Human Factors and Aerospace Safety 6(1), 51-70

PRACTITIONER PAPERS

The evolution of error and violation descriptions in French Air Force accident reports: the impact of human factors education

Michelle Aslanides*, Claude Valot**, Anne-Sophie Nyssen*** and Rene Amalberti**

* ADVISES Research Programme, University of Liege and IMASSA, Belgium/France

** Institut de Medecine de Service de Sante des Armees, France

*** University of Liege, Belgium

Abstract

This paper compares the way human errors and violations were described in two series of accident reports, made before and after the introduction of the 1994 French Air Force Human Factors (HF) Safety Plan (1992-93 versus 1998-2002). The plan aimed at reducing the accident rate by installing a better safety culture with the introduction of multiple incentives, namely a voluntary reporting system and extensive Human Factors education programmes including CRM courses for all pilots, safety officers, and accident investigators. The paper analyses the conclusion sections of 70 accident investigations (35 before and 35 after the introduction of the plan), categorising coding the text from these conclusions to

Correspondance: Rene Amalberti, IMASSA, Departement de sciences cognitives, Bretigny sur Orge, BP73, 91223, France or e-mail ramalberti@imassa.fr

get equivalent semantic categories describing errors, violations and their attributed causes. The main results show a wider systemic consideration of factors in the reports and a more standardised phrasing of errors after the HF plan was introduced. The use of the term 'violation' is absent in both periods, replaced by several related, less emotive words (incorrect procedure, deviance, etc) – but which are also much more underspecified, thereby creating the potential for loopholes in the accurate description of causes contributing to the accidents and in proposing their associated solutions.

Introduction: general context

In the early 90s, the accident rate in international civil aviation had reached a plateau of 10^{-6} accidents per departures. At the same time, the figure for military aviation in Western Air forces was running two orders of magnitude behind, with a rate of accident close to $0.5*10^{-4}$ per flight hour[s]. This was the case of France. An annual average of 25 accidents or severe incidents was the standard for the French Air force in the 80's[2]. Not surprisingly, considering the usual figures in civil aviation (Boeing stat summary, 2003), human errors causes were also cited as the primary cause in about 70% of these Air Force military accidents (see figure 1).

In the early 90s in the French Air Force, most safety directives and organizational aspects were issued in the 70s. At that time, safety officers were appointed in each squadron. The flight safety bureau was positioned in the central Air Force headquarters. This bureau was placed directly under the authority of a Major General (four stars), second in command of the Air Force. The safety bureau was in charge of a series of continuous actions like educating the corresponding officers or editing a safety bulletin and, last but not least, the bureau was in charge of all accident investigations. The role of the bureau in accidents was threefold: (i) initiating the after accident process, appointing experts to the inquiry board; (ii) making provisional safety decisions such as a 'temporary grounding the fleet' if required; (iii) and once the report was available, closing the process and initiating follow up technical and /or disciplinary actions.

Despite the apparent value of this safety organization and despite the continuous safety improvements observed in the past decades, the pressure to

[1] Civil aviation uses a denominator for accident statistics based on airport departures (instead of flight hours) in order to neutralize long cruise periods where the risk of accident is moderate. Such a correction is needed less in the military, because most military flights are much shorter (often below one hour for fighters in the 80s).

[2] Military aircraft accidents are defined as events where the consequences are either substantial damage on the aircraft or death or serious injury. Severe incidents correspond to near accidents. Accidents involving paratroopers and military flying clubs using gliders and aircraft are included in the accident analysis.

vastly improve military aviation safety grew in the early 90s. Three factors initiated a profound change in the attitude of the Air Force Commanders' regarding safety.

