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ANALYSIS OF THE P-51D CRASH IN ENGLAND IN 2017 FOR THE CONCEPTS OF COGNITIVE ERGONOMICS

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Abstract

In 2017, after intermittent engine failures during his performance at the Duxford Air Show in England, the pilot of the P-51 Mustang had to make a forced landing on a farm near the runway, causing only damage to the aircraft and no casualties. Aviation accidents are usually analyzed from the perspective of cognitive ergonomics, seeking to elucidate the aspects that normally cause or contribute to human error. However, it is worth noting that the pilot's actions in this accident, for the most part, serve as good examples within the concepts of cognitive ergonomics. Based on these concepts, based on a literature review on human performance and error, attention, observation of operations in cockpits and in nuclear power plant control rooms, the authors analyzed reports, lessons learned and two videos of the accident, available on the internet.

Keywords: Plane Crash; Human Error; Pilot.

1. INTRODUCTION

Aviation is an area in which various ergonomic concepts apply. Initially, anthropometric concepts, relating topics such as the shapes and sizes of control elements and dials and the functional range of the crew member with these items were the subject of studies and have been included for some time in design guides and standards, such as MIL-STD-1472 (US Department of Defense, 2012). Even in a cockpit that meets all of these ergonomic principles, there is still room for what is known as "pilot error" to occur (Fitts and Jones, 1947).

Since then, several factors have contributed to improved aviation safety, but accidents still exist. Especially in commercial and military aviation, it is from the point of view of cognitive ergonomics and complex and automated systems that accidents are analyzed and studied, mainly through the basis provided by the studies of Bainbridge (1983), Rasmussen

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(1983), Wickens (1988, 2010), Reason (1990) and continuously improved, as in the case of the "Human Factors Analysis and Classification System". HFACS, Shappel, 2000 and Lower et al, 2018).

The authors of this study analyzed two videos (Air Safety Institute, 2018; High Flight, 2017), the report (AAIB, 2017) and two reports (Airscape 2019; Hirschman, 2018) about the accident, evaluating the actions observed in the videos and described by the pilot based on the ergonomic concepts shown in the literature review.

2. Description of the accident

On July 9, 2017, during the final part of the second day of presentations at the Duxford, England air show, the P-51D Mustang aircraft was part of a formation pass with other historic aircraft over the runway. Before performing the maneuver, the pilot changed the fuel tank, a standard procedure performed every 30 minutes of flight, selecting the right wing tank. After the pass, the aircraft formation rose to a height of approximately 300 meters and, in order to stay in position, the pilot had to continuously adjust the throttle During one of these activations, the aircraft had the first anomaly in the operation of the engine, which quickly returned to operation, but began to exhibit intermittent behavior. The pilot made an attempt to approach the runway, but the plane's glide was insufficient for landing, given the unreliability of the propulsion and the low altitude. Alternatively, the pilot sought some favorable point for an emergency landing in the nearby wheat fields. Already in the descent procedure, low and close to the runway, the engine stopped definitively, causing the landing on a farm (AAIB, 2017, Airscape, 2019 and Hirschman, 2018), without victims and only with damage to the aircraft itself.

This is one of 30 accidents that occurred in air shows that year around the world, in which 34% occurred due to mechanical failure, double the historical average for this type of failure (Barker, 2018).

3. Aircraft

The P-51D Mustang, registration G-TFSI (Fig. 1) was a single-seat fighter aircraft originally delivered to the U.S. Air Force in 1945, remaining in service until 1956. In 2007, after six years of work to overhaul, upgrade and convert the original P-51D model to a two-seat trainer model (TF-51D), the aircraft was transferred to Duxford airfield, England (AAIB, 2017).

The plane was sent to the US for repair and, the following year, it performed at the same show (AIRSCAPE, 2019).

