

# From Flight Time Limitations to Fatigue Risk Management Systems

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**Abstract.** This paper presents the outlines of the STARE project that aims at developing the basis of a Fatigue Risk Management System (FRMS) that will enable the French regional airlines to comply with the new European regulation on flight and duty time limitations. More specifically, the new regulation requires for an operator to implement a FRMS in the case of reduced rests. The FRMS is a data-driven system integrated in the future Safety Management System (SMS) of the airline. The whole process of the FRMS is described, including the use of predictive models of fatigue, a systematic and focused monitoring. The principles of the FRMS are discussed with regards to resilience engineering.

## 1 INTRODUCTION

In July 2008 the new regulation on Flight Time Limitations (FTL) (EU-OPS-sub-part Q) has come into force in Europe. Besides the changes in the FTL introduced by this regulation compared with the current national regulations it introduces the concept of Fatigue Risk Management System (FRMS). A FRMS is defined as “*A scientifically-based, data-driven flexible alternative to prescriptive flight and duty time limitations that forms part of an operator’s Safety Management System and involves a continuous process of monitoring and managing fatigue risk*” (ICAO). The EU-OPS requires the implementation of a FRMS in three cases: the use of reduced rests, of split duty or extended flight time. Reduced rests, which will be considered in this paper, is defined as a rest time below the standard requirements (i.e. below 11 hours). Reduced rests are commonly used by French regional airlines for economic reason, by allowing the same crew to operate rosters that include a late evening arrival at a layover (e.g. 22:00) followed by an early morning duty (e.g. starting at 06:00).

In some countries, the FRMS approach is applied since several years as an alternative (partially or totally) to the flight and duty time limitations. In fact, traditionally the most direct approach to prevent fatigue has been to set up regulations to limit Flight and Duty time. This prescriptive approach which is the most commonly used in aviation or in other industries has been more and more questioned concerning its efficiency to prevent

fatigue. (Caban et al, 2002). The main reason is that mental fatigue is not accumulating or recovered in a linear manner (Dawson et al, 2004). For example, because of the circadian rhythms a break will not have the same recovery value depending on the time of the day, the timing of the break being more important than the duration of the break itself. Therefore, a prescriptive approach only based on time limitations cannot take into account all the complexity and interactions of factors that are linked to the hours of work. This is the reason why alternative to prescriptive approach such as FRMS are more and more being developed. Most of these FRMS are based on a risk management approach applied at various levels of the organisation. They generally use biomathematical models that are able to predict the risk of fatigue occurrence associated with a specific working hours pattern. Several models have been developed that may be usable to evaluate the risk of fatigue associated with work schedules (for a review see Neri and Nunneley, 2002). In fact, most of these models predict the level of sleepiness which is one manifestation of fatigue.

To date, several industries and airlines in the world have already evolved towards a non prescriptive approach focusing on the fatigue risk management rather than solely on the compliance to a FTL scheme. The first FRMS approach has been developed for Australian truck drivers by Queensland Transport (Mahon et Cross, 1999). In aviation, New Zealand has the longest experience in the development of FRMS. In 1995, the regulations were altered so that air operators could either complying with a standard prescriptive scheme or by applying to an alternative, company-specific scheme approved (Civil Aviation Authority of New Zealand, 2007). In this last case the operator has to take into account additional factors that may result in fatigue (Signal et al, 2008) (e.g. rest prior duty, effects of time zone change,...). The introduction of Ultra Long Range flight by Singapore Airlines in 2003 is another example of a FRMS application. In fact the CAA Singapore has allowed the airline to operate those flights after the results and recommendations coming from a scientific based on biomathematical modeling (Spencer et al, 2007). The assumptions of the models have been validated on the first 6 months of the flights. In Europe, easyJet became the first major airline to be granted alleviation from the current FTL in 2005 (Steward, 2006). The UK CAA agreed the alleviation based on the results of a safety case report of a 6 month roster trial. The trialed roster was a 5/2/5/4 roster (5 early duties, 2 days off, 5 late duties, 4 days off), which exceeds the FTL (CAP 371) limit of 3 consecutive early duties. easyJet presented a safety case which demonstrated that, compared to the 6/3 roster (3 early duties, 3 late duties, 3 days off) in operation at the time, the 5/2/5/4 roster was associated with a significant reduction in fatigue risk and flight deck error.

These examples suggest that airlines and other industries would progressively try to expand their operational envelope to increase their productivity while demonstrating that they maintain safety by an effective fatigue risk management.