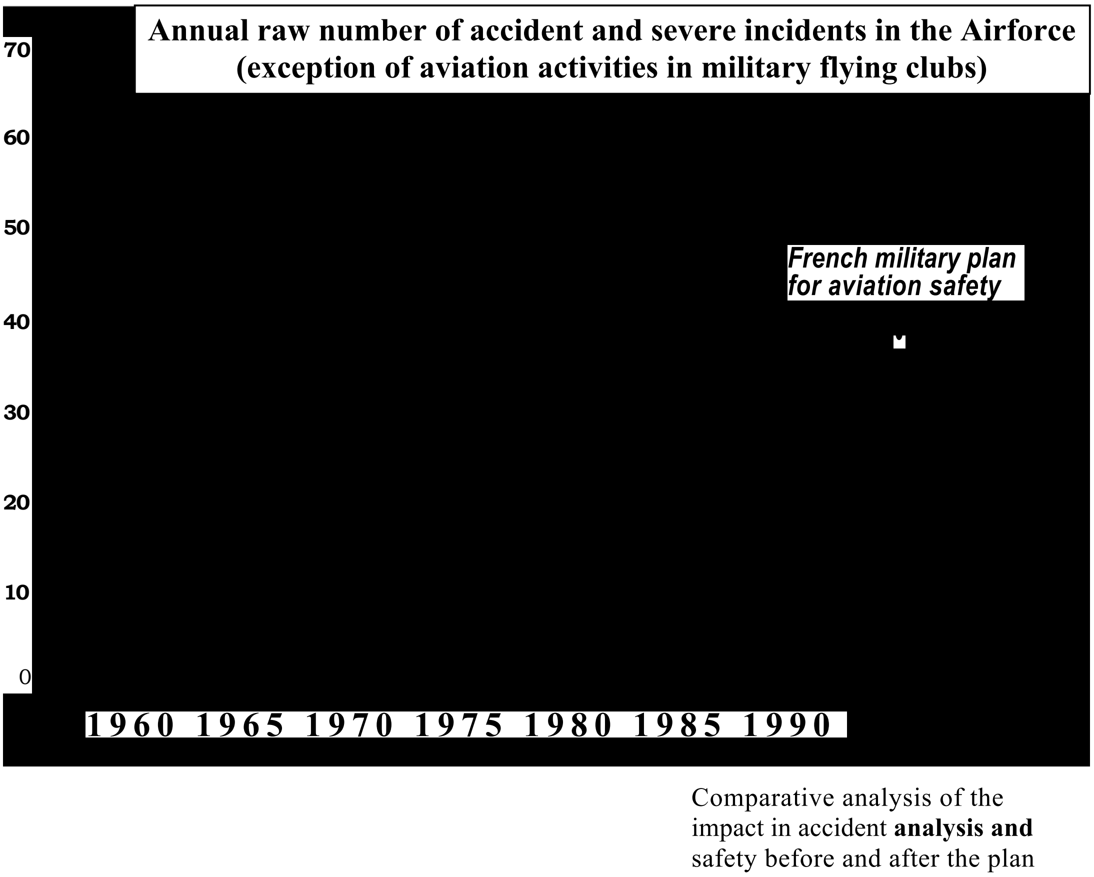

Figure 1 Evolution of the raw number of accidents in the French Military Air Force (excluding military flying club activity)

- The first factor was a direct consequence of a series of political and technical revolutions. It was decided in the late 80s to drastically reduce the composition of the French fleet from 560 fighters to about 380 within a period of 20 years. This reduction followed a new political deal in Western Europe and in the NATO forces, and was associated with a significant modernization of the fleet. The 'numerous low cost' old generation fighters (Jaguars, Mirage III and Mirage IV) were replaced with the new high performance Mirage 2000 generation, and more recently to the Rafale. Not only was the fleet was reduced by one third, but the new fighters costed at least three times the price of a fighter of the old generation. These reasons made any new hull loss even less acceptable and reinforced the rapid need for better safety.

- The second factor echoed a series of new ideas coming from the human factors community. During the 80s, major psychological advances were being made worldwide in aviation safety management. This human factors `upgrade' proceeded in two major steps. Firstly, in the early 80s, came Charles Billings's NASA team and other well known associated fellows, like Bob Helmreich and Earl Wiener (for example, see Foushee, 1984 or Wiener, Kanki and Helmreich, 1993 for an oerview of this period). The impact of this group of people on Aviation Human Factors was tremendous. With the introduction of the CRM (Crew Resource Management) concept they shifted the focus of Human Factors towards pilot behaviour and training issues. Human Factors issues then expanded from a group of enlightened designers, to thousands of people in the airline business all around the world. The second revolution came in the late 80s with Jim Reason's ideas on human error, which had a considerable impact on aviation safety. Reason and other contributors (Reason, 1990, 1997; Westrum, 1995; Maurino et al, 1995) introduced the central paradigm of a systemic approach to safety, stressing the role of accident precursors through latent organizational failures, corporate and national cultures and beliefs. This came with the support of cognitive engineering in design offices, pushing engineers to go beyond errors and to reconsider automation paradigms, shifting from quantitative evaluation concepts (workload) to more qualitative cognitive concepts (such as situation awareness –Billings, 1997, Woods et al, 1994, Sarter and Amalberti, 2001). Investigators were educated in parallel to pilots and rapidly brought these concepts into the national bureaus for air accident investigation all around the world. It was hard for military aviation to evade these new concepts during investigations.
- The third factor was the consequence of a growing need for sky sharing with civil aviation and ATC and also the Justice Department's evolution to be more inclined to question and consider wider consequences of military accidents. These moves pushed the Air Force Commanders to demand their military training schools to prepare military pilots to hold a civil pilot professional flight licenses. This, the human factors training in JAR FCL and JAR OPS were logically included in this alignment with the civil diplomas.

Given these circumstances, the Air Force Commander launched a Priority Plan for Aviation Safety in late 1993 to improve safety and better consider the system-wide approach to human factors. The plan aimed at reducing the military accident rate by an order of magnitude within a period of ten years. Four steps for improvement were considered to be the first priorities:

1. To develop a basic and systematic HF education for all military pilots (including accident investigators) aligned with the JAA civil requirements for the ATPL.
2. To develop CRM courses for all squadrons and all types of aircraft,
3. To develop a voluntary and anonymous reporting system on HF causes of incidents and near accidents.
4. To suggest concepts, methods and training curricula to develop stress coping strategies for pilots.