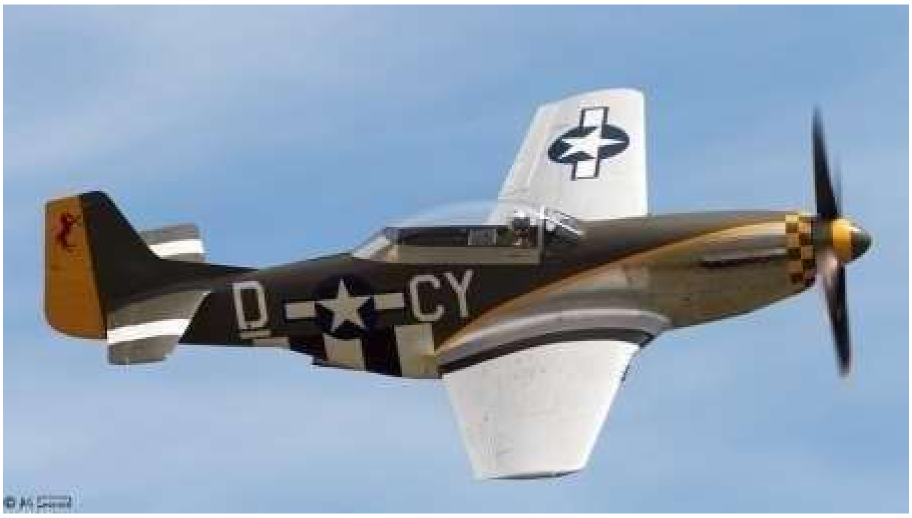

Figure 1 - TF-51D Mustang "Miss Velma", registration G-TFSI, one day before the accident Source: Leonard (2017), with distribution permission CC BY-NC 2.0 (CC, 202?b)

The P-51 Mustang is an American fighter jet of World War II, originally designed by North American Aircraft for the Royal Air Force in 1940. In just 117 days it was designed and the prototype made its first flight. After the U.S. involvement in that war, it came into use by the U.S. Army Air Force, being employed with great success in both the European and Asian theaters. More than 14,000 units were produced, with the P-51D model being the most produced, with 8,302 units (Smithsonian, 201?). Because of the end of the war and the introduction of jet fighters shortly after the end of it, these fighters were sold as surplus to various air forces, companies and even private individuals. Currently, several P-51s are still kept in flying condition by private individuals, museums, foundations or companies, whether for racing or air displays, which is the case in which this particular model fits. Fig. 2 and 3 highlight elements that will be mentioned later: the throttle

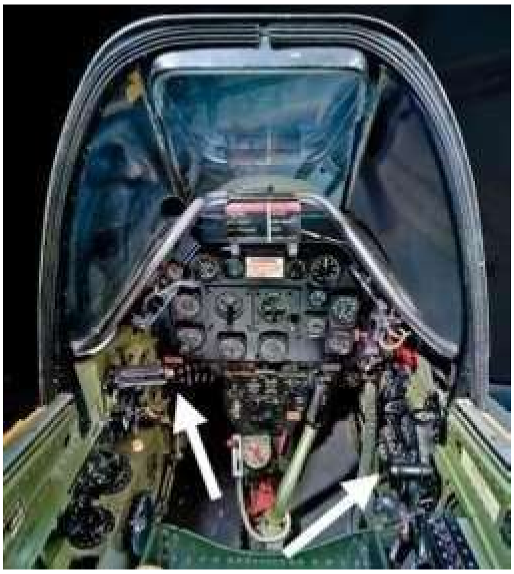

Figure 2 - Cockpit of a P-51D. The arrows show the throttle (left) and hood opening handle (right)
Source: Adapted from Smithsonian (201?), with distribution permission CC0 (CC, 202?a)

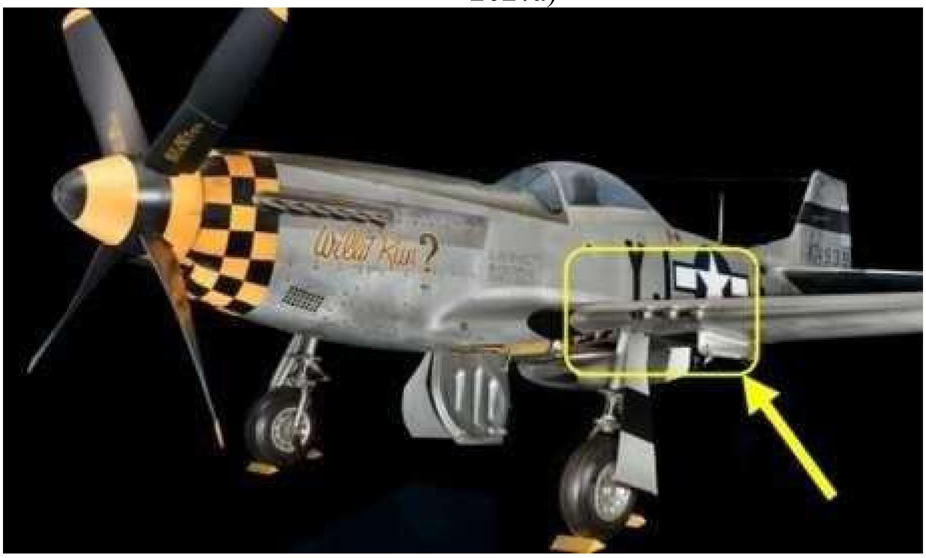

Figure 3 - Machine gun opening in the wings of the P-51D
Source: Adapted from Smithsonian (201?), with distribution permission CC0 (CC, 202?a)

4. THE PILOT

The pilot was Mark Levy, flying for the aircraft restoration company Anglia Aircraft, which owns the aircraft (Airscape, 2019). He is a pilot for British Airways and has extensive experience in air shows on other aircraft, participating in these since 1989. He has a total of 21,000 flight hours in several aircraft, but only 9 in Mustang until the day of the accident (AAIB, 2017 and Hirschman, 2018).

