

# Non-Adherence to Procedures

## - Why Does it Happen?

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### 1 Introduction

#### 1.1 Human Error as contributing factor to aviation accidents

In the Jurassic ages of aviation, aircraft incidents and accidents were mostly associated with catastrophic structural, engine or system failures or adverse weather conditions. Investigations into the causes of accidents tended to focus on the technical aspects of the accident or incident under investigation. And there were good reasons to choose this approach: reliability of aircraft systems was not always guaranteed and indeed, things went wrong with aircraft because newly introduced technologies were applied to the design limits or even beyond. Because of this approach, aircraft accident investigators were mostly trained professionals with an engineering background, specialized in determining the cause of the accident, as long as it happened because of a technological mishap. Sometimes the flight crew just messed up, and the only conclusion the investigating team could come to was to label this one as ‘pilot error’.

In the seventies, when commercial jet transports became commonplace, technologies applied in the jet-age reached a level of maturity that introduced a steady decline in accidents caused by catastrophic hardware failures. Furthermore, a number of high-profile accidents brought to attention the role of the human crew. It became apparent that accidents were occurring where the primary cause of the accident could *not* be associated with a mechanical failure. The science of ‘Human Factors in Aviation’ was born. The International Civil Aviation Organization (ICAO) took up the gauntlet and acknowledged human error research as the most relevant opportunity to increase safety. In 1989, reflecting the results of research into the human factors in flight operations of that time, ICAO stated the following:

*“The expansion of Human Factors awareness presents the international aviation community with the single most significant opportunity to make aviation both safer and more efficient”* [ICAO, 1989].

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Ten years later, this remark is still remarkably alive!

By now the general term ‘human error’ is commonly regarded as the most common contributing factor in aircraft accidents. Figure 1 shows that crew-related issues were mentioned in as much as 69% in all accidents, as reported by the accident investigating authority. Note that the data presented in Figure 1 does not distinguish between primary and contributing factors. Such distinctions are often difficult to make and are sometimes arbitrary. The ICAO Accident and Incident Reporting Database (ADREP) therefore only identifies ‘factors’ for the accidents, rather than ‘primary factors’ and ‘contributing factors’.

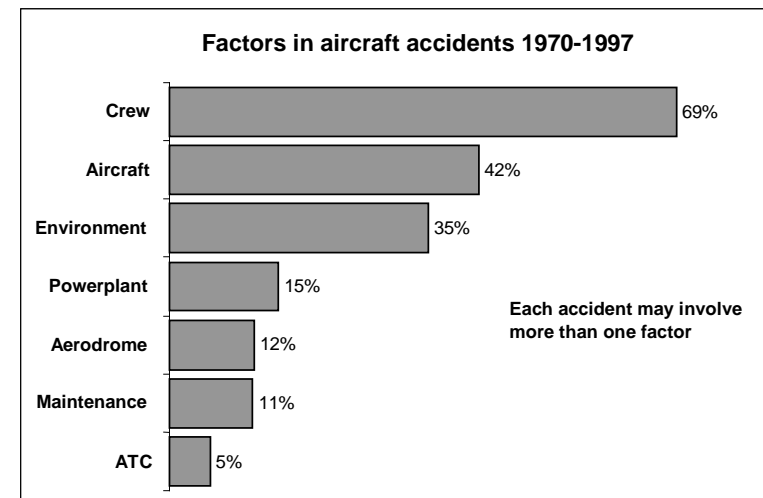


Figure 1 : Factors in aircraft accidents 1970-1997. (Data: ICAO ADREP)

#### 1.2 Human Error versus Non-Adherence to Procedures

Human error can originate from several causal factors: fatigue, incapacitation, lack of training or experience and lack of crew management are just a few. This paper focuses on a special kind of human error: the crew did not follow prescribed procedures. That is, the *ability* of the crew is not in doubt, but for some reason the crew deviated from what it was supposed to do. It must be mentioned that, when accidents are the focus of a study, the non-adherence was often causal to the accident and therefore is regarded in a negative way. However, undoubtedly countless times aircrews have been totally right in ignoring a prescribed procedure, because in the special

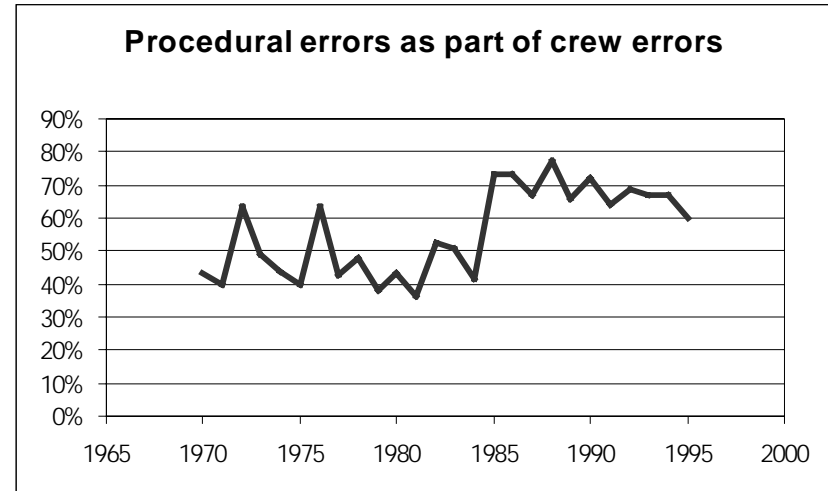
circumstances presented to the crew at the moment, adherence would have deteriorated the situation. This non-adherence therefore *avoided* an accident! Normally, such an occurrence would be recorded as an incident, but often these occurrences are not recorded at all. However, non-adherence to procedures still is a factor in accidents and thus must be regarded as a serious threat to aviation safety, as mentioned in earlier research as well:

In the early nineties research by Boeing introduced the pro-active approach to aircraft accident prevention with the introduction of Accident Prevention Strategies (APS). It was found that if 'pilot flying not adhering to procedures' could have been removed as contributing cause, 50% of all hull-loss accidents would not have happened. Close second and third were 'pilot not-flying not adhering to procedures' and 'other operational procedural considerations' [Graeber & Moodi, 1998]. These observations led to the development of the 'Procedural Event Analysis Tool' (PEAT), that Boeing is now supplying free of charge to the aviation community [Proctor, 1999; Graeber, 1999].