The paper is divided into four sections. Section one describes the objectives of the study and the expected changes. Section two sets out the methods used. Section three presents the main results and section four discusses the possible factors that have limited the impact of the plan on accident investigator's capability to code human failures in accident reports.

Human factors education curricula and related hypotheses on expected changes

Objective of the study

The purpose of the study is to evaluate the impact of an intensive Human Factors education program for accident investigators on their capacity to better search and explain human-related factors and causes in accidents.

The purpose of this study is not to analyze the real impact of the HF plan on the accident rate. Safety improvement may seem important when considering raw data (the reduction in the accident rate was by an order of magnitude of 2.2 within this period of five years). However, such a conclusion requires a careful discussion of the side-effects of and attribution of progresses in the HF plan. For example, during the same period of time, the Mirage 2000 progressively replaced the old generation of Jaguar with a much better and safer technology (fly-by-wire design) and the total flight hours in the Air force was also significantly reduced.

To sum up, this study focuses on the change in attributing causality after HF education and not at all on the global effect of the HF aviation plan on accident rate.

HF course curricula

Until 1993, before the HF plan there was no mandatory HF education of military pilots and accident investigators.

After 1993, after the HF plan was implemented, the Air Force commander imposed three training requirements:

- The first training requirement was composed of two modules taught by IFSA (Institut Francais de Securite Aerienne) on the specification of IMASSA. The courses were mandatory for all officers belonging to the central safety bureau, and all military regional safety officers (from among them was systematically chosen the chief investigator of Boards of Inquiry).
  - The first course was a one week Basic Human factors course. It included specific developments on human limitations and performance; perception; reasoning; attention and vigilance; crew rest; stress and human error; detection and recuperation and global management of risk. A specific chapter was devoted to violations, introducing Jim Reason's classification of routine versus exceptional violations, and giving examples of the paradoxical need for some violations to achieve some of the assigned tasks.
  - The second course was a two week course on accident investigation (with a significant contribution on human factors causes). The course gave extensive information on human error causality, emphasising the difference between the person versus the system approach. The Rasmussen' SRK model (1987), Reason's Swiss Cheese model (1990) and Hollnagel's phenotype of error modelling (1993) were the reference models for most of these lessons. A significant part of the course was also devoted to improving safety culture (Westrum, 1995) and to the concepts of situation awareness, and its application to automation-induced accidents (Sarter and Woods, 1992, 1995).
- The second training requirement was comprised of CRM at the squadron level. The deployment of CRM into squadrons started in 1993 and was completed in 1998. This interactive operational course included chapters on teamwork; authority and leadership; communication; human error; fatigue and stress management, and ended with some case-based accident analyses. All regional safety officers, and potential chief investigators received this training during the period 1993-1998.
- The third and last training requirement for HF training was accomplished through the annual recurrent training on HF problems and via the new human factors voluntary reporting system introduced in 1995 (Vortex system), This led to multiple feedback from squadrons.

From this process, two outcomes were expected to be seen in the accident files after the plan: first a more standardized academic-oriented analysis and phrasing of human error with more explicit reference to errors types, and secondly a growing consideration for systemic issues, looking beyond error to latent failures in the organization.

Note that the analysis of the impact of the HF education of investigators has already been undertaken, for example in selected US and Canadian aviation accident reports between 1996 and 2002/2003 (Holloway and Johnson, 2004;

Johnson and Holloway, 2004). The results show that the majority of high consequence accidents were attributed to human error. A large number of reports also mentioned wider systemic issues, including the managerial and regulatory context of aviation operations. These wider issues are more likely to appear as contributory rather than primary causes in accident reports. Apart from these results, it is important to note that Johnson (2003) also pointed to considerable controversy over this systemic view of failure which could result in inverting the whole paradigm of accident investigation, absolving the responsibility of front line actors to the detriment of the organization, regulators and managers (see also Johnson and Holloway, 2003). It can also be difficult to identify precisely which factors play a significant role in the latent causes of an accident or incident. It was therefore also of interest in this study to evaluate how much difference education had made the move to attributing systemic causality.

Method

General principles

The method is based on a comparison of a set of accident investigation files before and after the launch of the 1994 Air Force plan for aviation safety.

The BEFORE PLAN PERIOD is made up of all of the 35 accidents files which occurred in the last two years before the plan (1992 and 1993).

The AFTER PLAN PERIOD is made of an equivalent sample of 35 files. We considered a period starting in 1998, five years after the launch of the plan. To get an equivalent series of 35 accidents compared to the BEFORE period, we had to consider a much longer period of time, covering all files between 1998 and mid 2002.

