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Integrating aircrew resources variability into the design of future cockpit

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Cockpit design may have major consequences on future pilot's tasks. Functions needed to ensure flight safety are shared between pilots and aircraft systems. Today, cockpits are designed considering a theoretical minimum level of crew resources availability although it is widely acknowledged that availability of crew resources may vary from time to time because of aircrew internal state. Therefore, it is crucial to ensure that future cockpits are designed while taking into consideration this variability. This work aims at developing a methodology enabling designer to systematically integrate crew resources availability in the design process. In order to assess the impact of different sources of variability, the principles of the systemic model FRAM is used. The present work is analyzing the impact of crew resources availability on several use cases using FRAM principles. The data are collected by the means of focus group with operational and human factors experts. Some preliminary results are presented and discussed.

Aviation is considered as a high reliability system where safety is the result of complex interactions between human, machine and organization. Aviation evolves in a dynamic environment (reorganization of air traffic management in Europe, growth of traffic...), implying a constant development of new adapted design solutions to respect the required safety level. This implies a better human-machine cooperation and an evolution of pilot role and task from low level tasks to high level one. Historically, aircraft automation was developed based on the best compromise between performance and safety at an acceptable cost. System automation has grown on the assumption that human are better than machines on strategic tasks but not on repetitive one. But the growing complexity of aircraft systems makes them less transparent for users, leading to other problems of adaptation of pilots interactions with glass-cockpit (Amalberti, 1998). Furthermore, cockpits are designed considering a theoretical constant level of crew resources availability although it is widely acknowledged that availability of crew resources may vary from time to time because of endogenous factors such as fatigue, stress, sickness.... In this context, we propose to extend the traditional aircrew incapacitation definition to any situation that leads to a decrease of aircrew resources to a level lower than the required level of resources.

From a design perspective, the risk of incapacitation should be managed at 3 levels: prevention (avoid a decrease of aircrew resources), detection (detect the decrease of aircrew resources) and recovery (compensate for the decrease of resources).

The aim of this work is to develop a methodology that enable designers to integrate incapacitation in the design of future cockpits. The proposed methodology relies on two main stages, a risk analysis phase and a risk management phase. This paper focused on the risk analysis phase. After an overview of the theoretical background, some preliminary results are provided.

Theoretical Background

Models that account for human variability

Some models of cognitive psychology and physiology bring useful elements to understand human resources variability. Among cognitive models, the computational model of resources developed and revisited by Wickens (2008) is the most appropriate for this research as it defines resources according to the type of information process. Other useful models are relative to decision making (Klein, 2008), situational awareness (Endlsey, 2000) and problem solving (heuristics, strategies). Furthermore one of the critical resources that support the above cognitive function is alertness that is known to vary as a function of a wide range of factors. Recent progress in modeling has shown that alertness is regulated by 3 processes, i.e. sleep homeostasis, circadian factor and sleep inertia (Akerstedt, Folkard & Portin, 2004) Therefore from these scientific findings it becomes now possible to predict rather accurately what could be the alertness level of an operator during a given duty.

Theories on human machine interaction

In order to adapt aircraft systems to the variability of crew resources, several theories might be useful to bring elements in order to build aircraft artifacts adapted to human variability. In the automation design, Parasuraman, Sheridan & Wickens (2000) proposed a model to set the human performance regarding the types and levels of automation. Another theory proposed by Dinadis et Vicente (1999) suggested design principles based on the Rasmussen's model SRK – Skills Rules-Knowledge- (Vicente & Rasmussen, 1992) in order to adapt the type of information provided to the operator linked with the situation. The joint cognitive system theory brings a fruitful framework in the development of effective decision support to human activity (Hollnagel, 2003). The framework of adaptive automation is also considered as it refers to systems that can adjust their functioning or level of operation dynamically. Moreover they are linked with biocybernetics theory that suggests monitoring changes in workload to adapt the systems (Pope, 1995).

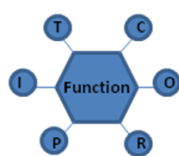
Evolution of safety models

In order to be able to integrate human variability in the design of future cockpit it is also necessary to understand the evolution of safety models in complex sociotechnical systems. These systems are characterized by multiple interactions (Perrow in Hollnagel, 2004). To address the complexity of these models, safety models have evolve from sequential and linear (e.g. the domino models from Heinrich, 1931) to systemic models (e.g. stochastic resonance model from Hollnagel, 2004). Table 2 shows safety models evolution and its consequences on design.