The development of these new approaches raise several issues, such as the complex links between the risk of fatigue and the risk on safety, the multi-factorial nature and sources of fatigue, and the management of this specific risk at the various levels of the

organization. In order to allow the implementation of these FRMS, a preliminary scientific study has been initiated by the DGAC (Mollard et al, 2006). This preliminary study allowed summarizing the available scientific knowledge and has grounded the basis of a more complete research. From this preliminary study DGAC has initiated a 24-month research project the STARE project (Sécurité du Transport Aérien et gestion du Risque fatiguE) run by a multidisciplinary consortium and the partnership of three French regional airlines (Cabon et al, 2008). First results are presented and discussed with regards to resilience engineering both at individual and systemic level.

## **2 OUTLINE OF THE METHOD**

The starting point of the data analysis is the systematic analysis of all the individual aircrews' plannings (cabin and flight crew) over 12 months. A 12-month period has been selected in order to take into account the cumulative effects and not only the acute effects of fatigue. From the planning analysis, high and low risk sequences of plannings are identified by the means of the use of a biomathematical model, the Fatigue Risk Index (FRI) (Folkard et al, 2007). One of the output of the model is the probability (multiplied by 100) of recording a value of seven or more on the Karolinska Sleepiness Scale (KSS) The KSS (Akerstedt and Gillberg, 1990) is a subjective measure of sleepiness with 1 being the minimal value (alert) and 9 being the maximum value (extremely sleepy). Values of 7 or below are associated with intrusion of sleep and an increased risk of behaviour malfunction. From this process, safety and health data are analyzed through a systematic and a focussed monitoring. The next section provides first results of the planning analysis focussed on the reduced rests. Only the outlines of systematic and focused monitoring are given as these steps are currently being initiated. The whole process of the FRMS is then summarized and discussed.

### **2.1 Planning analysis**

In order to evaluate the fatigue risk induced by reduced rests, the duty rosters associated have been extracted from the planning database. Then, the FRI score was applied to the duties that follow each of the reduced rests. Surprisingly, a rather large variability is observed, the scores ranging from 4.05 to 42.76. A more detailed analysis suggests that this variability is mainly due to the position of the reduced rest in the sequence of planning and therefore to a cumulative effect. For example, the fatigue risk increases dramatically from a reduced rest falling at the beginning of a week to a reduced rest falling at the end of this week. This suggests that those reduced rest should be planned by taking into account the cumulative effects induced by the succession of disruptive hours of work. Interviews with the planning officers in the airlines suggest that this cumulative effect is not currently taken into account and that the rosters are more processed as isolated blocks.

### **2.2 Systematic monitoring**

The systematic monitoring aims at studying the potential use of existing safety data (that are already systematically analyzed) to measure aircrew fatigue in the perspective of a

FRMS. Two kinds of data are used, the Air Safety Report and the Flight Data Monitoring. ASR and FDM are currently being collected and analyzed with regards to the fatigue prediction coming from the planning analysis. The aim is to identify potential markers of fatigue in these safety indicators that could be used in a systematic manner to monitor the aircrew rostering. First analyses suggest that some patterns of ASR and FDM would be linked with the fatigue risk.

To complement the safety analysis, it was deemed necessary to integrate the health dimension within the project. In fact, fatigue may not only impact safety but also health with a potential impact on absenteeism. Therefore, several data such as sick leaves are currently being analyzed to try to correlate health data with the planning analysis.

### **2.3 Focused monitoring**

Besides the existing safety data included into the systematic monitoring, a focused monitoring is currently being developed. This focused monitoring covers two main tools:

- A website survey where aircrews are asked to provide their own experience about fatigue (causes, consequences and coping strategies)
- In-flight follow-up where sleep and fatigue data are collected on given planning blocks including weekly rests. In-flight observations are carried out on selected roster to better understand the impact of contextual factors on fatigue as well as the main consequences on fatigue on aircrew activities.

These two sources of data should complement the systematic monitoring by taking into account more precisely the experience of aircrew regarding fatigue and its management as well as the impact of fatigue on in-flight activity.

## **3 DISCUSSION - CONCLUSION**

The project presented in this paper aims at defining the scientific basis of a future FRMS. This process will be embedded into the SMS structure. The first step of the FRMS deals with the fatigue risk reduction at the level of the aircrew rostering by the means of predictive models of fatigue. The introduction of fatigue modeling would imply education of the rostering staff. Once the roster implemented, it will be monitored through the systematic analysis of data such as ASR, FDM and health data. If specific changes that are linked to aircrew fatigue are detected in these data, a focused monitoring is then launched to better understand the main causes of fatigue (e.g. the context associated with specific airport, such as delays, weather,...). This is done through surveys and in-flight data collection. From this focused monitoring, recommendations and mitigations measures are then developed both at the individual level (education, guidelines on sleep and fatigue, nutrition,...) and at the organizational level (scheduling, rest facilities,...). Therefore this process should enable the organization to continuously monitor and manage the fatigue risk as other risk in the organization. Three modes of monitoring are considered: (1) a proactive mode that will be triggered by any substantial changes in the airline that may impact aircrew fatigue

(e.g creation of a new route), (2) a “routine” mode that will monitor the daily operations and (3) a reactive mode that will be triggered by events (incidents, ASR,...) where fatigue may have played a role.