Table 1 Characteristics of accidents files considered in the two chronological series. All files have been considered without exclusion. The category 'miscellaneous' covers accidents involving paratroopers, gliders and propeller-driven aircraft (Numbers in brackets correspond to accidents were Human factors is cited as a primary cause)

Aircraft Type	BEFORE	AFTER
Fighters	17 (12)	17 (14)
Transport aircraft	2 (1)	
Training aircraft	2(1)	7(1)
Helicopters	5(5)	2(2)
Miscellaneous	9(6)	9(8)
TOTAL	**35**	**35**

The accident files from the two periods were considered in the chronological order of occurrence, without any filtering or exclusion process. Therefore, the accidents of training aircraft, paratroopers, military gliders and propeller-driven aircraft are included in the list and grouped in the miscellaneous category.

The distribution of the types of aircraft involved in the accidents is given in table 1.

The strict pairing of the types of aircraft in the two sets of accidents –before and after the implementation of the plan – is not an object of comparison for two reasons:

- Firstly, the goal of the study was not to compare the raw data, but merely to compare the attribution of causal factors and the phraseology on human error used in the reporting of these adverse events. We can make a reasonable hypothesis that such changes, if they exist, are primarily dependent upon the investigator and not on the type of aircraft.
- Secondly, the study gives priority not to aircraft type but to accidents where human factors are cited as the primary cause (and where human error or violations were explicitly suspected).

Detailed methods

The accident file as basic material The basic material used for all analysis was the accident file. Until 2003, and the creation of the *Bureau Enquetes Accident Defense,* the investigation board was composed of four people: the Chair, always a pilot (a regional chief safety officer) and three assessors: a pilot from the Air Force base of the damaged aeroplane; a mechanic with knowledgeable of that aeroplane, and a flight surgeon. Each of the three assessors wrote a sub report, then the chair wrote a cover report ended by a one page executive summary of the circumstances and presumed causes. This was expected to be delivered with a provisional conclusion within three to six months. This report was then transmitted through the hierarchy to get additional comments and recommendations (squadron commander, Air Force base commander, Medical headquarters – the IMASSA was in charge of this process – AF safety bureau, and finally the Air Force Major General was in charge of deciding the corrective actions and sanctions (if needed). Usually one year was needed to close an accident report.

All accident reports considered in this analysis come from the library of IMASSA. All files are closed. They have almost the same structure in terms of content even though they were all made before the initiation of the new *bureau enquetes accident defense (BEAD).*

The procedure for extracting relevant information for the analysis consisted of two steps.

First step: global reading and analysis A careful reading of each accident file by two of the authors of this paper was undertaken. The readers compared conclusions.

Table 2 Principle of the analysis of executive summary: coding categories and related number of occurrences (in brackets)

(70) Accident files Executive summary	(566) Expressions Coding of the executive summary	1. Context (117)	1. Factual context description
		2. Human error-related expressions (287)	2.1 Explicit abnormal action expressed in mission and a/c procedures terms (104)
			2.2 Explicit human deficiency expressed in crew-centred terms (69)
			2.3 Explicit patent human error mechanism (65)
			2.4 Explicit latent factors / systemic cause (49)
		3. Violations-related expressions (49)	3.1 Explicit voluntary non standard procedure or action (40)
			3.2 Explicit latent factors / systemic causes (9)
		4. Technical failure related expressions (87)	4.1 Explicit failure immediately consequential for flight (58)
			4.2 Explicit latent factors / systemic causes (29)
		5. Environmental failure (weather, birds, etc.) - related expressions (26)	5.1 Explicit failure immediately consequential for flight (24)
			5.2 Explicit latent factors / systemic causes (2)
		6. Miscellaneous	6. All statements unrelated to previous categories (27)

This reading provided:

- A global understanding of the accident synopsis, as well as a list of hypothesis and facts, as noted by investigators
- A classification of the accidents depending upon their primary causes: (i) technical and environmental failure–related accident (ii) human error-related accident, and (iii) violation-related accident. Although the distinction technical/environmental causes versus human causes is generally explicit in reports. The distinction between human error versus violation causes depends on the authors' judgment based on the story and the

expressions used for describing the human failures. The criteria for classifying a file in the violation group were that there were explicit mentions in the report that one or many actors involved into the accident chain voluntarily made a deviation from standard operating procedures.

