Improve safety by understanding the interaction between pilot and operational context

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ABSTRACT

This paper presents a method for analyzing pilots/crews performances. It aims to reduce errors through better understanding of interactions between crews and operational contexts. It includes a performance analysis model which takes into account the crew resources and the threats. The model, based on the cognitive information processing literature, facilitates the identification of failures, with their relationships, and allows to come up with realistic dynamic training scenarios. Digital visualization tool of those scenarios, provided by the model, completes the method. The theoretical part of the model has been already used for training in a professional environment, for two years. The feed-backs were positive.

Keywords

Performance, Crew, Safety Bubbles, Systemic Analysis Tool, Error.

INTRODUCTION

Civil and military aviations put a lot of emphasis on the analysis of pilot's performance, on a daily basis or after an incident/accident, in order to enhance human performance and safety. Therefore a pilot in training is debriefed by his/her instructor. A pilot in line operations analyses his/her own performance daily, often with structured debriefing methods, i.e. the Threat and Error Management (TEM) debriefing method, and sometimes as part of a first-hand experience feedback. For their part, the operators use complementary analysis tools (i.e. flight analysis). All these practices are based on the idea that the understanding of their activity will allow crews to improve their performance.

The article introduces a method which falls in line with this approach : "*Accidents are preventable, but only if they are correctly described and understood*" [9]. Its purpose is to be used by pilots, trainers, and any person involved in the analysis of aerial events.

CONTEXT

Until recently, training programs were still trying to deal with all the situations a crew could come across. But experience has shown that accidents scenarios are often unpredictable. "*It is impossible to foresee all plausible accident scenarios, especially in today's aviation system where its complexity and high reliability mean that the next accident may be something completely unexpected"* [11]. This observation led the industry to develop the Evidence Based Training (EBT) [11]. It was a major turning point in the training of crews, a new training philosophy. Developing skills that allow to deal with unusual situations became a priority. *The scenarios recommended in EBT are simply a vehicle and a means to assess and develop competence* [11]. Trainers are invited to analyse in greater depth : *"EBT refocuses the instructor population onto analysis of the root causes to correct inappropriate actions"* [11]. This refocusing on skills is in line with Captain Dan Maurino's analysis on the relevance of the Threat and Error Management, a process integrated in the EBT *"Operational consideration of human performance in aviation had largely overlooked the most important factor influencing human performance in dynamic work environments: the interaction between people and the operational context ... "* [12].

To facilitate the performance analysis of crews, several theoretical tools or methods have been developed, like The Reason's Model, The Human Factors Analysis and Classification System (HFACS), The Integrated Process for Investigating Human Factors, The Procedural Event Analysis Tool (PEAT) and The Aircrew Incident Reporting System (AIRS) [6].

The method presented here is looking for the root causes of inappropriate actions. It is part of the EBT philosophy. It is also close to the AIRS. However the method distinguishes itself from these tools by the use of a dynamic model that aims to facilitate the identification of the interactions between people and the operational context. The use of a model in the performance analysis of crews offers many advantages : Complexity reduction (visualisation of the interactions), better understanding (in-depth analysis of vulnerabilities), systemic and constructivist approach (the pilot act as a whole), visualisation of coupling threats (e.g. stress will impact situational awareness), reproduction and creation of realistic scenarios [1].

THE METHOD

We call performance the result, good or bad, of the crew activity. Yet every crew is regularly confronted with threats, meaning events or processes likely to seriously alter the performance [2]. Some threats, called external threats (ET), escape the influence of the crew. Others on the contrary, called internal threats (IT), are directly linked to the activity of the crew. Using a theoretical model of the performance, the method helps to identify and analyse the internal threats which brought (or could have brought) failure, the impact of the external threats, and all the interactions. To complete the model, a visualisation tool of the events scenarios helps to understand the dynamic and potential effects of the threats.

The model

The model includes three levels of analysis : the very general one of the domains, the one of the elements, and the more specific one of the threats. It offers therefore actions, called counter-measures, that reduce the risk of errors.

The domains

The domains are similar to the SHELL model. They are 5 : Aircraft, Environment, Team, Personal Commitment and Knowledge. Those are different fields towards which thinking and analysis can turn in order to understand performance.

The elements

The elements, for their part, are the dimensions (or variables) which directly determine the performance linked to the domains. There are 11 elements combining with the domains as follows. For the "*Aircraft*" domain we can find the elements Aircraft control and Procedures. For the "*Environment*" the determining elements are Flight conduct, Decision, Situational awareness. For the "*Team*" domain the element is Crew. The domain "*Personal Commitment*" is impacted by the elements Physiology, Pressure Management, Attitude, and Stress Management. Finally the last element, Knowledge, underlie the performance, linked to all the domains (figure 1).