Table 1. *Evolution of safety models in complex sociotechnical systems (adapted from Hollnagel, 2004)*

Type of safety model	Example	Main assumptions	Consequences on design
Sequential models	Domino model, event trees	Identify specific causes and contain them	Automation is used as much as possible to improve performance and safety level
Epidemiological models	Latent conditions, Pathological systems	Identify latent conditions, multiple causes for an accident	Systemic approach and automation to make defenses and barriers stronger
Systemic models	Chaos model, stochastic resonance	Complex interactions and performance variability lead to the event	Monitor and control performance variability using adaptive automation and systemic barriers

Systemic models allow accounting for complexity of sociotechnical systems. They are composed of multiple sub-systems, each one comprising several functions. Functions are defined as the goals the system has to achieve to ensure its good functioning. Each function may have a variable performance in achieving its own goal. Variability is inherent to a system, specifically at the front line operators level, who are adapting their work to the environment in order to maintain the required level of efficiency. In complex socio-technical systems, activity is always under-prescribed facing the possible changing conditions in which task must be performed. Necessary adjustments are made by the operator at the best compromise between thoroughness and efficiency as described in the ETTO principle (Hollnagel, 2009). Internal state of the operator is an important criteria in this trade-off. Cognitive and physiological limitations are the main reason why in a complex sociotechnical system, human is the most important source of variability facing a dynamic environment (more than technology or organization). These principles have been recently developed in the framework of Resilience Engineering. In this context, accidents are seen as the result of the resonance between the variability of sociotechnical systems functions rather than the results of failure or human errors . In Resilience Engineering theory, variability of performance should be monitored and managed. A methodology is proposed by the Resilience Engineering theory in order to understand and model functional variability. Nowadays, the only method focused on performance variability analysis is FRAM - Functional Resonance Analysis Method - (Hollnagel, 2004) that is based on a functional approach. The first application step of this method is to define functional entities not based on system structures (even if in some cases a functional entity may be close to a structural unit). Each function is characterized by six parameters: input, output, time, control, preconditions and resources. (figure 1)



I: Input : That which the function uses or transforms to produce the outputs

O: Output: That which the function produces

T: Time: Time available and factors that affect time availability

C: Control: Control and protective systems that exist to supervise or restrict function

P: Preconditions: That must be fulfilled to perform a function

R: Resources: That which the function needs or consumes

Figure 1. One function visual representation in FRAM, applied to each function description.

The potential variability of each one is assessed using criteria and the identification of dependencies among them leads to the functional resonance assessment. Once potential variability is described, barriers should be defined by assessing the required performance level. The three axes for barrier design are prevention, detection and recovery. This study will focus specifically on recovery aspects using two solutions principles:

- decrease level of required human resources
- and/or reallocate available resources

Preliminary results

The current research is conducted according to the following steps :

- incapacitation categorization
- selection of a use case
- instantiation of FRAM model (i.e. the simulation of the impact of a given incapacitation on a selected use case).

Incapacitation categorization

Because of the very wide spectrum of incapacitation (from a light fatigue to a sudden death), incapacitations have been gathered according to their potential consequences in terms of safety rather than on the basis of their causes. From the various possible incapacitations a total of 6 classes (table 2) have been identified in the literature in order to assess the potential sources of human variability and so the risk classes.

Table 2. *Presentation of the Incapacitation classes.*

<u>Incapacitation class</u>	<u>Definition</u>	<u>Example</u>
<u>C1</u>	Sudden and total incapacitation of one pilot	Heart attack, AVC...
<u>C2</u>	Progressive and partial incapacitation but with impact on activity	Gastro intestinal disease, infectious disease, drugs...
<u>C3</u>	Subtle and partial incapacitation no visible for other crew member	Attention, fatigue...
<u>C4</u>	Progressive, in a first time partial then total incapacitation of crew	<u>Hypoxia...</u>
<u>C5</u>	Inappropriate behavior	Psychiatric decompensation...
<u>C6</u>	Rapid and total incapacitation of crew	Barotraumas, depressurization...

Use case description

As already mentioned, the research is based on the instantiation of the model on several use cases. A use case is defined as an operational situation that requires a replanification by the aircrew, a dynamic phase with a temporal pressure and a high workload. The first use case chosen is the Late Runway Change during the approach flight phase as:

- it is considered as a normal operation,
- a replanification process is required,
- it can generate events,
- it accounts for a supplementary cost for the airline (passengers are later at gate, higher volume of fuel used),
- the performance on task may be influenced by the crew state and external conditions (temporal pressure...).