- A classification of accident responsibility (front line actors; Air Force base support; Military operations and regulations; Training school and training courses; Maintenance; Military Authorities; Manufacturers) as they appeared in the final conclusion signed by military authorities

Table 3 Example: segmentation and recoding of one executive summary (excerpt). From raw data (categorisation of the executive summary) to recoded causes (type of causes, patent versus latent associated factors)

Raw material **Phrasing in the executive summary (excerpt)**	**Expressions (categorisation of the summary)**	**Coding category**
.../...The fighter pilot stationed in the middle east was preoccupied from start with a heating failure in the cockpit and made a series of negligence in managing the flight parameters.	El : The fighter pilot stationed in the middle east	Cat 1 (factual context description)
	E2 : (The pilot) was preoccupied from start with a heating failure in the cockpit	Cat 2.2 (Human centered abnormal situation)
	E3: (The pilot) made a series of negligence in managing the flight parameters.	Cat 2.3 (explicit patent human error mechanism) (at this stage, there is no intention mentioned, therefore the item is classified in the error category)
The pilot made unfruitful tentative to control the heating system. He was probably head down for seconds.	E4: The pilot made unfruitful tentative to control the heating system.	Cat 2.1 (explicit abnormal action expressed in mission and a/c procedures terms)
	E5: (The pilot) was probably head down for seconds	Cat 2.2
.../...The a/c lost altitude and crashed in a inhospitable region 5 minutes after T/0.../...	E4: The a/c lost altitude and crashed in a inhospitable region 5 minutes after T/O	Cat 1
It is the second accident with the same cause on the same a/c type .../...	E7: It is the second accident with the same cause on the same a/c type	Cat 2.4 (latent factor)

Second step: a detailed coding of the executive summary A one page executive summary closes each report, containing a brief synopsis of the event, listing plausible causes and recommended actions.

The executive summary of each accident file was recoded into six generic categories of accident causes with the associated expressions describing the human or technical failure (see tables 2 and 3). For example, the category violations-related accidents was subdivided into two subcategories, one describing violations at a factual level, and the other describing latent factors associated with the violation.

Results

Similar distribution of primary causes

There were an equivalent number of accidents where HF was cited as the primary cause (25 from a total of 35 in the two series). The number of accidents where error was cited as a primary cause versus a violation was cited as a primary cause was also stable (six before the HF plan Versus seven after the plan was implemented).

Table 4 Categorisation of expressions in the two periods before and after the introduction of the HF plan

Categories of expressions	92-93	98-02
1. factual context description	59	58
2.1 explicit abnormal action expressed in mission and a/c procedures terms (104)	41	63
2.2 explicit human deficiency expressed in crew-centred terms (69)	29	40
2.3 explicit patent human error mechanism (65)	27	38
2.4 explicit latent factors / systemic cause (49)	17	32
3.1 explicit voluntary non standard procedure or action (40)	19	21
3.2 explicit latent factors / systemic causes (9)	3	6
4.1 explicit failure immediately consequential for flight (58)	23	35
4.2 explicit latent factors / **systemic** causes (29)	5	24
5.1 explicit failure immediately consequential for flight (24)	18	6
5.2 explicit latent factors / systemic causes (2)		2
6. all statements unrelated to previous categories (27)		27
TOTAL	**241**	**325**

The description of errors and violations changed considerably between the two periods

The number of expressions for errors and violations in the executive summaries in the second period was much greater than in the first period (241 expressions in 35 accidents before the I-IF plan versus 325 expressions in 35 accidents after the plan – see table 5). This is true for all categories except the categories regarding the factual contextual descriptions and of the environment. The summaries become longer, therefore much more detailed.

Table 5 Comparison of the number of expressions related to latent causes

Raw number of expressions related to latent factors	1992-93	1998-02
Cat 2.4 Latent factors associated to Human error	17	32
Cat 3.2 Latent factors associated to violations	3	6
Cat 4.2 Latent factors associated to technical failures	5	24
Cat 5.2 Latent factors associated to environment	0	2
TOTAL	**25**	**64**

More systemic causes

There was a significant change between the two periods with a much more consideration of and a wider search for systemic causes, as well as a more frequent conclusion concerning responsibility for the accident going beyond the front line actors (see tables 6 and 7).

Table 6 Comparison of responsibility as they appear in the final conclusion signed by military authorities

Classification of accident responsibility as they appear in the final conclusion signed by military authorities	1992-93	1998-02
Front line operators	59.7%	44.1%
Management, military authorities , design of operations and procedures		17.7%
Designers/ manufacturers		2.9%
Inadequate or failing materials	22.6%	14.7%
Maintenance		1.5%
Miscellaneous (specific context, etc.)	17.7%	19.1%

Table 7 Summary content analysis of category 2.3. This table shows a detailed analysis of expressions associated with category 2.3 of the grid (explicit obvious human error mechanisms). There are 27 expressions in period 1 belonging to this category versus 38 in period 2. Note the enrichment of vocabulary in period 2, contrasting with the very limited introduction of Reason's categories of errors

Before HF plan (25 files, 27 expressions) 1992-93		After HF plan (25 files, 38 expressions) 1998-2002	
Key expressions to express human failure	Associated qualifying	Key expressions to express human failure	Associated qualifying
Lack of (7)	Attention Visibility Technique (3) Correction Vigilance	Lack of (9)	Divided attention Stress management Rigor, experience Vigilance
Error (6)	Perception Analysis (2)	Error, Erroneous(9)	Routine Perception Sensory illusion Situation analysis Situation awareness Attention management
Bad, inappropriate, incomplete (6)	Appreciation, attention, representation, time management	Bad (3)	Situation awareness Divided attention Reflex
		Excessive (6)	Fatigue Euphoria Overconfidence Over-demanding outside information Complexity
Miscellaneous(8) Technical wordings such as 'wrong action on stick and throttles'		Technical wordings such as 'wrong action on stick and throttles'	
Miscellaneous (9)			

A different phrasing for human errors

The description of human errors are more detailed in period two (see table 5). This result is true and of similar magnitude for all categories of expressions (technically-centred, human-centred, related latent factors). This result proves a greater willingness to detail and go beyond simple descriptions of error.