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force presented its Final Report in 1998. Based on the analysis of 287 fatal accidents, the Task Force concluded that "Omission of action/inappropriate action" by a flight crewmember was identified as the most common primary causal factor. Further analysis of 76 accidents and serious incidents revealed that the most frequent causal factor (74 percent) was poor "professional judgment/airmanship". Another form of poor decision making, "press-on-itis," accounted for 42 percent of all occurrences. Standard operating procedures deviation was the second most frequent causal factor (72 percent). The "deliberate non-adherence to procedures" accounted for 40 percent of the sample. "Failure in CRM (cross-check/coordinate)" was the third most frequent causal factor (63 percent). [Khatwa & Helmreich (ed.), 1998].

An NLR study [Roelen, 1998] compared potential safety improvement opportunities on the criteria relevancy, feasibility, effect and cost. This research concluded that based on these criteria the best scoring safety improvement opportunity is "Increase the likelihood that the appropriate crew member will comply with, rather than deviate from, an established procedure if such procedure exists and is familiar to the crew member".

If the data presented in figure 1 is analysed in some detail, it is also found that a substantial part of the reported crew-related factors can be categorized as a 'non-adherence to procedures' (NATP). Figure 2 shows the relative percentage that procedural errors, as reported by the investigating authority, played as a part of the above given crew error plotted against time.

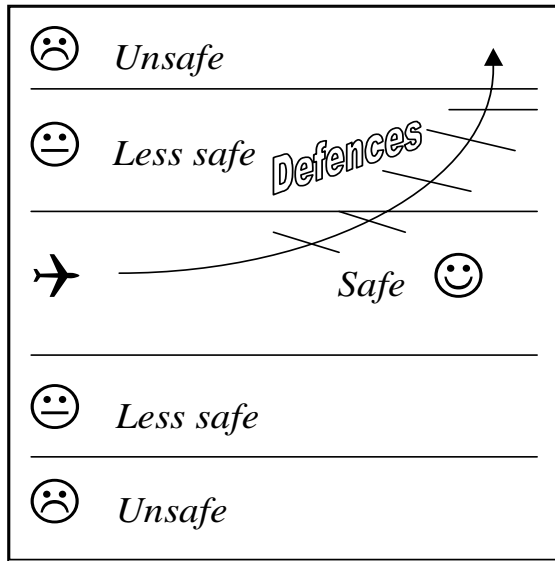


**Figure 2: Procedural errors as part of crew errors. (Data: ICAO ADREP)**

Note that in 1984 the percentage rises from approximately 50% to 70% for 1985 and later. This can be explained by the fact that by 1984 ICAO acknowledged the importance of accurate reporting of human factors elements and improved the ADREP reporting form [ICAO Doc 9156, 1987]. From 1985 onwards, accident investigators could report their findings in more detail, resulting in an increase of 'procedural' errors being reported, while the percentage of crew error mentioned in figure 1 remained constant at approximately 70%. It seems that those mishaps that were reported as 'crew error' prior to the ADREP improvement, were often 'procedural' error. Due to lack of reporting detail, this information could not be stored: the reporting form itself can introduce a reporting-bias.

Procedures are written to shape the crews behaviour towards what is considered safe. As such, they can be regarded as part of the defences against accidents. Compared to "hard" defences (fail-safe designs, engineered safety features, mechanical barriers), procedures, regulations and safety instructions are "soft" defences tend to fail more easily [Reason, Parker & Free, 1994]. Breaking of rules is therefore a challenge to every safety system. The situation can be envisaged as in Figure 3. It takes the elusion of

several defences, “hard” and “soft”, for the aircraft to move from the safe operating environment, through the less safe into the unsafe area.



**Figure 3: Elusion of safety defences may lead to unsafe situations**

There are several reasons to assume that “soft” defences are increasing in number, as well as relevance. Firstly, with an aircraft in service, the operating procedures are constantly amended to cover changing working habits and policies and to adapt to hardware modifications and changes in the aviation environment. Most significantly, when some aviation incident or accident happens, this is often followed by the introduction of a procedure or instruction to avoid such a mishap occurring again. With increasing time-into-service, the number of procedures to handle an aircraft will normally rise. The “hard” defences are embedded in the design of the aircraft, and it takes considerably more effort to develop and introduce “hard” defences into the operation of aircraft. The paradox is now, that with the introduction of new procedures to avoid previous mishaps, the number and *complexity* of procedures rises, and thus the likelihood of violations being committed [Reason, Parker & Free, 1994].

Secondly, the ever-present drive to increase capacity and efficiency of aircraft operations gives rise to increasing operating modes that for a large part rely on the

aircrew adhering to yet another set of procedures. Examples of such operations introduced in the last couple of years are:

- Noise-abatement procedures
- ETOPS
- Reduced Vertical Separation Minima above FL290
- RNAV operations
- GPS or RNP-based approaches
- High-angle Approach and Landing procedures
- Land-and Hold Short Operations

Coping with an ever increasing number of rules, manuals, amendments to amendments, and all other issues is considered the “norm” for the airline pilot. It seems that regulatory agencies, industry and operators alike assume that safety issues related to the introduction of a new operation can be covered by publishing a new rule or procedure, and then relying on the aircrew to adhere to this procedure. There is some evidence that the limit of what can be expected of a human pilot in this respect is in sight [Huntzinger, 1998; Eastaway, 1999].

Summarizing, it is commonly accepted that human error is the predominant factor in aviation accidents. It appears that a more-than-average part of what is reported to be ‘human error’ is in fact NATP, where the pilot’s ability is not in doubt, but just the way things are handled. Not only is NATP therefore perhaps the single most important factor threatening aviation safety, with the introduction of new, more efficient, operations, the industry is increasingly relying on aircrew adhering to procedures to maintain present safety standards.