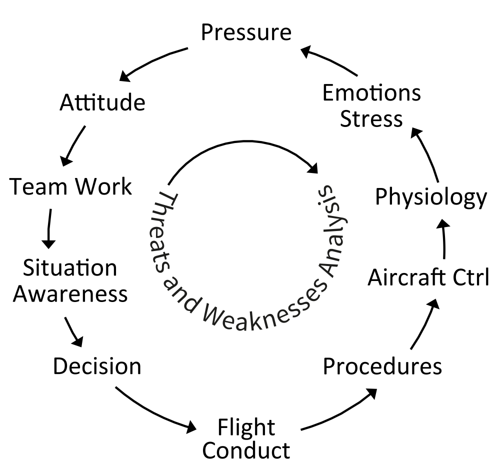

Fig. 1

The elements essentially come from the EBT Core competencies. However the elements linked to Personal Commitment come from our synthesis of Personnel factors and Condition of operators (Preconditions for unsafe acts) of the method Human Factors Analysis and Classification System (HFACS). In this synthesis, to make sure "*The Link Between Safety Attitudes and Observed Performance in Flight Operations*" [13] is understood, Attitude has been identified as a fully fledged element.

The threats

Since the method is following a systemic approach of performance, all the threats (internal and external) must be taken into account. These threats come from an in-depth examination of critical events (first-hand experience, investigation reports). Internal threats (there are 80 of them), relating to crew failure, are selected according to the definition of threats by the Australian CASA : " *…a situation or event that has the potential to impact negatively on the safety of a flight, or any influence that promotes opportunity for pilot errors*" [2]. An internal threat that will alter the performance being considered a failure (F). They have been selected following criteria defining each element, i.e. in the Decision element we can find a judgement criteria : a threat "*Bias of judgement*" is selected. A review of literature on the most frequent crew failures completed the selection [5].

External threats complete the performance analysis process. Based on the external threats presented in the Threat and Error Management process [10], 40 common threats classified in 8 families have been selected : Weather, Aircraft, ATC, Airport, Organization, Demanding situation, Operational constraints, Other threats. Each family presents a non-exhaustive list of threats. For example for the "*Weather*" family, we can find Icing conditions, crosswind, extreme temperature, etc. Many of these threats have a generic scope, like Icing or Unknown situation. They allow to discover numerous situations.

How the model works

In line with works on cognitive control [4, 8], the elements of the model interact with each other with an entry "*perception*" (the input) via the physiology element, and an exit "*action*" (the output) in the Aircraft domain. For each element of the model a list of internal threats/failure is proposed. From an event, the analysis consists in going back up the elements of the model, asking the question "*why* ?" as many times as necessary, looking for failures and subsequent problems. With the model, the sequential approach of questioning allows to operate links between domains, starting from an adverse event related to the Aircraft up to the domain Personal Commitment.

Example

Let's take the example of a runway excursion after a series of failures (F) of the crew among the different elements (el), combined with the emergence of external threats (ET). The method consists in answering a succession of questions, to approach all the reasons why the aircraft left the runway.

- Why did it leave the runway ?

Because it was going too fast [Piloting (el) Piloting precision (F)] + [Collective (el) Lack of callout (F) of the excessive speed].

- Why wasn't the announcement made ?

Because, while landing at night with heavy rain and strong crosswind [Demanding situation (ET)], both crew members were focusing solely on keeping the runway centerline [Situational awareness (el), Focus on one flight element (F)].

- Why wasn't the contamination of the runway Airport-contaminated rwy (ET) taken into account?

The contamination wasn't announced clearly by the ATC [ATC Non standard phraseology (ET)] and the workload was important. The crew didn't catch the right information. [Situational Awareness (el) Workload Vigilance (F)] + [Team work Lack of safety information (F)].

Possibilities for a more thorough analysis

In order to analyse a bit more in-depth a particular event, it is possible to divide the analysis in several stages, following the chronology of the flight, and compiling the successive analysis in a tree of failures (figure 2).

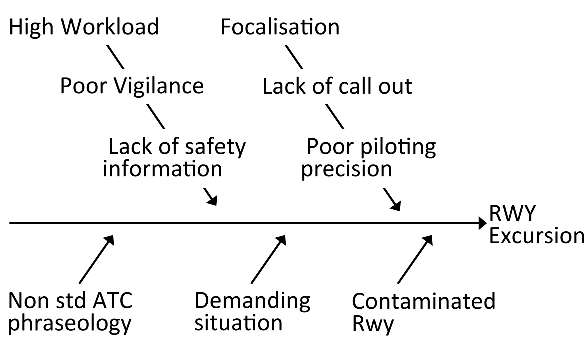

Fig. 2

Counter measures

The analysis of practical cases helps to make understand that the performance elements and threats are all variables: the situation awareness can be good or bad, the crew can be fit or tired, etc. Yet, the crews can act to keep their safety margins, either by changing the value of variables (when possible), or by limiting their consequences. Thus we can oppose a specific list of counter-measures to each threat. That way 70% of the activities of a piloting crew can be linked to the application of counter-measures.