However, a content analysis of category 2.3 (production and recovery mechanisms) shows little improvement between the two periods. The error mechanisms evoked in the two lists of expressions remains relatively similar, based on simple psychology (see table 7). There are few references to Reason's wording of the categories of errors, and almost no reference to recovery mechanisms. Two little differences may nevertheless be noted: the first is the explicit greater proportional use of the word 'error' in the expressions in the second period. The second is the much greater references to psycho-physiological states as contributors to the erroneous behaviour.

It can be concluded that the impact of HF education is effective in the investigator's consideration of human error. The investigators say more, especially about the physiological and psychological background factors that may have contributed to the production of errors. However, the phrasing remains simplistic and with little reference to theoretical frameworks. This could be either the result of a superficial education or an attempt to avoid 'psycho-babble' and stick to an easily understood language for decision makers and end-users (to whom the reports are intended in the first place).

Coding the expressions related to violations

There is no difference in the number of expressions related to violations in the two series (19 expressions in the first period belonging to this category versus 21 in the second period). This trend is clearly opposite to the result obtained for human error.

The content analysis of category 3.1 (see table 8) shows two major results. Firstly, the word 'violation' is never used, whatever the period. Only equivalent terms are cited (i.e. excessive risk, illegal action, unruly behaviour) with scarcely an explicit reference to the operator's intention. The classification in this category of violation therefore results from additional inferences made by authors based on information contained in sections of the accident file. In rare cases (two files), the authors asked for confirmation from the original investigators. Secondly, there was no significant change between the two periods in the content analysis.

It can be concluded that the HF education plan has had little or no (visible) effect on the phrasing of violations. The explicit use of the term 'violation' still remains taboo, probably because of the associated risk of litigation.

Table 8 Summary content analysis of category 3.1 about violations. This table show a detailed analysis of expressions associated with category 3.1 of the grid (explicit voluntary non standard procedure or action). There were 19 expressions in period 1 belonging to this category versus 21 in period 2. There is no difference between the two periods

Before HF plan (25 files, 19 expressions) 1992-93		**After HF plan (25 files, 21 expressions) 1998-2002**	
Key expressions to express human failure	Associated qualifying	Key expression to express human failure	Associated qualifying
Excessive (3)	Obstinacy to continue Passivity	Excessive voluntary(1)	Bank to recover Risk taking Behaviour
		Unruly (1)	
Go beyond (2)	Acceptable boundaries Prescribed objectives	Go beyond (1)	Acceptable boundaries
Illegal (5)	Manoeuvre Procedure(3)	Illegal (5)	Take off with door open Escape manoeuvre
Lack of (3)	Discipline	Lack of (5)	Discipline Mission preparation Checklist Briefing
Erroneous (2)	Application of instructions		
Miscellaneous(4) Illegal actions in terms of technical procedure i.e. forbidden figure of flight		Miscellaneous (8) Illegal actions in terms of technical procedure, i.e., refuse landing on appropriate terrain	

Discussion

The study presented in this paper focuses on some changes that have occurred after the implementation of an Aviation Human Factors Safety Plan in the French Air Force.

There are many aspects to the impact of such a plan. The most immediate and obvious approach for evaluation tends to focus on direct and concrete safety data, this means the accident and incident rate. However, there are many other long term indicators, for example changes in the minds of people and the traceability of the acquisition of a safety culture.

It was not our purpose, in this paper, to debate the safety figures. Despite the raw rate of accidents objectively decreasing after the plan, we decided not to emphasize that result because of the multiple co-factors acting upon the accident rate. For example, a new generation of fly-by-wire aircraft, stall protected, came into service at the time of the human factors plan and had a significant positive impact on safety. To be honest, it probably had a higher impact than the HF plan itself.

Our priority was to evaluate the change of mentality and knowledge in the minds of investigators, who are in the front line in the safety improvement movement. They explain why accidents occur and put emphasis on local or systemic causes. These reports are the primary material that triggers and drives the changes in the system.

With this in mind, we may say that the human factors education delivered to investigators via the HF plan has had two main impacts.