Analysis of variability

The purpose of the present analysis is to propose solutions for barriers implementation in order to maintain balance between required resources and available resources.

The purpose of the approach phase after a late runway change is to fly the aircraft according to a new trajectory given by the ATCo (Air Traffic Controller) to the DH (Decision Height) with required performance.

The system under analysis is a late runway change operation as a whole. It is composed of three sub-systems, each one having an implication in the late runway change operation. The first one is the ATCo (as the use case is a Late Runway Change proposed by ATC). This means that the crew has to make the decision process to accept or not and need to update the action plan. The second and third sub-systems are the crew, PF (Pilot Flying) and PNF (Pilot Non Flying) and the aircraft.

Functional boundaries are defined in order to include the hardware artifacts of the cockpit, the procedures and humans. The operational boundaries of this study define the starting point of a late runway change when ATC asks the crew whether they accept it (after the Top of Descent and the first approach briefing) and ends at the DH where the missed

approach procedure or landing is performed. Finally, the hardware boundaries are FCU (Flight Control Unit) and FMA (Flight Mode Annunciator), PFD (Primary Flight Display) and ND (Navigation Display). Once the system and its boundaries have been described, The FRAM method is used to perform an analysis of variability of each function comparing this variability in nominal conditions and making several instantiations by varying aircrew resources.