## 2 Understanding the problem: what is going on?

It has been mentioned that “we currently lack insight into the human factors underlying procedural compliance errors” [Tullo, 1998]. Indeed, remarkably little is known about why aircrew deviate from prescribed procedures. Various attempts to assemble a taxonomy of non-compliance specifically for airline crew have been made using simulator-experiments [Schofield, 1980], analysis of accident and incident data [Corrie, 1995; Shapell & Wiegmann, 1997; Graeber, 1999] and observations of ‘regular’ flights [Helmreich & Hines, 1997; Klinect, Wilhelm & Helmreich, 1999], but every attempt to categorize non-adherence ends up with different results. The reasons are understandable: behaviour in the simulator is likely to be different from ‘the real thing’; the quality of accident and incident data is inadequate for addressing human

factors issues, and - although non-accident data is required to establish the norm - it is possible that in accident data different non-compliance behaviour is displayed than in 'regular' flights.

Why bother at all with classifying non-adherence? Regard the following examples. In each case the investigating authority determined that procedures or instructions were not properly applied.

*“The pilot, with over 17,000 hrs flight time, received a weather brief which reported low ceilings along his planned route of flight, and VFR flight was not recommended. He elected to go VFR and did not file a flight plan. Low ceilings were as reported, and they were obscuring the top of a mountain. The aircraft hit the side of the mountain about 100 ft below the crest.”* [ADREP 91004360]

*“During a CAT I approach in known CAT III conditions, visual reference to the runway was lost but the landing was continued. No flare was initiated. The aircraft touched down hard on the nose gear which sheared off. The aircraft stopped 1,300 m from the threshold on the runway.”* [ADREP 91004760]

*“The aircraft landed with the gear up and slid to a stop beside the runway, 1,075 m from the threshold. The pilot was instructing the co-pilot to land. He forgot to use the checklist and did not extend the gear.”* [ADREP 87001480]

In these examples it was determined that the flight crew did not comply with all relevant procedures. Is there a common method to be applied to each of these non-adherence instances? “Blame and train...?” Probably not. If non-adherence can be categorized, it might be possible to determine an appropriate solution for different kinds of non-adherence.

Rather than attempting to derive yet another model from the available data, in this study two models that are previously validated in other domains are introduced. From these models a taxonomy of airline crew non-compliance is derived. In addition, some statistics can be derived from the available accident data. In all, three approaches are pursued:

### *I. The Cognitive Approach*

What drives the pilot to revert to act contrary to rules or procedures that instruct otherwise? The Human Information Processing (HIP) model that is introduced in this approach is based on a consolidation of various theories and information processing models from cognitive psychology and is therefore labelled the 'cognitive' approach.

Applying this approach should result in a *complete* set of possible non-adherence categories.

### *II. The Behavioural Approach*

Rather than trying to model mental processes, the human is regarded as a 'black box'. Compared to the 'cognitive' approach, the 'behavioural' approach works backwards: starting with the violating behaviour, factors influencing this behaviour are studied. The Behavioural Cause Model (BCM) [Hudson, Verschuur, Lawton, Parker, Reason, 1997] is introduced as potential analysing tool. This BCM has seen extensive application in modelling violating behaviour in off-shore applications [Verschuur & Hudson, 1994].

### *III. The Data Analysis Approach.*

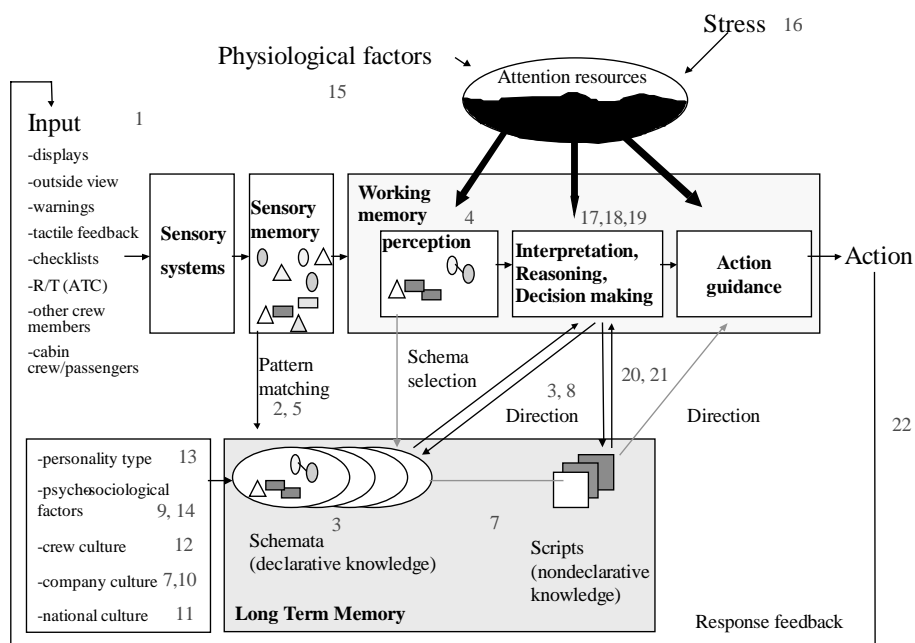
Finally, although it has often been mentioned that the disparity in accident reporting quality makes it impossible to achieve reliable results when trying to establish a better understanding of human factors related issues, accident and incident data *is* available, waiting to be analysed. Some interesting conclusions can be derived from even the shallow data available. This constitutes the third approach in this study.

## **2.1 The Cognitive Approach**

To be able to make a *complete* inventory of reasons why a pilot does - consciously or unconsciously - not adhere, a Human Information Processing (HIP) model has been developed. The model is a combination of several models and theories in cognitive psychology [Baddely, 1990; Dominguez, 1994; Endsley, 1995; Wickens, 1996]. The theories have been adapted in such a way that elements influencing pilot non-adherence to procedures can be described and as far as possible be explained.

The model presented below contains the following elements relevant for human behaviour (Dicks, 1993): Input, Sensory systems, Sensory memory, Long Term Memory, Attention resources, Working Memory, Action and Feedback.