- The first one was the significant increase of systemic causes cited as accident contributing causes. This result was expected and perfectly reflects the literature (Woods and al 1994; Reason, 1997; Johnson, Holloway, 2003). Two questions arise from this result. First, there is a risk of an excessive shift from front line operator responsibility to an increased responsibility of the hierarchy, the system, and the legislator. Since the systemic responsibility is easy to evoke, but uneasy to prove or argue, the very result could be the establishment of unclear responsibility at the end of the investigation and therefore here are fewer lessons and less progress than may be expected. Although there is the potential for this, this risk does not seem to be an obstacle at the present time. The global safety improvement shows that the change in balance is beneficial. Second, one can wonder if the observed changes mean a change in investigators' mental models or just a real change in accident causation (emphasising a greater role on technique and management)? The management has changed along with time, as well as the investigation technique. Over time supervisory control on operations by the chain of command has dramatically improved, thanks to the existence of AWACS and satellites. The military system is much more coordinated, implying that the accident, when it occurs, inevitably involves the chain of command. Should this be confirmed, the change observed in the investigation board should better reflect a true change in the manner of deployment rather than a change in the minds of investigators and the impact of HF education. Although it is not possible to make strong assumptions on the causality of these changes, the most probable truth is that many factors accumulate and combine to cause this result.
- The second impact is in the phrasing of human errors. We see a significant increase of explicit citations of human errors. Again, the improvement is much more quantitative than qualitative. We could consider either that it

was the intention of writers to preserve a comprehensive level of language for naive readers and decision makers or that they were unable to use psychological terms. It is probably a bit both. Then the very question is how much a naive phrasing reduces the reader's access to the relevant information, models and actions. Speaking about violations using the correct psychological references seems even to be a greater problem. Intentional deviations from procedures are frequent but explicit mentions are taboo. Violations are the most difficult unsafe acts to gather in any voluntary reporting system (Marx, 2001). Reporting violations may lay the individual open to accusations of negligence or professional misconduct even if there was no intention to endanger the system.

- The result of this potentially high reluctance of professionals to speak a comprehensive and clear language about error, and even more about violations, is to create the opportunity for ineffective and/or unreliable safety lessons from critical accidents. We know from extensive studies in Medicine that this point is crucial. The definition of error and adverse events remains extremely problematic in medicine and creates unreliable databases. Reporting for the same event is quite unreliable in phrasing and content (Cullen, 1995; Tamuz, 2004) in frequency (doctors report much less than nurses, Lawton, 2002) and the situation is even worse when the demanded information is perceived to only feed national databases. This instability of phrasing and content is recognized to be counterproductive for the acquisition of a safety culture and a learning organization (Sutcliffe, 2004).

Conclusion

The study presented in this paper indicates the quantitative and qualitative impact of a human factors plan on investigators' phrasing in accident investigation files.

Though this study suffers from the limitation of having only focused on accident file without contact with the investigators, it shows that the impact of such an HF education is clearly limited by cultural barriers and that the intended result of building a safe and just culture is not achieved and remains a long term objective asking for decades of continuous efforts.

References

Amalberti, R. (1997). Human Error in Aviation. In, H. Soekkha (Ed.), *International Aviation Safety Conference, IASC-97* (pp. 91-108). Rotterdam, The Netherlands: Utrech : Vsp.

Amalberti, R. (2001). The paradoxes of almost totally safe transportation systems. *Safety Science, 37,* 109-126.

Amalberti, R. and Hourlier, S. (2005) Human error reduction strategies, In P. Carayon (Ed.) *Handbook of Human Factors and Ergonomics in Healthcare and Patient Safety.* Hillsdale, New Jersey: LEA.

Amalberti, R., Paries, J., Valot, C. and Wibaux, F. (1998). Human factors in aviation: An introductory course. In, K. M. Goeters (Ed.), *Aviation psychology: A science and a profession* (pp. 17-43). Aldershot: Ashgate.

Boeing Commercial Airplane Company (2003). *Statistical summary of commercial jet airplane accidents, worldwide operations 1959-2002.* Seattle, WA: Author. Accessed from www.boeing.com/news/techissues.

Cullen, D., Bates, D. Small, S., Cooper, J., Nemeskal, A. and Leape, L. (1995). The incident reporting system does not detect adverse drug events: a problem for quality improvement. *Journal of Quality Improvement, 21,* 541-548.

Degani, A. and Wiener, E. (1994). Philosophy, policies, procedures, and practices: the four P's of flight desk operations. In, N. McDonald and R. Fuller,. (Eds.), *Aviation psychology in practice* (pp. 44-67). Aldershot: Avebury.

Fitts, P. and Jones, R. (1947). *Analysis of factors contributing to 460 'pilot error' experiences in operating aircraft controls* (No. TSEAA-694-12): Air-Material Command, WPAFB.

Foushee, H. (1984). Dyads and triads at 35,000 feet. Factors affecting group process and aircrew performance. *American Psychologist, 39,* 885-893.

Gerbert, K. and Spohd, G. (1982). *Investigation of human factors in Aircraft accidents and incidents of the German Airforce.* Paper presented at the Aerospace Medical Association Annual scientific meeting.

Helmreich, R. (1997). Managing human error in aviation. *Scientific American* (May), 62-67.

