Safety Culture in Modern Aviation Systems – Civil and Military

Valentin-Marian IORDACHE[1], Casandra Venera BALAN (PIETREANU)*,[1]

*Corresponding author
[1]"POLITEHNICA" University of Bucharest, Aerospace Engineering Department, Polizu Street 1-7, sector 1, Bucharest 011061, Romania
valentin.iord1504@gmail.com, casandra.pietreanu@yahoo.com*

DOI: 10.13111/2066-8201.2016.8.2.11

Received: 30 April 2016 / Accepted: 24 May 2016

Abstract: *Understanding important aspects of the safety culture should be the main objective for identifying hazards, mitigate and manage risk and find solutions to problems before accidents and incidents occur. The two defining elements of aeronautical decision-making are hazard and risk; risk management is an important component of decisional process and by understanding some issues regarding risk and safety, we will be able to realize the feasible solutions that we may have to apply in flight or ground operations. As aviation is in continous development and worldwide expansion, in order to better understand the associated risks and mitigate them, proper control methods which can give a thoroughly comprehension of the aeronautical system must be used.*

Key Words: *Organizational culture, safety, aviation systems, control, STAMP model*

1. INTRODUCTION

The world we live in is dominated by systems and risks. From an engineering standpoint, we can affirm that most aspects of this domain imply the existence of systems. For example, commercial aircraft can be considered systems which work within other systems, an economic one and an airspace control one.

Aircrafts are systems that operate within other systems, civil or military, as an integrated part of the international air traffic system. Therefore, systems have become a necessity in the modern world and imply complex technologies, exposed to risks, which, through faulty functioning can result in occurrence of incidents and accidents, system damages and prejudice in different forms.

The probability of a system malfunction and the implied results represent a risk. The systems in our life are interconnected like a spider web; every system has a distinct structure and a unique set of components. These systems present risks that can lead to certain events, more or less damaging. We always make a comparison between the advantages and the risks of a system; during the development and the construction of a system, but our main concern should be reducing and eliminating the risk. Some risks are so little that they can be easily accepted and others have huge implications that require immediate assistance. The control elements of a system, implemented since the first steps of development, leads to maintaining the risk at a low level. [1]

System safety is a formal process of identifying and controlling risk; moreover, it is a process that administrates the systems, employees, environment and improvement through development, testing, production, use and disposition of the systems, subsystems, materials and facilities. A domain as complex and dynamic as the aeronautic one needs a continuous use of control, inspection, improving and operation processes. [1]

Regarding the resemblance between civil aviation and the military one, we can't pass by the different nature of the operations that take place. Through the continuous improvement of the aeronautical systems elements we have reached a higher level of knowledge, training and cooperation, moreover, aircraft safety has developed considerably.

Most of the time, when we state that a certain action taken has an acceptable risk level, then the actions that must be taken are not dangerous; when we say that something is risky, that it has a high risk, then the risk must be controlled if eliminating it is not possible – the complexity of military aviation missions in the conflict areas, for example, implies very high risks. Even though we are talking about a long period of time, maybe years, in which no event has occurred, that doesn't mean that the risk has been controlled or eliminated. Statistics, most of the time, are not a relevant standpoint. A safety characteristic that must be analysed, monitored and implemented to obtain an efficient result is represented by risk management, and safety can be viewed as a system characteristic.

2. SAFETY CULTURE - A FUNDAMENTAL COMPONENT OF THE ORGANISATIONAL CULTURE

Safety culture (Figure 1) means sustainable values and priorities reflected on the individual as part of a group in an organizational system. It depends on the extent to which individuals and groups take responsibility regarding personal safety issues, such as: actions to maintain, improve and communicate safety-related elements, the desire for continuous learning, adaptation and change of a behavior (both at an individual and organizational level) based on lessons learned, control activities, recognition of merits in an appropriate manner with respect to cultural adopted values. [2]