Figure 4 shows the different elements and how these are interrelated. In the figure the numbers indicate 'opportunities' for error, in the end resulting in an action by the pilot that, in our case, is an action not complying with procedures. Based on this model, 23 distinctive categories of non-adherence have been identified, see table 1.



**Figure 4: Human Information Processing Model**

1. Lack of information
2. Misperception of information.
3. Inaccessible procedure formats cause interpretation problems.
4. No perception of relevant information due to competing activities.
5. Complacency (over-stimulation of schema's). Crew not perceiving information due to monotony.
6. Insufficient training/experience to perform procedure without errors.
7. Company culture stresses other elements as being more important.
8. Company philosophy, policies and procedures are not consistent.
9. Pilots do not share the company philosophy due to personal reasons.
10. Pilot professional culture makes pilots overconfident in their abilities.
11. National cultures influence the extent to which pilots will follow procedures.
12. Crew culture, behaviour of other crew members.
13. Personality type influence adherence to procedures.
14. Psycho/sociological factors, attitudes, influence procedural compliance.

15. Physiological factors influence the amount of attention resources available.
16. Stress reduces the amount of resources available.
17. Pilots might decide that certain procedures are ineffective.
18. Pilots might decide that a particular procedures takes too much of the available resources.
19. Pilots might decide that a procedure contains a mistake.
20. If a procedure has been renewed lately, the script of the old procedure might interfere.
21. If procedures for similar tasks resemble each other too much, their scripts might interfere.
22. Pilots do not receive (direct) response feedback.
23. Faulty decision making strategy

**Table 1: Non-adherence categories derived from HIP model**

The complete list of 23 non-adherence categories can be conveniently grouped as follows:

- No perception of relevant information (input) [1,5,22]
- Misperception of information (pattern matching) [2]
- Procedural design (input, interpretation) [3,8,17,18,19,20,21]
- Procedural experience/training (long term memory) [6]
- Cultural aspects (influencing factors) [7,10,11]
- Personality aspects/attitudes (influencing factors) [9,12,13,14,15]
- Situational factors (influencing factors) [16]
- Decision making heuristics (decision making) [23]
- CRM (attention resources) [4,18]

Every category can be associated with an avoidance strategy, specifically targeting the problem area. For example, non-adherence caused by unclear procedures or checklists requires a different approach than non-adherence caused by improper attention management.

## 2.2 The Behavioural Approach

To find the main reasons for violations of rules and procedures on North Sea oil rigs, Verschuur and Hudson (1994, 1997) developed the Behavioural Cause Model. This model attempts to integrate a number of different psychological processes leading to intentional deviations and describes different kinds of non-adhering behaviour.

Compared to the HIP model, the BCM works backwards starting with the (intentional) violating behaviour. When *planning* the action a decision is made to violate procedures. This decision is made to take account of:

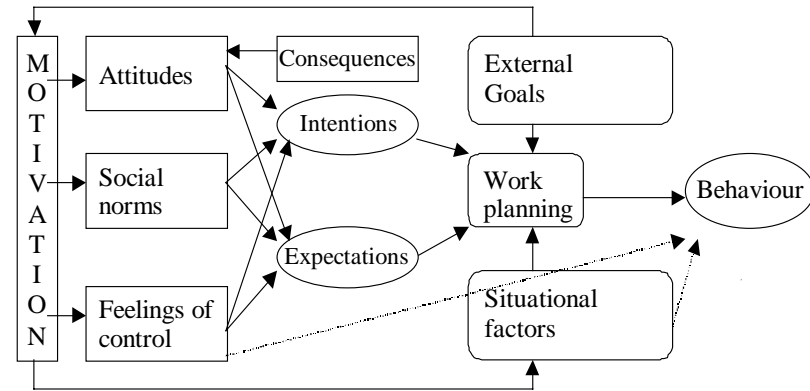
- *External goals*, like rewards and job requirements.
- The *intention* of doing things a certain way.
- The *expectation* that the work has to be done in a certain way.
- *Situational factors* like the existence of opportunity to do things faster (or better) or absence of supervision.

*Intentions* and *expectations* are determined by attitudes towards the job and towards the violation of procedures, by social norms and by feelings of control. *Attitudes* towards the violation of procedures are directly influenced by the perceived *consequences* of this behaviour. *Feelings of being in control* of one's own actions or *being out of control* are also called feelings of powerfulness and powerlessness. When suddenly losing the feeling of control a person can change previous well thought out behaviour. A deviation of plans can also occur when *situational factors* force someone to react immediately.

*Motivation* is seen as a general driver and is to some extent influenced by *external goals*. Highly motivated people see opportunities to do things faster or better. Unmotivated people are likely to be influenced by seeing opportunities do to things easier.

The defined constructs in the model were empirically tested at offshore platforms by means of a questionnaire. Results showed that 62% of the variance in violating behaviour could be predicted by only four predictors: *expectation*, *feelings of control*, *opportunities* and *planning*. *Expectation* turned out to be the biggest single factor in their study leading to rule breaking. Time pressure, lack of alternatives and/or poor procedures were usually given as reason for expecting violating behaviour.

Figure 5 gives a pictorial representation of the Behavioural Cause Model, an arrow is intended to show the causal chain.



**Figure 5: The Behavioural Cause Model**

For 'violations', performance levels (skill-based, rule-based and knowledge-based) serve as a framework to classify types [Reason, 1990].

Situations	Control modes		
	Mainly conscious	Conscious and automatic	Mainly automatic
Non-problematic situations			Skill-based performance
Familiar or trained-for situations		Rule-based performance	
Novel or atypical situations	Knowledge-based performance		

**Table 2: Rasmussen's Performance Levels**

In routine circumstances, the pilot's behaviour can be described as skill-based. In challenging, but familiar circumstances, more conscious rule-based control is required. In unfamiliar circumstances (e.g. complex system failures not previously rehearsed in the simulator) the pilot must revert to conscious knowledge-based control.

