HUMAN FACTORS: A PROBLEM INTERACTION IN L-L INTERFACE AS A CAUSE OF THE BOEING 737-505 CRASH NEAR PERM

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Abstract: This paper presents problems of L-L interaction based on the Official report on the causes of the Boeing 737 crash near Perm. The Edwards-Hawkins SHELL model is an explanatory model for the L-L interface causes of the crash that killed 88 people.

Keywords: accident; SHELL model; L-L interface; problem interaction

Introduction

Due to the specifics of aviation activities, human factors in aviation are studied as an element of a complex system. This approach to human performance in aviation responds to the efforts of the aviation community to seek alternatives in solving flight safety problems.

In order to get a better understanding of the aviation system's complexity, Elwin Edwards developed a general model, which considers the interaction between a human operator (Liveware) and several components:

Software, Hardware, Environment – SHEL. Later Frank Hawkins modified Edwards' model by adding another L component (Liveware) due to the argument that the human element is a key factor that interacts with other components (Fig. 1).

Figure 1. The SHELL model (Hawkins 2010)

The SHELL model is seen as a *conceptual tool used to analyze the interaction of multiple system components*. At the center is the subject of the model – the L-component (Liveware), a human operator, that is the most valuable and most flexible component. *Humans do not interface perfectly with the various components of the world in which they work* (ICAO 2013), so the edges of the central block are not simply and clearly delineated and therefore the other components need to be carefully tuned (or more correctly, systematically tuned) to them to avoid a potential bad outcome in the system.

The H (Hardware) component includes equipment, tools, instrumentation, apparatus, workspace, buildings, and other physical resources.

The S (Software) component consists of non-physical resources such as organizational policies, rules, procedures, symbols, etc.

The E (Environment) component includes environmental factors such as climate, temperature, vibration, noise; socio-political and economic factors.

The second L (Liveware) component consists of human – human interaction factors such as communications, leadership, norms, team (crew) processes, i.e., interactions between operators at all levels in the organization.

According to Hawkins, the interaction between the central L-component and the others unfolds through the L - H, L - S, L - E, L - L interfaces.

The second L block may include operators from different levels of interaction with the central L block. Arguably, the L - L interface is more unpredictable than others, since it deals with at least two Liveware components, because the L - L interface describes the interaction between the central block in the SHELL model, whose edges are not simply and clearly delineated, and one of the side

blocks, whose edges are also not simply and clearly delineated. The problems in L-L interactions may include communication errors due to misleading, ambiguous, inappropriate, or poorly constructed information, mismanagement of crew resources, and lack of cockpit leadership. This diversity could be the cause of adverse events or accidents.

Such a severe aviation accident is the crash of Boeing 737-505 near Perm, Russian Federation.

1. The Boeing 737-505 crash near Perm

The Boeing 737-505 crash is described as published in the Final report of Air accident investigation commission.[1]

On September 14, 2008, an Aeroflot-Nord flight crew (captain and first officer), operated a scheduled domestic passenger flight AFL 821 on a Boeing 737-505, registration VP-BKO, from Moscow (Sheremetyevo) to Perm (Bolshoye Savino).

The night flight was uneventful until the start of the descent in the area of Bolshoye Savino. The crew started a descent from the flight level to waypoint Mendeleyevo. After passing over Mendeleyevo, in compliance with the Perm Approach Control instruction, the aircraft flew via the outer marker of runway 21 which was the initial approach fix for runway 21. After passing over, the crew, following the controller's instruction, turned right for back course, and started maneuvering for Instrument Landing System approach to runway 21. With the autopilot and throttle disengaged, the aircraft approached the landing course at 600 m altitude and after the base turn began to climb to 1300 m, rolled 360° over the left wing and collided with the ground. The aircraft crashed during the approach, being completely destroyed, and partially burned by the resulting fire. It was impossible to survive this accident, and all 88 people on board perished.

The Commission concluded spatial disorientation as the immediate cause of the accident, and the main factor – insufficient professional training of the crew (both in the technology of interaction and in lack of proficiency in aircraft handling, crew resource mismanagement and lack of skills associated with upset recovery an aircraft with a direct indication of the artificial horizon).

With respect to the Commission's conclusion, the focus of this article is on the L – L interface: a problematic interaction between the central L-component (the captain) and the second L-component (the first officer) as a crew.

2. The central L-component (the captain)

2.1. The captain's professional training and experience

The Air accident investigation commission verified the current status, flight training and flight experience of the captain of Boeing 737-505. His total experience on Boeing 737 was 1190 flight hours, including 477 hours as a captain. He was permitted to fly as a captain in February 2008. Previous aircraft types: Tu-134 and An-2 (flight college). He did not have any experience as captain, and he did not pass Crew Resource Management (CRM) training before transitioning from Tu-134 (four flight crew) to Boeing 737 (two flight crew).