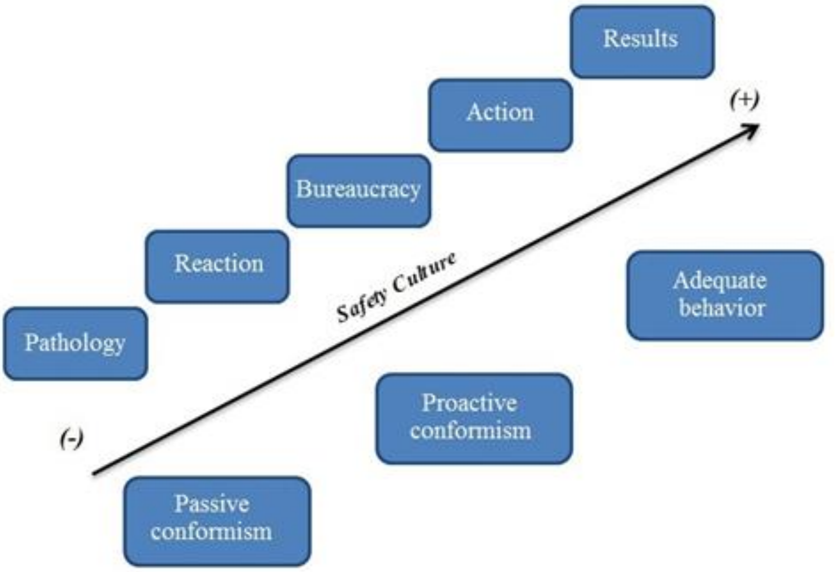

Figure 1. Organizational evolution of safety culture [3]

Aeronautical safety culture is actually a sum of several other cultures, each with an important role, based on rigorous principles and doctrines, which is understandable, given the complexity and implications of the aeronautical field.

The culture of any group can be analyzed in terms of three levels:

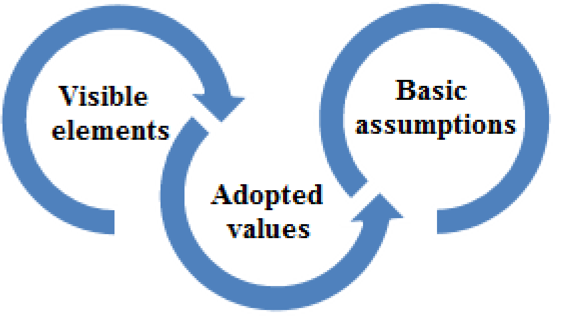

Figure 2. Levels of analyzed group culture

If the basic pattern of the group's specific prevalent manifestations is not properly understood, than the visible elements can't be correctly interpreted and it can't be determined how much credit is to be given to the values adopted. The essence of a culture lays in its basic assumptions; once these are understood, the other levels can be easily understood as well, thus leading to an efficient management. [3]

The first element of the safety culture is an *informed culture*: those implied in managing and operating the system need a package of knowledge related to human, technical, organizational and environmental factors that determine the system's safety. It is important for the personnel involved in aeronautical activities to be prepared and not to be reluctant to report mistakes, both personal, as well as of others; this is, therefore, a *reporting culture*. At the same time, the awareness of the fact that no flight is similar to another is needed; there is no particular pattern for the evolution of aeronautical operations; according to the situation demands, a culture must be able to adapt in order to accomplish tasks and, of course, to perform the mission safely and efficiently – which means a *flexible culture*.

By its contribution to the society and due to the desire to improve their results, the organization must have the ambition and skills needed to draw reliable conclusions from the work done, but also have the will to resort to major reforms, if necessary, acquiring knowledge – consequently, *a learning culture*.

Between members of the organization, an atmosphere of trust is necessary, regardless the status of each individual. It is important for people to be encouraged and appreciated for their contribution, more or less essential, to safety improvement, but it is also extremely important to be aware of the border between what is acceptable and what is not –, hence *a fair culture*. [4]

Aeronautical personnel involved in aerial operations must have thorough knowledge regarding human factors principles, since anyone can be affected by such issues, one way or another. Safety and efficiency are maximized when the human factor is considered an integrated part of operations.

A significant component of human behavior and performances is variability. Human factor issues that represent possible causes of aviation incidents are seldom the result of a consistent behavioral model.

Most of the time, an individual who has shown an average performance, or even an excellent one, throughout his career, falls victim of human factor issues and inevitably contributes to the occurrence of an accident. The conduct of the pilot or the crew is influenced by various auto generated or external factors.

These influences may profoundly affect the actions of the crew and especially predispose them to make errors.

Therefore, the following classification was carried out: [5]

- Environmental influences - factors that affect the flight and cannot be controlled by the pilot or by the aeronautical organization; ex. ATC communications and services, weather conditions, other aircraft that are participating in traffic;
- Organizational influences - factors that cannot be controlled by pilots/crew, but which are controlled by the aviation organization; ex. the pressure of the working environment, internal ATC communication networks and services, maintenance and training;
- Informational influences - the content and form of operational information available to the crew; ex. checklists, manuals, navigation maps, standard operating procedures etc.;
- Personal influences – it involves the internal state of each individual involved in air operations; ex. level of knowledge, fatigue, operational stress, personal stress, post-incident stress, emotion, level of awareness, spatial disorientation, complacency, moral, medical status, social interactions etc.

The existence of some influences is quite obvious, even though others are subtle and more difficult to observe and control. All these can affect situational awareness, judgment and decision-making factor; basically, the probability of making mistakes. An important aspect of modern theory and practice, relating to the human factor, is the ability to help the human operator understand these influences and channel the knowledge necessary to reduce and avoid making errors.