With regards to resilience engineering concepts, one of the challenges of this research is the identification of the underlying links between fatigue and safety. In fact, in low reliability systems such as car driving, fatigue is directly responsible of around 30% of accidents (Cabon et al, 2001). The identification of fatigue as a cause of car or truck accident is made by the means of published criteria such as absence of skid marks or other signs of hard braking beforehand (Horne and Reyner, 1998). Therefore, it can be assumed that the link between fatigue and safety is rather linear in this transportation system. These criteria are obviously meaningless for high reliability system such as aviation. In this system the link between fatigue and safety is by nature non linear in particular because of the high level of automation of these systems that protect the systems against aircrew performance decrements. Therefore, other models have to be considered to figure out the complex relationship between fatigue and safety. In this perspective, the FRAM model appears to be relevant (Hollnagel, 2004). This model describes accidents as the result of a resonance of the normal variability of functions. In fact, fatigue can be considered as a major source of variability or, i.e. a Common Performance Condition. The role of a FRMS is clearly to reduce as maximum as possible this variability. However, because of the nature of fatigue, which is not only induced by organizational factors but also by personal factors which are not under the direct control of the organization, the FRMS should also consider what are the dependencies between functions and how fatigue could induce resonance among them. Therefore FRAM can be considered as a relevant theoretical framework for the analysis of the data collected in the FRMS. The other important challenge of the development of FRMS will be to induce a shift in the prevention of fatigue that rely mostly on flight limitations and aircrew education to a real organizational management of risk. A recent study (Signal et al, 2008) suggests that even after more than 10 years of implementation, the provision of more flexible regulatory options has not greatly changed fatigue management practices, suggesting a need to raise the level of knowledge within the industry regarding the causes and consequences of fatigue and of processes for its management.

From a more systemic point of view, it is important to consider that the regulatory developments for flight and duty time limitations in aviation are dependent on different processes which settle over the years. The technological and operational developments, the changes of social rules, and continuous improvement of safety are factors that contribute to establishing different consensus among States but also between various airlines. So when safety level is low and coupled with a fairly unreliable technology, there can be little regulations to limit the exploits of pioneers such as those of The Postale in the 1940s. When air transportation spreads within society with the advent of the first jets, the safety of a growing number of people become an issue which regulation can guarantee. In France, this regulation resides in a general high level text (Code de l'Aviation Civile) but not in the technical codes. Europe struggles for years, from the

first operational technical regulations in 1995 (JAR-OPS 1) to the advent of European Union regulation to be implemented in 2008 (EU-OPS) before such a technical text is adopted. It recently took years for ICAO to update international minimum standards for flight time and duty time limitations.

Scientific arguments and data are developed and argued but rarely come as a decisive argument in those debates. The recently amended ICAO requirements do not specify any figures. This situation is plainly recognised at high level, including in the above mentioned European regulation published in 2006 after a political agreement between States and European Union, where both the need for Air operators to demonstrate that they can achieve an equivalent level of safety by means other than the application of the common rules as well as the need for Member States to contract collective labour agreements which provides for better conditions as regards flight and duty time limitations and as regards working conditions for cabin crew in particular.

This situation can be best understood by reference to the controlling of borderline tolerated conditions of use (Polet, Vanderhaegen, & Amalberti, 2003). The regulator, the aircraft manufacturer and the airline jointly define the prescription of use of the system. The airline adapts the use regarding real needs. Under the constraints of economical pressure and technological performance improvement as well as secondary gains in the social area, the socio-technical conditions of work create conditions for performance to migrate and stabilise outside the expected safe field of use, which is generally defined by regulation. Thus the area of normal operations is larger than the expected “safe” or “legal” space.

Because the stress induced in the system is ever increasing, the role of regulation needs to change. Strict prescriptive regulations are no longer the unique way to address this issue appropriately. The migration mentioned above need to be managed so that the system can determine its normal space of use and is able to recover from unexpected events. It is difficult to imagine where to draw the line from a prescriptive perspective. The idea is then to incorporate mechanisms for managing safety margins at the organisation or system level. The concept of Fatigue Risk Management System fits into the category of adaptive mechanisms to manage the zone where drifts of use may occur. Excursions into the “gray” zone are therefore allowed and controlled with appropriate feedback and recovery protections to manage safety.

The difficulty of developing regulation for introducing resilience are illustrated in (Deharvengt, 2007). To overcome such difficulties, the implementation of management systems needs to be controlled. The study that DGAC set up for the implementation of FRMS therefore combines scientific expertise together with operational support, but also aims at long term support of those tools by developing guidance for airlines as well as for regulators surveillance.

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