth interviews with airline pilots describe situated practices on the flight deck and shed light on how the pilots collaborate and interact with automation. It is interesting to note that the level of automation is not regarded as a set entity throughout a flight, but is chosen strategically to reduce risk and based on an overall judgment of the operators' competence and situation factors such as weather and complexity of navigation. Automation is regarded both as an enabler as well as an obstacle for efficient teamwork. Our study shows how this distinct and proactive technology embedded practice facilitates a joint understanding of the situation at hand, an understanding imperative for the safe execution of flights.

*Keywords*: aviation, airline pilots, automation technology, situated work practice, social processes, human machine interaction.

## 1. Introduction

Automation in modern aircraft has been a major contributor to increased safety and efficiency in commercial flight operations during the last decades, still airline pilots hold a critical role in ensuring aviation safety (Wang et al. 2023). However, complexity of automation can reduce pilots' understanding and control of the aircraft thereby creating dangerous and even fatal situations. Sarter et al. (1997) found that although the introduction of new automation technology in the aviation industry reduced some types of failures, new types of errors and system breakdowns were introduced by operating a more complex system. They describe how the pilots needed new knowledge as system operators to detect and recover from errors and handle 'automation surprises' as well as managing new coordination demands. The performance-based operations rulemaking committee (FAA 2013) states in their report that a major factor in aircraft accidents and incidents is that pilots are failing to keep up with technological changes resulting in surprises and confusion caused by insufficient crew knowledge of the automated systems. Many studies have looked into automation in aviation (Endsley 2017) but much of the existing research focuses on how a single operator interact and use automation from a cognitive perspective. This is a rather one-dimensional view that does not consider automated systems controlled by multiple operators and the effect of social processes, for example are automated systems in airline cockpits operated by two pilots. Rankin et al. (2016) point out that pilot-automation coordination deserves further attention. We therefore set out to expand the established concept by exploring cockpit crew collaboration from a social perspective, focusing on interaction practices.

The objective of this qualitative study is to expand our understanding of human-automation interaction by examining how airline pilots use automation technology in a social and collaborative context. In-depth interviews with airline pilots describe situated practices at flight deck and shed light on how multiple operators collaborate and interact with varying levels of automation. The theoretical framework is presented in the next section, followed by an account of the applied method and data sources in section three. The analysis of the interviews is presented in section four and discussed in section five before we offer the concluding remarks in the last section.

## 2. Theoretical framework

In this section we start by presenting how different aspects of automation followed by a short account on maintaining awareness and use of procedures in computer supported collaborative work.

### 3.1. *Automation*

Automation is described by Parasuraman and Riley (1997) as the 'execution by a machine agent (usually a computer) of a function that was previously carried out by a human'. Levels of automation are used to describe to what extent a machine can act on its own ranging from a machine completely controlled by a human to the machine as being fully autonomous and acting without human input (Sheridan and Parasuraman, 2005).

Safe and efficient operation of commercial aircraft is to a large degree enabled by automation technology. ICAO defines automation as 'the assignment to machinery, by choice of the crew, of some tasks or portion of tasks performed by the human crew to machinery. Included in this definition are warning and alerting systems that replace or augment human monitoring and decision-making (this may not be at the choice of the crew, but preassigned, such as systems monitoring, flight status monitoring, fire detection)' (1992:3). The autopilot and the autothrottle are essential parts of the autoflight systems. These systems support essential work tasks, communication processes and decision-making in the cockpit (Evjemo and Johnsen, 2019). The automation replaces functions previously carried out by humans but are to be of assistance and not a replacement of the flight crew. Thus, it involves an interaction between humans and machines, that replace functions of both physical and mental labour with the overall purpose of increasing safety and efficiency of a system: Reducing workload, increase situation awareness and support the decision–making process. Still, the advancement of cockpit automation may also limit pilots' ability to comprehend and act in an adequate fashion during non-normal or emergency situations and have an overall negative impact their decision-making authority and lead to an erosion of flying skills (Holford 2020).

Parasuraman and Riley (1997) examined the factors that influence the use, misuse, disuse and abuse of automation. Why and how automation is used by sharp end operators is influenced by individual differences and factors such as attitudes towards the automation, mental workload, trust and system confidence. Misuse of automation indicates an overreliance on automation, which may result in a failure to monitor the system and decision biases. Common factors that influence automation misuse include workload, reliability and consistency, and the saliency of the status indicators. Disuse is when the automation is neglected or underutilized for example due to reoccurring false alarms and omissions. Automation abuse points to inappropriate application of technology by designers or managers and the tendency to disregard the consequences of changes for human's performance and the operator's authority over the system, it may even lead to increased automation misuse or disuse by the system operators.