Errors, in theory, are unpredictable because the interaction of contributing factors that generate them is probabilistic. To a large extent, the errors that the experienced aircraft crew commits are believed to be due to: [5]

- The characteristics and limitations of cognitive and perceptual processes;
- The events in which the tasks performed by the human operator goes beyond their control;
- The demands imposed on human cognitive processes by specific tasks and events;
- The social and organizational factors that influence the capability to respond, of the human operator;

Because the error is almost impossible to eliminate, it is important to demystify and understand the way in which the situations that arise despite all the efforts made, can be resolved.

From this point of view, aviation safety represents the capacity of the aeronautical system to maintain stability by optimizing the functionality of specific parts and managing the specific risks, in order to achieve some objectives.

This is achieved and maintained by performing the appropriate management activities, the planning, control and progress, by complying with the regulations and the limits of the aeronautical equipment and by ensuring quality conditions of training for the entire staff. Ensuring optimum air safety is determined by the quality and the level of training of the aeronautic personnel, by the quality of leadership, by risk management, by the reliability and performance of the aeronautical technology and the flight insurance systems, by the level and quality of aeronautical maintenance, by the ability to properly detect and correct whatever the malfunctions may be and by the way the control activities are organized and the proper management of their results. [6]

We can conclude that an organization has a strong safety culture by analyzing what people do, not what they say. (Figure 3)

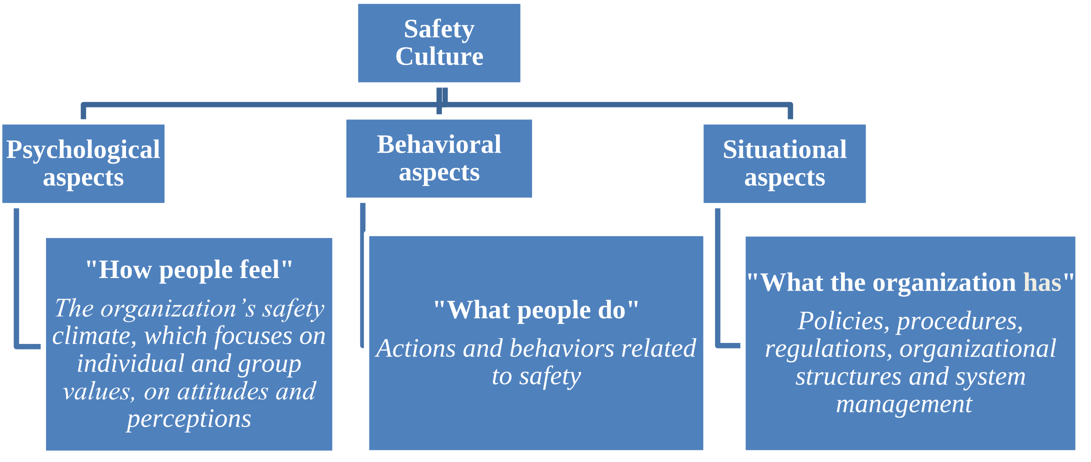

Figure 3. Organizational aspects of the safety culture [7]

3. A NEW APPROACH ON ORGANISATIONAL VULNERABILITIES IN AERONAUTICAL SYSTEMS

Purchasing new aircrafts, implementation of new organizational policies, willingness and capacity to development, among other things, obliges aeronautical organizations to achieve a reorganization of its system. Since not all the system's vulnerabilities are known, safety issues are omitted; this means that all functional subsystems are at risk and the result can be only one, chaos.

The interaction between man and machine is significantly shifting in the current tremendous technological process. New technologies must be well understood and the process of integration is extremely complex, with implications of risk portfolios. Aviation events can occur at any time the main cause being the lack of control over all structure components and subsystems and especially over the interactions between them.

Most methods of hazard analysis or risk assessment are based on a random chain of events, which is the main cause of accidents. Techniques based on these sequences have certain limitations to the study of modern systems. They do not represent viable alternatives for software-intensive systems analysis, complex human-machine interactions and systems-of-systems, leaving more room for personal interpretation, understanding and impacting the accuracy of management's specific vulnerabilities.

Therefore it was necessary to implement an advanced analysis model, able to carry out a rigorous and objective analysis of the system as a whole, to identify all the elements that need attention and can improve control.

Systems Theoretic Accident Model and Processes (STAMP) is a model for analyzing accidents, created by Nancy Leveson, a teacher at Massachusetts Institute of Technology (MIT) and an expert in safety system - with remarkable results in research for NASA and in nuclear field. She designed a model that relies on the idea of control, and based on systems theory; using concepts of engineering, math, social and cognitive psychology, organizational theory, political science and economics. In general terms, the STAMP accidents are the result of inadequate implementation of safety restrictions in the structure, development and operation.