Helmreich, R. (2000). On error management: Lessons from aviation. *British Medical Journal, 320,* 721-785.

Hollnagel, E. (1993). *Human reliability analysis, context, and control.* London: Academic Press.

Holloway, C.M. and Johnson, C.W. (2004) Distribution of Causes in Selected US Aviation Accident Reports Between 1996 and 2003 In, N. Welch and A. Boyer (Eds), Proceedings of the 22nd International Systems Safety Conference, International Systems Safety Society, 2004.

Johnson, C.W. (2003). How Will We Get the Data and What Will We Do With It? Issues in the Reporting of Adverse Healthcare Events. *Quality and Safety in Healthcare, 12,* 64-67.

Johnson, C.W. (2003). *The Failure of Safety-Critical Systems: A Handbook of Accident and Incident Reporting.* Glasgow: Glasgow University Press.

Johnson, C.W. and Holloway, C.M (2004). 'Systemic Failures' and 'Human Error' in Canadian TSB Aviation Accident Reports between 1996 and 2002.

In, A. Pritchett and A. Jackson (Eds), *HCI in Aerospace 2004.* Toulouse, France: EURISCO.

Johnson, C.W. and Holloway, C.M. (2003). A Survey of Causation in Mishap Logics. *Reliability Engineering and System Safety Journal, 80,* 271-291.

Lawton, R. and Parker, D. (2002) Barriers to incident reporting in a healthcare system. *BMJ Quality and Safety in Healthcare, 11,* 15-18.

Marx D. (2001). Patient safety and the 'just culture': a primer for health care executives. (2001). In, AHRQ (Ed). *MERS: Medical event reporting system for transfusion medicine,.* Washington DC.

Mauririo, D., Reason, J., Johnston, N. and Lee, R. (1995). *Beyond Aviation Human Factors.* Aldershot: Ashgate-Avebury.

Paries, J. and Amalberti, R. (2000). Aviation safety paradigms and training applications. In, N.S.R. Amalberti (Ed.), *Cognitive Engineering in the Aviation Domain* (pp. 253-286). Hillsdale- New Jersey: Lawrence Erlbaum Associates.

Perrow, C. (1984). *Normal Accidents, Living with High-Risks Technologies.* New York: Basic Books.

Polet, P., Vanderhaegen, F. and Amalberti, R. (2003). Modelling the Border line tolerated conditions of use. *Safety Science, 41,* 111-136.

Reason, J. (1997). *Managing the risk of organizational accidents.* Aldershot: Ashgate.

Reason, J. (2000). Human Error: Models and Management. *British Medical Journal, 320,* 768-770.

Sarter, N. and Amalberti, R. (Ed.). (2000). *Cognitive engineering in the aviation domain.* Hillsdale- New Jersey: Lawrence Erlbaum Associates.

Sarter, N. and Alexander, H. (2000). Error types and related error detection mechanisms in the aviation domain: analysis of aviation safety reporting system incident report. *International Journal Aviation Psychology, 10,* 189-206.

Sarter, N. and Woods, D. (1992). Pilot interaction with cockpit automation. I: operational experiences with the Flight Management System. *International Journal of Aviation Psychology, 2,* 303-321.

Sarter, N. and Woods, D. (1995). How in the world did we get into that mode? Mode error and awareness in supervisory control. *Human Factors, 37,* 5-19.

Strauch, B. (2002). Normal Accidents: Yesterday and Today. In, C.W. Johnson (Ed), Proceedings of the First Workshop on the Investigation and Reporting of Incidents and Accidents (IRIA 2002). Glasgow, Scotland: University of Glasgow, Department of Computing Science.

Sutcliffe K. (2004). Defining and classifying medical error: lessons for learning *BMJ Quality and Safety in Healthcare, 13,* 8-9.

Tamuz, M., Thomas, E. and Franchois, K. (2004). Defining and classifying medical errors, lessons from patient safety reporting system. *Quality Safety and Health Care, 13,* 13-20.

Valot, C. and Amalberti, R. (2001). Ergonomics in aviation. *Le Travail Humain, 64, editorial* (3), 193-196.

Waring J. (2004). A qualitative study of the intra-hospital variations in incident reporting *International Journal for Quality in Health Care 16,* 347-352.

Westrum, R. (1995). Organisational dynamics and safety. In, N. McDonald, Johnston, N. and Fuller, R. (Eds.), *Application of psychology to the aviation system* (pp. 75-80). Aldershot: Avebury Aviation.

Wiener, E., Kanki, B. and Helmreich, R. (Eds.) (1993). *Cockpit Resource Management.* London: Academic press.

Woods, D., Johansnesen, L., Cook, M. and Sarter, N. (Eds.). (1994). *Behind Human Error.* CERSIAC SOAR 94-01. Dayton OH: WPAFB.

Acknowledgements

We thank Doctor Sylvain Hourlier for his helpful proofreading and contribution.