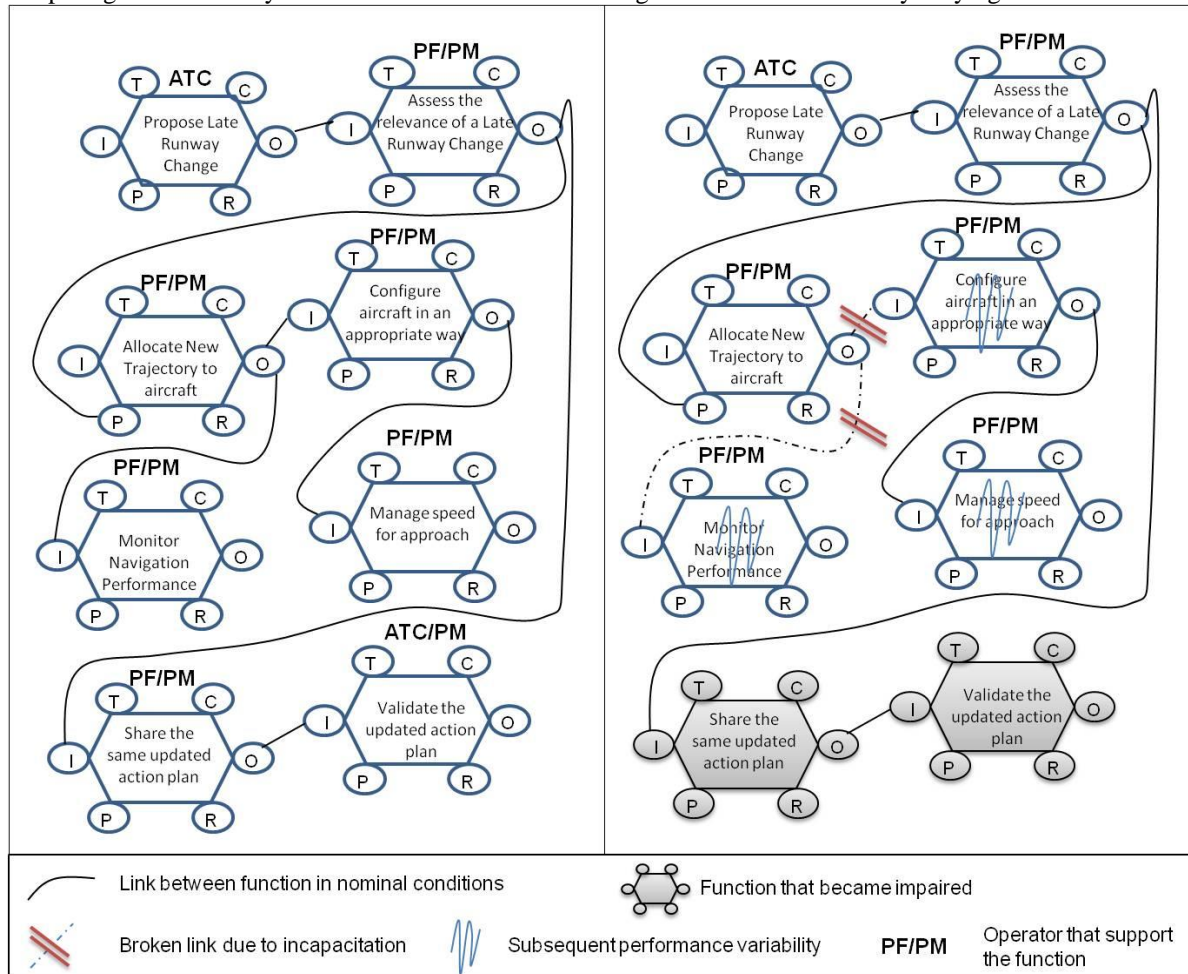


Figure 2. FRAM instantiation in nominal condition versus FRAM instantiation with incapacitation class C1.

The instantiation presented in figure 2 as an illustration shows the potential variability of several function if the performance of one of them (the function 'Allocate new trajectory to aircraft') becomes unpredictable due to an incapacitation. In this illustration, the incapacitation concerns the PF and is a sudden and total one, corresponding to class C1 of incapacitation. In order to fit with the use case, the incapacitation arrives after the function 'Crew accept the Late Runway Change' has been performed. Comparing the nominal condition and the instantiation with incapacitation, FRAM allows to show a resonance process leading to performance variability on functions 'configure aircraft in

appropriate way', 'monitor navigation performance' and 'manage speed for approach. Moreover, the functions 'share the same updated action plan' and 'validate the updated action plan' became impaired due to the lack of resources provided by the pilot suffering of the incapacitation. As described in the theoretical background of FRAM, the next step aims at defining the type of barrier needed : physical, functional, symbolic or incorporeal.

Conclusion

The study presented in this article aims at defining methodological principles in order to take into account human resources variability in the design of future cockpits. In order to assess the performance variability, one of the methodological choice is to assess the benefits of the only method available to assess variability, FRAM. Even if the link between functions is an illustration, it seems interesting to use FRAM in order to assess potential variability of other functions if the performance of one is weakened. This preliminary results suggest that FRAM can be a useful element in the overall methodology as an enabler to focus on variability sources. In order to ease the risk management phase process, pilots strategies will be apprehended. Once the methodology for risk analysis phase validated, it will be applied on several use cases.

The second step of the research will be a risk management phase lying on focus groups with experts in order to propose barriers to improve the stability of the sociotechnical system with a particular focus on recovery. To improve the quality of inputs of the focus groups, tools provided by the creativity theories will be used. All this will lead to the identification of principles for design of future cockpits, hopefully leading to the development of a systemic method taking into account crew resources variability.

References

- Akerstedt, T., Folkard, S., Portin, C. (2004). Predictions from the three-process model of alertness. *Aviation, Space and Environmental Medicine*, 75, 75-83.
- Amalberti, R. (1998). Automation in aviation : A human factors perspective. In D. Garland, J. Wise & D. Hopkin (Eds.), *Aviation human factors* (pp. 173-192, chapter 7). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Dinadis, N., Vicente, K.J. (1999). Designing functional visualizations for aircraft systems status displays. *International Journal of Aviation Psychology*, 9, 241-269.
- Hollnagel, E. (2009). The ETTO principle: Efficiency-thoroughness trade-off: Why things that go right sometimes go wrong. Farnham, UK: Ashgate.
- Hollnagel, E. (2004). Barriers and accident prevention. Aldershot, UK: Ashgate.
- Hollnagel, E. (2003). Cognition as control: A pragmatic approach to the modeling of joint cognitive systems *IEEE Transactions on Systems, Man, and Cybernetics*, Special Issue.
- Hollnagel, E., Goteman, Ö. (2004). The functional resonance accident model. *In Proceedings of cognitive system engineering in Process Plant*, CSEPC 2004, 155-161.
- Parasuraman, R., Sheridan T.B, Wickens C.D. (2000) A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, and Cybernetics*, 30, 286-297.
- Pope, A.T. (1995). Biocybernetics system evaluates indices of operator engagement in automated task. *Biological psychology*, 40, 187-195.
- Klein, G. (2008). Naturalistic decision making. *Human Factors*, 50, 456-460 Doi: 10.1518/001872008X288385.
- Vicente, K.J., Rasmussen, J. (1992). Ecological Interface design : Theoretical foundations. *IEEE Transactions on Systems, Man, and Cybernetics*, 22, 589-606.
- Wickens, C.D. (2008). Multiple resources and mental workload. *Human Factors*, 50, 449-455. Doi: 10.1518/001872008X288394.