STAMP includes the traditional analytical methods subset and addresses in depth analysis systems so that includes dysfunctional interactions between functional components, errors in software and logical structure, errors in complex decision-making processes and different organizational factors - workforce, processes and safety standards or other factors such as organizational management, social and cultural factors. [8]

Safety can be seen as a control issue, being managed by a control structure which is integrated into an adaptable socio-technical system. The assumption underlying this model is that it is a useful control theory in which accidents can be analyzed, in particular those whose result are injuries. The model, based on control theory, is useful in analyzing accidents especially those that result in damages.

In this model safety accidents occur when external disturbing factors, use of unsuitable components or dysfunctional interactions among components are not properly managed by the control system; they occur because of inadequate control or due to an exaggerated safety measures implemented in the structure or in the system operation. Safety can be seen as a matter of control, being managed by a structure embedded in a socio-technical adaptable system.

The purpose of the control structure consists imposing system operating restrictions for safe operations. In this context, understanding the cause of an accident, requires determining why the control structure was inefficient. Preventing accidents in the future requires designing a control structure to implement the necessary limits. [8]

In STAMP, the systems are seen as a sum of interconnected components that are maintained in a state of dynamic equilibrium response by loops of informational and control elements. In this concept a system is not static - but it is in a dynamic process, continuously adapting to the desired result and reacting to any structural or environmental change. The organizational management should impose the necessary safety control methods on the system to ensure safe operation.

The process leading to the accident can be described as a function of adaptable response which cannot maintain safety while the performances are changing in order to fulfill a set of goals and values.

Safety management in the context of preventing those component dysfunctions which can occur, is defined as a continuously control activity to impose the necessary component limitation measures for safety changes. [9]

STAMP is built on three concepts:

- Restrictions (limits),
- Levels of control, and
- Procedural models.

Based on these concepts we can realize a classification for control mistakes that leads to crashes.

The systems are seen as hierarchical structures where every level impose restrictions about the activity from the next inferior level; therefore the cause of an accident is not perceive like a series of events but like a result of the lack of restrictions. In the afferent theory of systems terminology, safety is a feature that appears when the system's components interact in an environment.

The emergent features are controlled or imposed by a set of restrictions related to the component's behavior from the system.

Accidents are the result of some inappropriate restrictions on interactions between components.

Why the structural limitation has such an important role in the complex systems, especially in systems with an advanced software ?

The computer has an extremely important role because it eliminated a lot of physically limitations of the electromechanical systems. Physical restrictions impose a certain discipline on structure, construction and the visible elements of modification; in the same time, they control the complexity of the things that we build. Using the soft, the limits of "what can be achieved" are totally different from the limits of "what can be achieved safely and succesfully". [9]

The impact of the higher level objectives and values needs to be adequate and evaluated in a formal manner.

While generic policies will be needed to prevent accidents, the small details can be finalised by the lower levels. Each level can have its own input and the feedback is needed to evaluate the efficiency of the new functions.

As in any control structure, the response time influences the control actions and the feedback, which in turn affects the efficiency of the control loop. For instance, certain standards require years to be finalised and in the meanwhile the technology progresses. Inadequate exercise of the control actions is another way to breaks the limits imposed by the control process and occurs when the control commands are incorrectly transmitted or when they are incorrectly executed.

Another common mistake in developing the systems consists in miscommunication on safety information gathered by the safety engineers and the personnel involved in testing and development.

The safety control system can degrade in time due to changes and routine supported by the elements of control for safety within the process. The reasons causing insecurity are specific to each system and can be complex.

The analysis or prevention of accidents demand not only a better understanding of the static structure of the system (the complexity of structure) and the structural changes over time (structural dynamics), but also of the dynamics behind the changes (dynamic complexity).

4. CONCLUSIONS

The fundamental pylons of aeronautic operations are safety and efficiency. For the coordination of those two elements and for successfully reaching the objectives set, the aeronautical organizations must solve any problem – vulnerability, dysfunctions - on the structure of its system, due to dynamics and complexity of modern systems; this can be achieved only with the support of rigorous control instruments, consistent both with operational objectives and the organizational performance.

The control has become the key word in aviation; there is always the desire for the flexibility of the conducted processes, achievement of high performance, high operational capacity, comprehensibility and continuous developing.

Without control it cannot achieve an organized medium, safe and efficient, and without obtaining performance at micro level – national system, it cannot talk about performance at a macro level – international system.

The absence of control means organizational chaos; it represents the lack of desire of improvement and achieving a high level of performance.

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