Sheridan and Parasuraman (2005) highlight two aspects of automation systems: 1) the interaction with automation does not need to be in absolute terms (on/off), there are various degrees of appropriate application which is dependent on its' context 2) the process stages in a complex system are automated appropriately to different degrees. Parasuraman et al. (2000) present a 10–level scale where the higher levels represent an increased autonomy of computers over human actions. At the lowest levels the computer offers no assistance and the human makes all decisions and actions. With higher levels of automation, the human is given increasingly less alternatives and at level 6 or above, the human operator is given limited time to be able to veto before executing a decided action. At the highest level the computer decides everything and acts autonomously. The concept of adaptive automation utilizes dynamic function allocation where the level and/or type of automation will vary during system operation (Sheridan and Parasuraman 2005). If the performance at the higher levels of automation is not within limits of what is acceptable by the system, the system automatically moves to a lower level or may even provide full manual control to the operator if it deems the situation as critical enough. An example is the 'moded' input devices found in the cockpit such as the throttle levers, yokes, and switches. These do not operate the same way at all times, but are context-sensitive, and may increase pilots' cognitive workload or result in automation surprises or confusion (Sherry et al. 2022).

As described above automation often involves full or partial replacement of functions that was previously carried out by humans creating human-automation interactions. This the human operator can be both a passive and an active benefactor of automation, e.g. be when pilots program their Flight Management System (FMS) enabling the autopilot to fly the aircraft on pre–programmed lateral and vertical flight paths. The pilot may at any time intervene and manually take over when they perceive a problem or a deviation.

### 3.2. *Awareness of automation and procedures*

Workplace studies demonstrate the importance of social interaction in computer supported collaborative work (CSCW) (e.g. Suchman 1997; Luff et al. 2000). The classical workplace studies from 20-30 years back, might look fairly analog at first sight, focusing on less sophisticated technologies than what we find in aviation. However, many of these studies demonstrate the role of coordinative artefacts such as computer displays in collaboration activities () and shared physical environment in creating mutual awareness among control room operators (e.g., Goodwin & Goodwin, 1996; Heath & Luff, 1992). More recent research concerns the fragmentation and decentralization of control rooms and how tasks are distributed among several actors and organizations (e.g. Luff & Heath, 2019). The developments automation and artificial intelligence in many fields will lead to changes in existing socio-technical systems and more distributed ways of working. Luff et al. (2017) claim that the increase in fragmentation, distribution and hybridity of control bring about new demands on coordination and collaborative work. We think this also applies to aviation and how work is carried out in the semi-automated cockpit.

In particular it can be challenging to ensure safety in the 'handover' between automated operation, when the human operator takes over or are supposed to take manual control of a system operated by computers. Endsley (2017) uses the term 'automation conundrum' to describe how although robustness and reliability of a system is increased as the result of added automation, the situation awareness of the humans operating the system may decrease and lower the likelihood that they will actually take over manual control when needed. This problem is associated to challenges of monitoring, control and trust, which has been recognized as key aspects of safety in human-automation interaction across domains. This indicate a need to develop new collaborative standards and practices of negotiating and handing over control that is not only based on verbal and deictic interaction in the cockpit between two pilots, but between a pilot and the autopilot.

Another aspect is how to regulate the use of automation through rules or procedures. Haavik et al. (2017) found that although airline pilots' work practices are to a large extent governed by standard operating procedures they also exercise discretion in a context-sensitive adaption of the technical environments and the procedures. This may lead to a gap between preferred and actual work practice and eventually a difference in how work is imagined or thought of and how work is actually done in the cockpit. Hollnagel (2015) describe this as WAI (work as imagined) and WAD (work as done). To understand the difference between the two can serve as a source of information about how work is actually carried out and give the opportunity to improve work as well as procedures. It can be compared to what Reason (1997) described as 'necessary violations' explaining how sharp-end operators such as pilots optimize their workload by finding a balance between procedures and experience-based problem solving.

## 3. Research method

The empirical material presented below is from fifteen semi-structured interviews with professional Norwegian airline pilots. See table 1 for an overview of the informants' experience with different aircrafts and years of flying. The informants were at the time of the interviews employed with four different airlines that operate from Northern Europe.