Related with the level of conscious performance, four violation categories are defined:

### *Routine violations*

Violations of this kind, as their name implies are common practice. They often occur with such regularity that they become automatic and unconscious behaviours. Such deviations from formal working practice are often perceived by pilots to involve little risk and are accepted as the normal way of doing the job. Violating the rule has become the group norm.

### *Optimising violations*

This category of violations is related to the nature of the job or the task itself; as optimising violations frequently occur in an attempt by the employee to make a job more exciting or interesting. These violations also occur where the rules are regarded as overly restrictive or seen as out of date.

*“After take-off the pilot requested and received permission to overfly the airport before heading for destination. Over the airport at 15-20 m, the pilot abruptly changed pitch to steep climb. During this manoeuvre the tail hit a mast.”* [ADREP 85000850]

### *Situational violations*

These violations occur as a result of factors dictated by the employee's immediate space or environment, which make it difficult for the employee not to violate. Extreme pressure on on-time arrival is an example that triggers situational violations.

*“The aircraft touched down nearly half-way on runway 16 and overran by 300 m. The pilot tried to recover lost time and requested a landing on runway 34. The controller told him that the wind was 160 deg/15-20 kts. The pilot considered this to be within tailwind limits and landed straight in, passing the threshold at 175 kts rather than 120 kts.”* [ADREP 88002360]

### *Exceptional violations*

These violations tend to happen in very unusual or unfamiliar circumstances like an untrained emergency or complex equipment failure or when the pilot is suddenly faced with a dramatic change of situation. Exceptional violations can be the result of either conscious decision-making or instinctive reactions.

*“The co-pilot experienced a stick shaker stall warning at rotation after the pilot called out V1 and VR. The pilot took the controls and landed fast and hard. The aircraft went off the left side of the runway [...] The sensor had malfunctioned on 9 previous occasions, and was inspected and returned to service without a determination on the reason for the intermittent malfunction. The co-pilot had incorrectly perceived that the a/c was stalling*

*and gave control to the pilot without proper coordination of the transfer of control.”* [ADREP 92002290]

Hudson & Verschuur focus on intentional ‘violations’ and treat unintentional non-compliance (‘error’) as one large group of non-adherence. Unintentional non-compliances have been grouped in different categories by different researchers. For reasons explained below, the following four sub-categories for unintentional non-compliance are postulated:

### *Procedural errors*

The intention is correct but the execution flawed.

*“When computing the take-off data, the co-pilot inadvertently used B767 data [...] During lift-off the a/c over-rotated and the aft fuselage contacted the runway.”* [ADREP 90000360]

### *Communication errors*

Information is incorrectly transmitted or interpreted.

*“During take-off the aircraft lifted off near the mid-point of runway 15. At 100-200 ft AGL it entered an extremely nose high attitude and climbed another 500 ft. The aircraft then rolled to the left to an inverted attitude and crashed on the ramp. An elevator control block had jammed the co-pilot's control column. The block had been installed following the previous flight. The co-pilot had been hired six days earlier [...]. There was an unwritten practice for the co-pilot to install and remove the device.”* [ADREP 86010810]

### *Proficiency errors*

Insufficient knowledge or lack of stick and rudder skills.

*“...The aircraft rolled first right then left to the inverted attitude and struck the ground. The pilot under instruction had not flown any Learjet in over a year and had never flown a Learjet 35...”* [ADREP 85003970]

### *Operational decision errors*

A discretionary decision that is not a violation, but unnecessarily increases risk.

*“At destination, amid torrential rain, the pilot landed on runway 13 [...] soon the aircraft began to veer to the left, leaving the runway 300 m after starting the landing roll [...] cause: deviation of the aircraft beyond the lateral limits of the runway, causing damage, due to an improper operational decision by the pilot, i.e. choosing to land at an aerodrome during a heavy rain storm which had an*

*adverse effect on wind conditions, visibility, and runway steering and braking actions.” [ADREP 91004130]*

These four categories of ‘errors’ have been used by Helmreich et. al. in analysing the Line Operations Safety Audits (LOSA), and can thus provide the non-accident data for comparison with accident-data [Helmreich & Merritt, 1998; Helmreich, Klinec & Wilhelm, 1999].

An initial attempt has been made to determine frequencies of the violation- and error-types used in the description of non-adherence behaviour in accident- and incidentdata. Preliminary results indicate that in the accident sample, intentional non-compliance does not occur more often than in line operations. The most common violation seems to be ‘optimising’. In the accident sample, ‘decision error’ is found relatively more often than in line operations. So, although violations do not necessarily end in disaster, the safety margin is reduced and a subsequent violator’s own or other people’s error (or not foreseen situational factors) can turn seemingly safe violations into disaster. As Hudson states: violation + error = death / doom / disaster.

Summarizing the model development efforts, the HIP model provides a comprehensive list of 23 types of non-adherence, conveniently grouped in 9 clusters. Every one of these 23 types has different origins in the mental process leading to a non-compliant action. So the conclusion ‘pilot did not adhere to operating procedures’ can in principle reflect any of these 23 types of non-adherence. The BCM provides insight in the dominant factors leading to non-adhering behaviour. It has been validated in off-shore applications, why wouldn’t it apply in aviation? Non-adhering behaviour is either intentional (‘violation’) or unintentional (‘error’). Both types of behaviour can be subdivided in four subcategories. Violation-types are based on performance levels required for different situations, error-types are rather arbitrary chosen to match a taxonomy previously used in the analysis of line operations.

### **2.3 The Data Analysis Approach**

The first question to be asked before attempting such an approach was: how to limit the amount of data under consideration? And: should the analysis be limited to accident data, or should incident data be included as well? And: Is the available data reliable? Due to reporting bias present in incident databases, it was decided to initially limit the study to accident data.