2.2. The captain's physiological and psychological status during Flight 821

Because a passenger had sent a text message from aboard the plane prior to the start of the flight expressing her concern that the captain's voice sounded like that of a drunk person, the Commission ordered the remains of the captain and other crew members to be checked for ethyl alcohol content prior to death. The forensic medical examination confirmed the presence of ethyl alcohol in the captain's body before his death. No alcohol was found in the bodies of the other crew members.

Furthermore, the captain's recent work schedule during the time period before the accident contributed to fatigue and did not comply with national regulations.

As the Commission needed to get more objective assessment of the psychological status of the pilots in the accident flight, they conducted instrumental tests of the crew's speech, which included an analysis of the main tone frequency. The main tone frequency analysis showed that within the last 30 minutes the Captain's level of stress was higher than operational and was equivalent to a high level of stress.

In addition to the information provided in the central L component, independent psychologist experts stated that the captain's character accounted for his easy adjustability in contacts, flexibility and adaptive behavior in situations when he is playing secondary roles.

3. The second L-component (the first officer)

3.1. The first officer's professional training and experience

According to the Commission's report, the first officer took transition training for Boeing 737 at the Flight Training Center between December 2007 – January 2008. His previous types were An-2 (over 7000 flight hours, over 3400

of them as a captain) and Tu-134 (first officer, 1600 hours). Thus, just like the captain, the first officer had not had any experience on aircraft with spaced-apart engines, glass cockpit, and a direct indication of the artificial horizon.

During the simulator training there were numerous instructors' remarks that he should pay more attention to the Standard Operating Procedures (SOPs), especially regarding the callouts, the CRM and the distribution of the pilots' duties. The instructors also noted the first officer's insufficient level while making flights with thrust asymmetry and recommended that he should pay more attention to the attitude and speed control during approach. By the time of the accident the first officer had experience of 236 flight hours on Boeing 737.

Based on the conducted analysis, the investigation team concluded that the crew formation was made without considering the actual level of the pilots' training and skills.

3.1. The first officer's physiological and psychological status during Flight 821

The main tone frequency analysis of the crew's speech shows that the first officer's state was within the mobilization level, and 30 seconds before the crash it reached high levels of stress.

4. Problems in L-L interaction

4.1. *The captain and the first officer as a crew formation*

It was the third flight of the captain and the first officer together. Based on the conducted analysis, the investigation team concluded that the crew formation was made without considering the actual level of the pilots' training and skills. The two-member crew was formed of pilots who had little experience on this type of aircraft, and both were used in operating multicrew aircraft only.

According to independent expert psychologists the formation of the crew was also done without considering the psychological traits of the pilots.

In the final and critical for flight safety seconds, both pilots experienced levels of stress higher than operational, equivalent to a high level of stress – this state inevitably affected the airmanship in a destructive way.

4.2. *L-L crew resources and errors mismanagement*

The Commission summarized in the report, that during the whole flight, the crew significantly deviated from the SOPs, namely: mandatory cross-checks

were not carried out; flights modes were changed without informing the other pilot; no callouts about the indications or flight mode changes were made; the checklists were not read; the before landing preparation as well as the recurrent one after changing the approach pattern was not carried out; the Pilot Flying (PF) / Pilot Monitoring (PM) duties distribution was not complied with, the CRM was unsatisfactory; the control was passed from one pilot to another without the mandatory callout, which resulted in situations where during parts of the flight virtually nobody controlled the aircraft; the order and sequence of actions, particularly at takeoff and approach, was not followed.

4.3. *L-L miscommunication*

The Commission noted in the report, that the crew members' speech contained obscene language with extremely rude and unjustified references to the flight attendants and the airport's air traffic control service, as well as lengthy arguments that were not directly related to the tasks at hand, which hindered the crew from properly focusing on the resolution of the urgent aircraft management tasks. The aforementioned negative aspects of behavior certainly did not contribute to maintaining optimal operational attention of the crew as a whole, provoking fragmentation and distortion of the perception of the real flight situation, which inevitably leads, in cases of unforeseen complications or changes in flight conditions, to the occurrence of erroneous actions.

Both pilots learnt Technical English at a non-certified training center. The teachers who conducted the training did not have any aviation, linguistic or pedagogical education. The first officer's level of English proficiency did not allow him to properly use the technical documentation, as for this type of aircraft it is published only in English.

Discussion

For every complex problem
there is an answer that is clear,
simple, and wrong.
(Attributed to H. L. Mencken)

There are other people involved in the L-L interface too, such as the approach controller, as well as the maintenance personnel that had to ensure the aircraft was fit for the intended flight, the medical team that permitted the crew to fly, the airline management that was responsible for the airline's policies.

Because the crew was paired without taking into account the psychological compatibility of the pilots, an aspect to reflect on is the fact that the captain's perceived state from passengers (it was understood from the message sent by a passenger, that the intonation and speaking style were informative about the captain's use of alcohol before the flight) did not affect the first officer (it is obvious from his level of perceived stress, as measured throw analysis of the main tone frequency), remained unchanged until the last seconds of the flight. There may be various reasons for this, but as the discussed flight was the third joint flight in this formation, one possible reason is that the first officer found the captain's behavior familiar from previous flights which had ended successfully and did not attract his attention. The published results of the Flight 821 crash lead to the conclusion that there was no leader in the cockpit despite the two pilots' presence. The aircraft outperformed the crew in every respect because the crew lacked adequate training and knowledge of how to operate it.