The interviews were carried out digitally and were recorded using the built-in software in the digital platform. The semi-structured design made it possible for the informants to speak freely about their own experiences and to explore interesting aspects in depth. The interviewer focused on examples from specific events brought up by the pilots. These stories shed light on actual use of automation and how this influenced situated work practice in the cockpit and were usually explored in more detail by follow-up questions. The recordings were transcribed and translated from Norwegian to English. The transcripts were then coded following a thematic analysis approach where the material was first empirically coded and then thematically categorized (Bryman 2012).

*Table 1 Overview informants*

| Rank | Years* | Aircraft Type** |
|---|---|---|
| FC | 6 | B737NG |
| FC | 32 | SA226-AT; Merlin 4, MD80, ATR, F50. N737NG |
| FC | 23 | DC9, MD80, MD90, B737CL, B737NG |
| FC | 24 | F16, MD80, MD90, B737CL, B737NG |
| FC | 24 | F50, DC9, B737NG |
| FO | 6 | B737NG |
| FO | 3 | B737NG |
| FO | 4 | B737NG |
| FO | 15 | AC90, V, A20N |
| FO | 4 | B737NG, B38M |
| FO | 25 | F16, F5, MD80, B737, A333, A343 |
| FO | 2 | HD8A, DH8B. DH8C |
| FO | 2 | DH8D |
| FO | 2 | B737NG, DH8a |
| FO | 8 | PA31, B737CL, B737NG |

FC: Flight Commander/Captain
FO: First Officers/Co-pilot
*Years of experience as commercial pilot
**Aircraft type according to ICAO abbreviations

## 4. Results

The interviewed pilots highlight that the overall purpose of automation is to ease their workload in busy phases of a flight and increase their capacity to handle unexpected situations and change of plans. They point to the complexity of the automation and describe how it may be an enabler as well as a disabler for safe and efficient teamwork. They emphasize the importance to practice flying the aircraft manually in different phases of a flight and under various conditions. This build the needed confidence and system understanding needed to pilot an aircraft in a safe manner.

### 4.1. *Technology mediated planning*

Planning is a substantial part of pilots' work. It is a formal requirement, but the informants explain that it also allows them to 'obtain a bigger picture'. It gives them the opportunity to be prepared, not only on navigation details, but also to be focused at the flight at hand and allow capacity to emerging tasks. One example is the pre-flight briefing where the pilots identify possible threats during departure and talk about how to handle these.

Much of the detailed planning is done prior to flight but some planning or re-planning is done in flight. Factors that influence the planning practice is length of flight, weather conditions, amount of traffic en-route or at destination. If the flight-time is short, more planning is required prior to departure. On longer flights it is impractical to plan the approach and landing at the destination as many factors may change while airborne. A first officer gave an example from a short flight in Norway in bad weather during winter: 'We engaged the autopilot as quickly as we could after departure so we could start planning and dividing the work between us in the cockpit'

The process of obtaining 'a bigger picture' includes being able to plan ahead. Automation is essential in this process, relieving pilots from basic flying tasks in order to keep focus on planning. One of the first officers explain that the aircraft automation 'enables us to handle everything from complex traffic patterns to problems that emerge during the flight. The informants mention a number of factors that may increase the demands during flight and where the autopilot can help reduce their workload and free capacity to plan and handle emerging tasks: weather changes, unfamiliar areas or destinations, large airports with dense traffic, detailed departure or arrival procedures with multiple restrictions, nighttime or at the end of a long work day.

Many of the pilots use the phrases ’getting behind’ and ’ahead of the plane’. The latter indicate that they are mentally prepared for what may come and able to react quickly if something happens. Some explain that use of automation may increase the risk that the pilot ‘gets behind’ and lose time in critical situations even if they are monitoring the aircraft’s performance. They sometimes find the information provided by the automated systems difficult to interpret. One of the informants said that ’the systems are not adapted to the intuitive way of humans thinking’ indicating that the pilots need to compare and contrast information from a number of sources before they can make sense of it. It requires experience and in-depth knowledge of the systems in order to understand ’what the aircraft is trying to tell you’. One of the first officers told about an incident from an aborted landing while on autopilot: ‘We initially thought that the aircraft performed an uncommanded go-around, but there were no indications of the fact. We were all the sudden several rows back in the aircraft, becoming more like passengers than pilots.’