To find and understand the significance of counter-measures, the model also allows the discovery of successful recoveries. The way to go about it is the same as described previously, the elements simply taking positive values: an "*excellent*" level of piloting, a "*good*" allocation of tasks, a "*good*" situation awareness that led to a "*quick and adapted*" decision, made easier by "*wide*" experience, as well as "*good*" stress management.

Visualisation of the flight dynamic.

The dynamic nature of flight introduces an important dimension of complexity. The perception of operational reality, with its time dimension, is therefore sometimes difficult to grasp. That is why a scenarios simulator has been imagined (work in progress). It relies on the visualisation of the control of space/time by the crew. The latter having to control his/her aircraft and its immediate trajectory between t_0 and $t+x$, as well as its environment between t_0 and $t+y$: the crew is "*in front/ahead of the aircraft*". This control can be represented by two temporal dimensions of safety, called Safety Bubbles: one for the aircraft and one for the environment (see figure 3). This visualisation also allows to detect the priority of tasks between t_0 (fly) and $t+y$. The size of these bubbles is governed by Aircraft Situation Awareness (SA) and Environment SA [7].

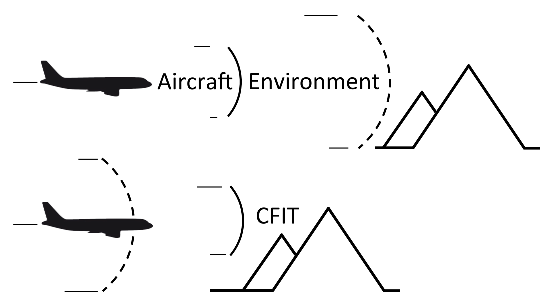

Fig. 3

Safety Bubbles [3] are more or less resistant to the onset of threats : they expand or shrink according to the events. In cognitive overload, the management of a space happens at the expense of the other : the crew is busy solving a machine problem, the SA environment decreases, its protection bubble retracts, goes behind the aircraft, and the risk of CFIT emerges (Controlled Flight Into Terrain)

The possible uses of the method

The method must be usable, in auto debriefing within the framework of the SPRM (Single Pilot Ressource Management) or CRM (Crew Ressource Management) trainings, and more generally during all trainings dealing with the performance of crews (e.g. Flight instructors). By modifying the elements of language as well as the list of threats, the method can adapt to different referentials or different activities (e.g. Recreational aviation).

LIMITATIONS AND FUTURE ORIENTATIONS

The proposed method is backed up by an in-depth analysis of the literature about human factors and psychology. It is also based on a thorough analysis of incidents/accidents. However, this method remains empirical.

It needs a minimum of experience from the trainer to be used (more so if the crew is using it as an auto-debriefing tool). Used by a trainer, it is perfectly suited to analysis for teaching purposes (where the result can differ from reality). However, even though the method makes analysis easier, it must be used with cautions in the search for the reality of events. Indeed perfect crews do not exist, and therefore a multitude of failures is more likely to be found. Yet if the precise weight of each of these failures is not known with accuracy, there are true risks of being out of step with reality.

During the development of our theoretical model, if the choice of elements was made without too much difficulty, thanks to a quite broad agreement in the literature, the choice of threats was a lot more difficult because of the lack of a precise method of selection. The list of selected threats could be improved.

As it is, what is the method really worth ? The theoretical model of analysis has been used by trainers with 240 instructor pilots in the French Air Force. A questionnaire handed to the teaching manager of the trainers brings us the following information. The method is quickly assimilated by trainees. Used in group work, it provides common elements of language that make interactions easier. The model facilitates in-depth analysis, with the access to the "*Commitment*" part. Trainers also outline the fact that the method is easily assimilable by professionals as well as accessible to non-professionals (e.g. glider instructors), but is less attractive to the latter. They also insist on the importance of simplicity ; some knowledge or process presented in the user manual are sometimes hard to grasp.

If the feedback from the French Air Force is positive (the method is integrated in their training process), it will have to be refined with a questionnaire addressed to trainees to identify more precisely its strong and weak points. This evaluation will be made shortly among the trained crews.

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