### **Accident data source**

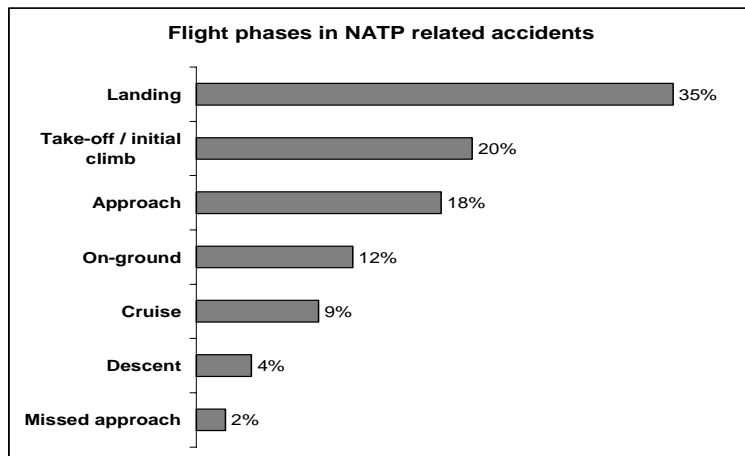
The data source used for this study is the ICAO Accident/Incident Reporting ADREP database [ICAO Annex 13]. This database covers accidents and incidents with fixed wing aircraft and helicopters with a takeoff weight of 5,700 kg or higher. Accident/incident data are available from 1970, worldwide. The database contains a large amount of factual information about the occurrence such as aircraft type, location, weather, crew information etc. Also a sequence of events is given for each occurrence. For each event the flight phase at which it occurred is recorded. Factors can be identified for each individual event to indicate what contributed to the particular event. Factors can be selected from a code list. The list is subdivided into a number of categories. These categories are basically: flight crew, aircraft, powerplant, environment, aerodrome, maintenance and air traffic control. NLR has a nearly complete digital version of ADREP available with information on more than 8,000 accidents and incidents. However for 50% all accidents/incidents factors are identified.

### **Data selection**

In this study only accidents are considered that occurred with fixed wing aircraft worldwide. According to ICAO Annex 13 an accident is an occurrence associated with the operation of an aircraft which takes place between the time any persons board the aircraft with the intention of flight until such time as all persons have disembarked, in which a person is fatally injured and/or the aircraft sustains damage or structural failure. The initial period analysed runs from 1970-1997. In 1984 the human factors data elements in ADREP were changed. Therefore a large part of the presented analysis in this paper deals only with data starting from 1985 and beyond. Only accidents with known factors were selected for the presented analysis. An accident sample of 264 accidents in which a non-adherence to procedure (NATP) was indicated as a factor was compiled for the following analysis.

### *Flight phase*

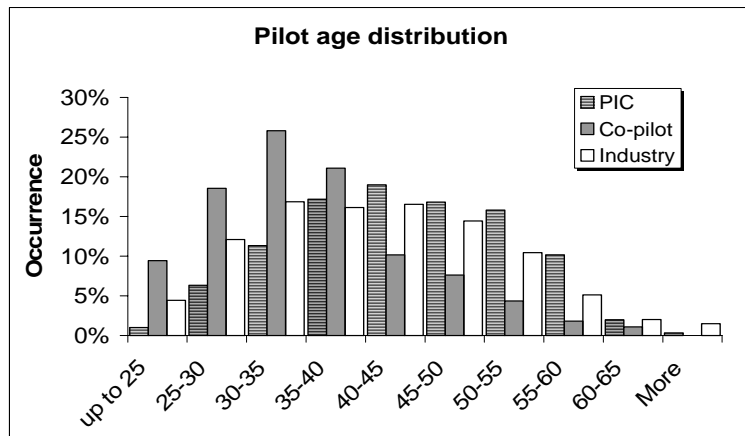
The distribution of flight phases in NATP related accidents shown in Figure 6 is not different from that found in other accidents. Approach & landing and take-off & initial climb are the most critical flight phases. In these flight phases the crew has to follow a lot of procedures compared to for instance the cruise phase which explains why in the approach & landing and take off & initial climb phase most of the NATP’s occur.



**Figure 6: Flight phase distribution in accident sample**

### Age

The age distribution of the pilot in command (PIC) and co-pilot in the accident sample is shown in Figure 7. The overall industry pilot age distribution is also shown for comparison [Source: Flight International "Pilot Employment Survey", 1998]. There appears to be no abnormality in the age distribution of both PIC and co-pilot. In the accident sample most PIC's are in the age of 40-45 and most of the co-pilots are 30-35 years old.