Not understanding or knowing what the system is doing is a concern among the informants since this may make them unable to handle the aircraft if the system becomes inoperable. It is not possible to know all the details about the automation systems as they are extremely complex. One of the first officers explains: ‘Automation can be your best friend as long as you understand what it is doing, but you have to be well read on the systems, it can be your worst enemy if you don’t’. Another of the pilot’s states: ‘the autopilot is the dumbest pilot in the airline… it only does what it is told to do’ The autopilot executes what it has been programmed to do, without asking questions. If provided with erroneous inputs, the A/P will execute the task which can lead to dangerous situations.

The expression ‘you must be pretty lazy to be a pilot’ is used to illustrate that they use the automation to reduce the number of tasks to have capacity to handle unforeseen events. It also indicates that they need to manage boredom. The work of pilots is highly standardized and the informants explain that it is easy to become a little too laid back when following the same routines over and over. They explain that many procedures and repetitive tasks in a highly reliable system may lead to complacency and a too high degree of trust in the automation. Several of the pilots mention that they are particularly aware of this risk when flying on routes that they are familiar with and have flown many times. This is illustrated by one of the captains who say: ‘I do not double check as much when flying a familiar route as when flying to a new destination. I am a lot more focused and systematic with every entry point in the A/P if it is to a destination that I have never flown to before.’ Another of the pilots use the expression ‘the mind can drift away’ to describe how boredom on uneventful flights causes inattention and increases the risk for making minor errors such as failing to announce a change in automation mode to the other pilot.

### 4.2. *Choosing the right level of automation*

The duties of a pilot consist of an array of tasks that have to be performed during the course of a flight, and is not limited to flying the aircraft. The pilots have a mutual understanding of what is expected of each other, based on the various roles they have in the cockpit on that flight. There are two formal roles with a distinct set of responsibilities as the Flight Commander (FC) /captain and First Officer (FO) linked to rank and legal responsibilities. The roles of Pilot Flying (PF) and Pilot not Flying (PNF) are more fluid and can vary from flight to flight as they plan the day. Pilots explain that the tasks and workload become distributed between them when using automation. If PF chooses to fly manually, more tasks are placed on PNF and the procedures dictates how to distribute the work task. Manual flying will usually increase the number of tasks placed on the PNF and require more planning to manage the workload.

Some of the less experienced pilots say they feel reluctant to fly manually as they don’t want to inconvenience their co-worker and don't know the other person's competence level. One of them explained that 'The captain next to you is expecting that you are going to engage the autopilot so he or she can relax more (. . .)'. The crew's total capacity as whole is thus dynamic and the use of automation must be planned according to how much capacity they are expected to have. One of the captains explain: 'I have to monitor more and be sharper if the other pilot is flying manually … I am not so keen on doing that after a 14-15-hour day, because you're tired…rather do things the easy way, letting the automation do its thing while we focus on the landing or have spare capacity if an emergency should occur'

All the interviewed pilots regard themselves as team members and see work in the cockpit as a team effort. They talk about the total capacity as a crew rather than individual workload. If one has a reduced understanding, it affects the other and impacts the crew performance. There are various strategies that pilots use to ensure that the other pilot is 'in the loop'. One of the first officers state; 'I want to know that the person I am flying with knows what I am doing. There is a continuous dialog about what I have planned and thought. It is discussed and talked about before executing the task in order to obtain a shared situation awareness."

National and international regulations as well as company guidelines state how and when pilots should use available automation. Some airlines encourage their pilots to fly manually and practice their skills, whereas others are more restrictive of which situations pilots can disconnect. Pilots state that the airline must trust the pilots to know what they are doing and the freedom to fly the aircraft in the manner in which they consider to be the most safe and effective.

The pilots highlight the importance of understanding the environment in which the airline operates and the restrictions they have to follow, in order to understand the intended use of automation. Some airlines often operate in challenging flight conditions; with demanding terrain, rapidly changing weather conditions, terrain and short runways that require them to have looser boundaries. While other airlines mainly fly in and out of larger international airports with dense traffic patterns, and have routes across restricted areas that require greater accuracy. Pilots explain that there is a greater chance they will be unable to meet performance requirements when flying manually compared to when using automation. First Officer 3 states: "The probability that you mess up the approach when flying manually is greater compared to if you are using the autopilot. Particularly for us that fly so little [manually]."

Some rely more on the autopilot and start programming in situations where the best solution is to take manual control. The experienced pilots particularly observe this in younger, less experienced or confident pilots when they hesitate to override the automation, particularly when having to manage situations where you have to fly the aircraft manually and things may come as a surprise. Many mentioned the risk of becoming overly dependent on the technology, where experienced pilots would have disconnected the A/P and let the automation 'catch up'. During a go–around in good weather conditions with a young pilot as PF: 'The FO was completely confused, the go–around went fine, but we had trouble leveling off at 3000 feet and performing a turn. The FO struggled with the controls and attempted to engage the A/P without success'.