5. Literature review

Rasmussen begins his study by emphasizing that human beings do not act, or behave, simply as deterministic input and output devices and that our behavior is modified as a function of the signals emanating from the objectives to be achieved, which was defined as teleological behavior (Rosenbluth and Wiener 1943, apud Ramsmussen, 1983). In this context, he sought to distinguish the categories of human behavior in a qualitative way and did so in **three levels of human performance**, which are **ability**, **rule,** and **knowledge**. The different use of the information available at these levels of performance has distinctions, which led him to define them as **signs**, **signs,** and **symbols**, all within the model known as **SRK**, *Skill, Rule, and* Knowledge.

Based on this study and the areas of error research that divided it into "slips and lapses" and "mistakes," Reason proposed the Generic Error-Modeling System *(GEMS*), in which he creates a framework for understanding failures at each of those levels of human performance. An interesting concept is the **"strong-but-wrong" mental scheme** for problem solving, in which procedures accumulated over years of practice can be triggered and applied at inappropriate times, due to, for example, out of context or lack of information to properly diagnose the problem.

In this same work, the distinction is also made between **the active error**, the one whose consequences are immediately observed, and the **latent** ones, which are errors caused not necessarily by the operators, but by other people involved in the process, which may even be the designers, who cause failures that are hidden and revealed at certain times. The alignment of active and latent faults, which is a possible sequence that culminates in an accident, became known as the "**Swiss cheese theory**", because the various layers of "defense" of a system can contain, for various reasons, failures and imperfections that end up not avoiding the accident they should prevent.

From this distinction of active and latent failure and the Swiss cheese theory, the human factors analysis and classification system (**HFACS**) employed in aviation was developed, which is described by Shapppel (2000) and Lower et al. (2018). The main reason for the development of this system is the fact that Swiss cheese theory provides few details on how to apply it in the real world in a practical way (Kelly, 2019). This system describes **four levels of failures**: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. It should also be considered that there are situations in which the "problem is not fully understood and formal procedures and response options are not available" (Shapppel, 2000).

Human performance levels are, in a way, triggered by information from the context in which the equipment and the operator are inserted. But the full availability of information is no guarantee that the operator will be at the most appropriate skill level, as human beings have a strong limitation in their ability to process it, causing an **overload of information**. Wickes et al. (2010) classify our **attention** according to the treatment given to this information, that is, to external stimuli (or part of them), as **selective, focused and divided attention**. However, the sampling of signals within these attention modalities is affected by memory limitations and stress conditions (Wickens, 1988). Regarding attention and performance in tasks, Latorella (1999) states that interruptions through the ear canal increase the execution time and the making of errors in these tasks. It is interesting to observe in that study by Wickens that attention to a stimulus can happen unconsciously and, in a way, activating long-term memory, at a level called **pre-attentional**. This level is observed by Woods (1995), when he reports that nuclear power plant operators also perceive that something is happening through the sounds produced in the form of "clicks" by the electromechanical devices that control the control rods, which adjust the power of a nuclear reactor. Without necessarily looking at the parameters of the nuclear plant, operators quickly have the notion that the automatic system is, for some reason, acting in the movement of these bars. This is called by Mumaw (2000), in his field study with nuclear power plant operators, as "taking advantage of **unmediated indications**" (*exploit unmediated indications*), that is, information obtained even when there are no instruments for it, such as a resounding pump and the noise of electromechanical indicators operated intensively. Gaver et al. (1991), in the research where they synthesize **intrinsic sounds** of the system in a simulated environment and improve the efficiency of the operation, by creating adequate "acoustic icons", mentions that the sounds made by car engines are not designed, but they are properly used by people to know if they are working correctly or not.

In addition to the issue of information overload, affecting attention and its processing capacity, the signals can be ambiguous, bringing meanings that do not help in the diagnosis of a problem and the consequent decision-making to solve it (Orasanu, 1998). In high-risk and time-pressured situations, such as during actions in abnormal operations and in emergencies, decisions are often made based on the comparison of what they can identify as a pattern they have already learned, known as the **recognition-primed decision model** (KLEIN, 2008).

Bainbridge argues that even in highly automated systems, there are still occasions for error and, ironically, such occasions can still increase, due to the **loss of the motor ability** of the operators because they are no longer an active part of the control of some process and only start to monitor and intervene in the system, when the automation fails. We highlight the cognitive abilities of long-term knowledge and *working storage* in this study.