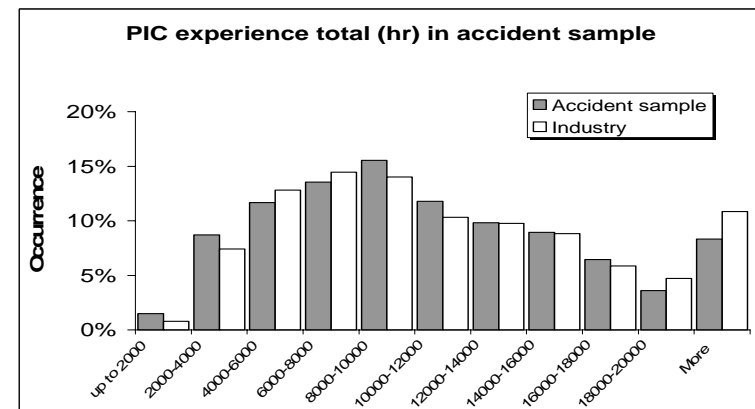


**Figure 7: Pilot age distribution in accident sample**

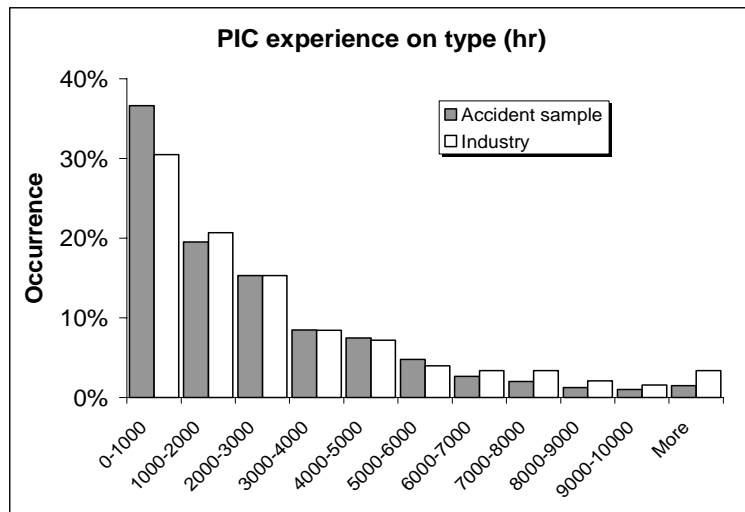
### Experience

The total experience in flight hours of the PIC in the accident sample is shown in Figure 8 together with the distribution found in the aviation industry. The total experience in the accident sample is comparable with the aviation industry [Source: Flight International "Pilot Employment Survey", 1998]. A different distribution is found when the experience of the PIC on current aircraft type is analysed. The result for the accident sample is shown in Figure 9. Both distributions (accident sample and industry) match closely, except for a spike in the low-experience end (<1000 hrs). Statistical analysis revealed that this increase can totally be attributed to pilots with less than 200 hours experience on type. The data therefore shows that in the accident sample pilot experience-on-type is not a factor in occurrence of non-adherence, with the exception of the first 200 hours.

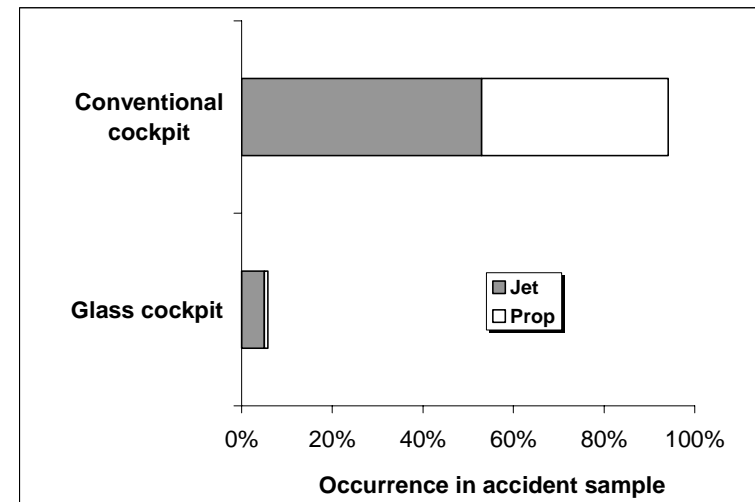
It has been argued that young, relatively inexperienced pilots would be violation-prone. Alternatively, the more experienced, 'seen-it-all' type of pilot is sometimes linked with violating behaviour. Quite remarkably, the data does not support the obvious presumption that age or experience are indicators for non-adherence behaviour.



**Figure 8: PIC total experience in NATP accident sample**



**Figure 9: PIC experience on type in accident sample**



**Figure 10: Aircraft cockpit design in accident sample**

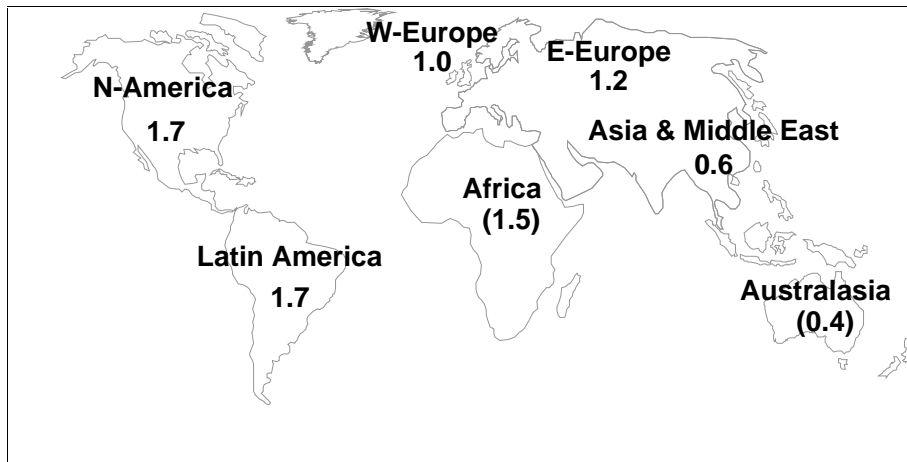
#### *Aircraft cockpit design*

There was some concern from civil aviation authorities that so-called "glass cockpit" aircraft would have a much higher NATP rate of occurrence than conventional cockpit designs [FAA Human Factors Team, 1996; BASI, 1998]. Figure 10 gives the number of aircraft in the accident sample that have conventional cockpit designs and that have glass cockpit designs. It is clearly illustrated that a vast majority of all NATP related accidents involve aircraft with conventional cockpit design. Of course to indicate whether or not this difference is significant in terms of risk increase, the number of flights conducted by aircraft with conventional or glass cockpit designs have to be considered. NLR aircraft cycle data shows that about 40% of all flights in the timespan of the accident sample were conducted with glass cockpit aircraft. Therefore there is a higher probability that an aircraft with a conventional cockpit is involved in a NATP related accident than an aircraft with a glass cockpit. This finding is robust, as it cannot be explained by differences in the accident ratio between these types of aircraft.

Different explanations for this observation can be given. It is possible that certain operators, with different company cultures and less external threats, fly glass cockpit aircraft. Another explanation could be that glass-cockpit aircraft are (too) complicated and do not invite the cutting of corners because the results could be unpredictable for the crew. No attempt is made here to comprehensively explain this observation.

#### *National cultural influences*

Much has been published on cultural influences on people's behaviour on the flight deck. The HIP model predicts national influence in non-compliance type 11. It has been shown that agreement across nations in handling styles of automation is even larger than agreements across airlines. [Helmreich, Merritt & Sherman, 1996; Sherman, Helmreich & Merritt, 1997]. Power distance, the regard for individuality or collectivism and the drive for uncertainty-avoidance have been demonstrated to be culturally influenced [Hofstede, 1980, Merritt, 1997]. The regional distribution of NATP accidents, corrected for the number of movements, is given in Figure 11, where the data is normalised *relative to* Western Europe.