The captain's high level of stress, which was above the usual operational level during most of the flight, could be a legitimate cause of the errors made. Judith Orasanu considers, that stress can affect humans' job performance and cause them: to make more mistakes than usual; to reduce attention (causing tunnel vision or selective hearing); to make scanning more chaotic; to reduce short-term memory; and to simplify the strategy (speed is preferred to accuracy) (Orasanu 1997). Monika Martinussen and David Hunter refer to an earlier study of Fitts and Jones (survey of a large number of U. S. Air Force pilots) in which the authors classify the main errors into six groups: substitution errors (confusing one control with another or failing to identify a control when it was needed); adjustment errors (operating a control too slowly or too rapidly, moving a switch to the wrong position, or following the wrong sequence when operating several controls); forgetting errors (failing to check, unlock, or use a control at the proper time), reversal errors (moving a control in the direction opposite to that necessary to achieve the desired result); unintentional activation (operating a control inadvertently without being aware of it; and unable to reach a control (inability to physically reach a needed control or being required to divert attention from an external scan to the point of accident) (Martinussen, Hunter 2010).

Examples can be identified in the captain's behavior for each of the deviations from safety behavior described by Orasanu, Martinussen and Hunter. In the conversations with the approach controller, he repeatedly erred in naming the flight number, wasted time in idle chatter, failed to clarify the flight path on the approach to landing, answered in the affirmative in re-

sponse to a question posed as to whether all was well in the cockpit when in fact there was a problem. He took control of the flight too late, in response to the co-pilot's insistence "Take it, take it!" replies "What to take, <an obscene expression>, I can't either" and abruptly and disproportionately made several wheel inputs. These inputs led to the left flip-over, a steep descent and the crash of the aircraft.

The first officer's behavior in the last stage of the flight showed fatigue, which combined unfavorably with insufficient training and lack of experience in piloting the Boeing 737. He had missed key elements of the aircraft's preparation for landing and in interacting with the captain, thereby confirming the validity of the quality of training observations noted by the instructors.

According to the International Civil Aviation Organization (ICAO) there are several hazards which reduce the quality of communications: failures during the transmitting process (sending of unclear or ambiguous messages, language problems); difficulties caused by the medium of transmission (background noises or distortion of the information); failures during receiving (expectation of another message, wrong interpretation of the arriving message or even its disregard); failures due to interference between the rational and emotional levels of communication (arguments); physical problems in listening or speaking (impaired hearing or wearing of the oxygen mask); use of English among native and non-native speakers; and encoding/decoding/noise (ICAO 1998).

Communication errors increase under stress and fatigue. This explains the errors in repeating phrases and the distraction of the crew. Both pilots failed to understand the approach route but did nothing to understand it. It looked as if the aircraft was overtaking its crew, who was engaged in conversations from which no clarity emerges on the basic parameters of the flight.

According to the Fatigue Risk Management Systems (FRMS) Manual for Regulators, fatigue measurements can be based on crewmembers' recall or current impressions of fatigue (subjective measures) or on objective measurements, such as performance tests and different types of physical monitoring. Crewmembers' recall of fatigue can be reported by using fatigue reporting forms that allow individual crewmembers to give vital feedback on fatigue risks when they occur in an operation. Crew members are encouraged to do this through an effective safety reporting system. The crewmembers' reports should be acted on by a Fatigue Safety Action Group in order to improve safety, not to attribute blame. Allowing crew members to provide feedback on fatigue or temporary inability to perform an operation is an essential element of Safety culture and that is one of the main responsibilities of every airline (ICAO 2012).

Conclusion

In discussing the problematic L-L interaction in the cockpit of flight AFL 821, we attempt to pose the problem of accountability to the tasks the crew is performing. Undoubtedly, the quality of training and experience are important for flight safety, which is also the conclusion of the Investigating commission in the published report, and this is the basis for their recommendations, with a preventive role for flight safety.

What is left out of the conclusions is the need to develop professional responsibility (as an element of personal conscientiousness) with regard to one's own training and working style, and as an important component of airworthiness. This responsibility, in its various manifestations, is an integral part of L-L interaction and is not confined to the cockpit but applies to every workplace and every specific individual who has a bearing, even indirectly, to flight safety.

Aviation safety is a result of the combined efforts of every human element in the system. No matter how many defenses are built by human reason into the complex system, human destructive nature remains a major safety challenge. Therefore, underestimating the "insignificant" risks we face daily in our work, is a type of irresponsibility that people may "forgive", but the laws of physics will not. In aviation, every underestimation of responsibility may result in loss of life, hence the saying "safety standards are written in blood".

NOTES

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