As for the **cognitive observation of an operation in the cockpit**, we can cite the study by Hutchins (1995), which is based on the analysis of manuals of the McDonnell Douglas MD-80 airplane and on direct observation of the landing inside the cockpit. In this study, different steps, procedures and devices used are analyzed from the point of view of cognitive ergonomics. This observation shows that this plane, the MD-80, on the landing trajectory, needs to change the configuration of the flaps depending on the weight and speed of the aircraft. Although these values are included in the manual, which is available to pilots at all times, a method is needed that reduces the workload and the short and long-term memory of the crew members, in this phase of the flight with great time pressure. This is done by placing indicators around the speedometer. When each speed is reached, the crew member monitoring the speedometer reports the value to the other, who adjusts the flaps.

6. Analysis of the pilot's actions from the point of view of cognitive ergonomics

Right at the beginning of the first video (Air Safety Institute, 2018) the pilot acts a lot on the throttle (Fig. 2) and it is possible to observe, through the camera mounted on the helmet, that he is observing another plane and tries to maintain the flight in graduation with it (also seen in High Flight, 2017), with focused **attention**. Then, at 47 seconds, the engine has the first failure and we can clearly see the pilot at a **skill** level, as he acts on the throttle But the engine soon returns to work, however, it operates intermittently. After 30 seconds the pilot realizes that the engine's performance is no longer reliable and "behavior patterns" emerge, causing him to keep the aircraft at an adequate speed for maintaining lift in flight, move the cowling opening lever (Fig. 2) and start looking for options for emergency landing in the surrounding fields. This denotes the level of performance as **a rule**, which triggers the **RPD**. The opening of the canopy is important in this case, as damage to its opening mechanism in a crash landing can leave the pilot trapped in the cockpit. This goes against the manual, which recommends jettisoning it, but he judged it not to be a good solution, trying to prevent a piece of almost 150 kg from falling on an adjacent highway, with a lot of traffic. In **the HFCAS** classification, this falls under an **exceptional violation**, within an **unsafe act** (Kelly, 2019). However, the engine starts again (1:32 of the video). Thus, he states that it is not a total engine failure, being a "partial and intermittent engine failure, which is much worse than a total failure", in addition to the engine not exhibiting any other symptoms of the possible cause of this intermittency. By stating that this is much worse than the first type of breakdown, it is clear that, now, the level of skill has become that of **knowledge**. Until this moment, the **signs** and **signs** come exclusively from the engine noises, as the pilot does not mention the use of instruments to seek more information and a more attentive observation of him to any instrument cannot be seen. The head movements indicate greater concern in the formation flight in which he was and looking for a landing site. Later, in the interview, he states that it could be an episodic problem, such as water in the fuel. That's the level of **skill**, certainly coming from experience with lower-powered planes, but the Mustang consumes "40 gallons (150 liters) of fuel per hour," so a small intake of water couldn't cause such a problem. This is the **mental scheme** called by Reason "**strong-but-wrong**". Communication with air traffic control has been impaired, as the pilot is **overloaded** with information, operating at the level of **knowledge** and **focused** attention. He reports that he is able to listen, but not listen, process and respond to this communication. In this case, traffic control notes that it is coming for landing, but the landing gear is not lowered. At **the skill level**, the pilot keeps the landing gear retracted so as not to run the risk of overturning on landing, something common in this type of aircraft.

Although he is an airline pilot, flying large commercial planes with a high level of **automation** and **complexity**, he maintains the habit of performing monthly screws and landings with the engine off, in order not to **lose motor skills** (Bainbridge, 1983). Moments before landing, it lowers the flaps completely, so that the plane loses a little more speed before touching the ground, once again, operating at a **rule level**.

In addition to the noise of the engine, the pilot uses "unmediated indications" (Gaver, 1991 and Mumaw, 2000) when he perceives that the horizon "rises" through the windshield at the same time that there was a whistle made by the air passing through the exit of the machine gun barrels on the leading edge of the wings (Fig. 3). This occurs in the P-51 when the plane has a high angle of attack, usually occurring in landings, indicating that the laminar flow of the wings approaches the stall (Hirschman, 2018). Combining these two pieces of information, high angle of attack and loss of altitude, he realized that the time to land was near.

7. Conclusion

Analyzing this accident from the point of view of cognitive ergonomics allows us to exemplify and contextualize several widely used concepts. Thus, and allied to the HFACS analysis system, it can be seen that, in this case, there was no alignment of the failures foreseen in the "Swiss cheese" theory and that the pilot's actions, which led to a landing only with consequences to the aircraft itself, for the most part, can be considered good examples of the concepts employed.

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