**Figure 11: Regional spread in accident sample, corrected for movements and relative to Western Europe**

The small numbers for Africa and Australasia do not allow a significant calculation and are presented in brackets. It appears that in the Americas, where individuality is regarded as a rule, the relative number of NATP-related accidents per movement is higher than in Eastern societies, where collectivism is the norm. Although reporting bias is likely to have influenced the data, the data seems to support previous research in this area.

Note that the actual regional *accident ratio* is just about inverse proportional to the spread in the NATP accident sample.

Summarizing the data analysis approach, it can be said that analysing data should be done cautiously as reporting bias and incomplete or inconsistent data are just a few pitfalls to avoid. From an accident sample compiled from the ICAO ADREP database, the (expected) influence of age and experience on deviating behaviour could not be reproduced. It was found that non-adhering behaviour was most commonly found in conventional cockpits, rather than in glass cockpits. Regions with individual societies are, even when corrected for movements, relatively over-represented in the accident sample.

### 3 Towards solutions

Combating non-adherence has been tried in several ways. “Blame and train” is a popular approach, but not likely to effectively prevent similar mishaps occurring

again. It has been suggested that personal motivation and discipline is the key to fighting non-adherence [Kem, 1998]. This is certainly true, but only part of the solution. There is a ‘best remedy’ for different kinds of non-adherence.

A comprehensive list of 23 different non-compliance categories has been established. From behavioural studies, both intentional and unintentional non-compliance have been categorized in 4 different groups. The BCM identifies factors influencing this behaviour. From the data analysis some preliminary results could be derived. How can remedial actions be extracted from these findings?

The Cognitive Approach identifies different groups of non-adherence. Remedial actions are likely to be different across different groups. Ideally, against every group a strategy to prevent non-adherence accidents from occurring should be formulated. A common remedy that is successful against every category of non-adherence is not likely to exist. Regrettably, the presently available data does not allow analysing accident or incident data against the non-adherence categories to determine the most efficient way to go from here. Specific data acquisition in this area is required

The Behavioural Approach, however, gives us some insight in remedial actions, as the different violation- and error-types can be associated with effective counter-measures [Hudson, Verschuur, Lawton, Parker & Reason, 1994]:

If *errors* are the problem, the rules themselves or the training process might be given some consideration. Also the distribution of the rules and the knowledge-level of pilots may be improved.

*Relevant question: Do pilots know and understand procedures?*

*Routine violations* can be the result of insufficient hazard awareness amongst pilots, or the rules themselves could be overly restrictive. Especially rules that are believed to protect management could perhaps be abolished, resulting in less procedures, but with procedures that pilots will want to follow.

*Relevant question: Are all the procedures relevant?*

Factors that promote *situational violations* include time pressure, high workload, unworkable rules, bad conditions, short staffing and poor supervision. Often these circumstances are ignored by management, until something goes wrong in which case the rule is held up in defence. Removing these factors is the prudent solution.

*Relevant question: Are there situations where it is impossible to adhere to procedures?*

Preliminary data suggests that *optimising violations* are the most common violation in the accident data sample used for the study. Optimising violations reflect the fact that people have many goals, one of which may be getting the job done in a professional manner. Especially when a company provides incentives for rule violations (e.g. bonuses for on-time arrival), optimising errors may be expected. Involving pilots directly in writing and evaluating procedures helps to combat optimising violations. Finally, providing incentives for compliance, rather than punishing rule violations may promote adherence to existing procedures.

*Relevant question: Is there a reward for breaking rules?*

Not every situation or combination of unique factors can be trained in the simulator, *exceptional violations* therefore cannot be ruled out. Although circumstances triggering exceptional violations can be found in accident data, exceptional violations sometimes save the day. Also it is impossible to devise a procedure for every eventuality. How many scenario-writers had thought of a total hydraulic failure on a DC-10? Although unlikely, pilots can find themselves in a situation that is unfamiliar, and requires a knowledge-based solution. Pilots should be aware how close they are to the edge. Improving the knowledge-level of pilots is a defence against uncalled for actions in exceptional circumstances. In this case one's own initiative should be used.

*Relevant question: Is it necessary to have a rule for every situation?*

There is some promise in adapting the BCM to existing accident data. Preliminary results indicate that violations do not occur more often in accident data than in normal line flights. However, violations do reduce the safety margin. When a violation occurs, it is likely to be an optimising violation.

#### **4 Summary and Conclusions**

Crew error is still the dominant factor in aircraft accidents. A large part of these errors are caused by the crew not adhering to procedures, in one way or another. In spite of this observation, and driven by environmental concerns or the promise of increased efficiency, new operations are introduced that increasingly rely on aircrew adhering to procedures.

When analysing accidents, a deviation is not just a deviation: different types of non-adherence can be discerned. Not every type of non-adherence is combated effectively with a given remedial strategy. It is therefore important to categorise non-adherence.

The first, comprehensive, analysis of non-adherence presented in this study is based on theories from cognitive psychology. A total of 23 different types of non-adherence could be identified, grouped in 9 subgroups. Every subgroup can be associated with a solution strategy. The detail of the categories does not allow analysing present accident or incident data with this taxonomy.

A model derived from behavioural science, the Behavioural Cause Model, shows some promise of applying the model to the available data. Violation types are based on performance levels allow defining a remedial strategy by asking one of the relevant questions:

- *Do pilots know and understand procedures?*
- *Are all the procedures relevant?*
- *Are there situations where it is impossible to adhere to procedures?*
- *Is there a reward for breaking rules?*
- *Is it necessary to have a rule for every situation?*

Although available data is often incomplete or inconsistent, some statistics can be derived from an accident sample. Obvious parameters as age and experience cannot be proven to be indicators of violating behaviour. Contrary to common belief, accidents involving non-adherence to procedures occur more often in conventional flight decks, rather than in glass cockpits. Regions with individual societies are, even when corrected for movements, relatively over-represented in the accident sample.

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