Although the use of automation can provide better accuracy, programming it can be time consuming and there are instances where pilots are able to perform quicker and more efficient maneuvers; e.g. having to dodge birds on an approach. Many of the captains encourage their co-pilots to fly manually emphasizing their role as mentors. Many of the pilots explain they leave the A/P off for practice purposes to improve their skills as well as to build or maintain confidence in their own piloting skills. Many prefer to fly manually to get a 'feel of the aircraft'. One pilot explains: 'I want to get the feeling of the aircraft in my hands [and] get the physical muscle memory. Keeping it hot. If I have been only flying with the A/P engaged 100% of the time for 2-3 months, then I would have felt that backbone-feeling weakening. The pilots emphasize that flying manually is the fun part of flying and that this is the reason they became pilots in the first place. Feeling the power, speed, forces and getting a sense of control when weather conditions are good and both pilots are well-rested is the best part of their job.

## 5. A dynamic use of automation

The objective of this qualitative study is to improve our understanding of human-automation interaction by exploring how airline pilots use automation technology in a social and collaborative context. The results describe situated practices at flight deck and shed light on how multiple operators collaborate and interact with automation.

It is interesting to note that the level of automation is not regarded as a set entity throughout a flight, but is chosen strategically to reduce risk, and hence manage safety. The level of automation is selected based on an overall judgment of operators' competence and situation factors such as weather and complexity of navigation. This dynamic use of automation is not only based on a continuous assessment of the technical state of the aircraft, but also the human actors and their level of awareness through situated practice, i.e., via various forms of both verbal and non-verbal cues. Automation is as such regarded both as an enabler as well as an obstacle for safe and efficient teamwork.

What is of particular interest from a safety point of view is the distinction between human-automation interaction as formally intended vs the interactions as they are actually carried out, or *imagined* vs *done* if one adopts Hollnagel's (2015) framework. The two perspectives also stand out when one wants to understand organisational safety - safety as a result of the absence of risk, or as the presence of organizational characteristics. However, our result indicates that safe work practices at the flight deck can be grounded in both perspectives - one perspective does not exclude the other when it comes to understanding safety as an organizational phenomenon. Safety in the cockpit depends on an understanding where both approaches appear mutually relevant, and in a sense mutually dependent on each other. The point is that through interaction with automation, the pilots make conscious and explicit choices related to appropriate levels of automation - choices that are based on distinct, contextual conditions where handling including mitigation of operational risk is central. At the same time, our results show that human-automation interaction on the flight-deck implies on the part of the pilots foremost that they will be able to *stay ahead* of the various phases of a flight. For the pilots, it is imperative to be at the forefront of various events - this makes it easier to maintain an overview of the situation, including managing control of the aircraft. In this respect, automation is primarily a facilitator, but automation also entails risks linked to loss of situational awareness, illustrated through the metaphor "becoming a passenger".

In this sense, it is timely to understand human-automation interaction on the flight deck as, firstly, facilitated through the presence of a distinct, local practice, a practice that is characterized by the pilots' ability to stay at the forefront of a flight's various phases through how degrees of automation are manipulated. Secondly, safe work practice is also about risk mitigation through how the automation is manipulated through situated practice.

## 6. Conclusion

The empirical material shows how this distinct and proactive technology embedded practice mediates a joint understanding of the situation at hand, an understanding imperative for the safe and efficient execution of flights. However, even if automation is foremost regarded as beneficial when it comes to workload management and situation awareness, the pilots do not always fully understand the capabilities and boundaries of the automation with regards to actual collaboration and interaction within the cockpit. This may lead to less efficient use of the available technology and have a negative impact on pilots' abilities to coordinate work and make in-flight decisions. Safe work practice and choosing the right level of flight deck automation must be understood through both organizational characteristics, i.e., the presence of local and context-based practice - at the same time, risk is also managed through that same local practice.

The results show that local practices are interactions that are difficult to formalize. This means that risk management in terms of different degrees of human-automation interaction must also be explored by carefully studying what pilots actually do in the cockpit during normal flights, in addition to the recognition of the importance of, for example, procedures per se.

**Acknowledgement**
The authors wish to thank the informants for sharing their knowledge.

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