Workshop FRAM – June 6-7/2012

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FRAM for risk assessment and design process

So far, FRAM has been mostly used in the area of accident analysis rather than for the purpose of risk assessment.

This paper aims to present two potential applications of FRAM in different steps of a research on aircrew resources variability in a risk assessment perspective. The aim of the research is to propose design requirements to integrate aircrew resources variability into the design of future cockpits. Today, in civil aviation, cockpits are designed considering a theoretical minimum level of crew resources availability, although it is widely acknowledged that availability of aircrew resources may vary from time to time because of endogenous factors (level of fatigue...) and exogenous factors (time of day...). In this research, the studied situations are those were the level of aircrew available resources is lower than the required level. These situations are defined as an incapacitation.

The main research objective is to develop a methodology that enables designers to take into account this variability in the design of future cockpit. The FRAM method is used in order to analyse the impact of aircrew resources variability on specific use cases in order to perform a risk analysis and propose mitigation means.

The current stage of the research does not allow choosing a specific use of FRAM as it can be used at two different levels: a global one and a local one. The next two paragraphs present the possible use of FRAM in this research in order to discuss with experts the advantages and limits of both approaches.

<u>First way: local approach: FRAM for data analysis</u>

Context: In this research an experiment was conducted with 8 crews composed of 16 experienced pilots. A full flight simulator was used to perform a flight scenario in which two levels of workload were compared. The type of workload was determined by the impact of fatigue on type of activity. Fatigue has an impact on knowledge based performance as it weakened the ability of divergent thinking and has few consequences on procedural based performance.

The simulated flight took place during night in order to induce crew fatigue and analyse their performance in two types of situation inducing two levels of cognitive demands:

- Rules level: Engine failure: performance variability for the application of the procedure to manage the engine failure during cruise phase
- Knowledge level: Late Runway Change: performance variability to choose a new runway during the final approach phase and perform the approach

Use of FRAM: In this approach, FRAM can be used to analyse the performance variability of each crew for each function covering the management of the engine failure and the Late Runway Change. Once the analysis performed for each crew, a general profile of performance variability can be created for the use case. The performance variability analysis can then be used to determine which means of mitigations should be implemented to maintain the variability of each function in order to have an acceptable overall performance.

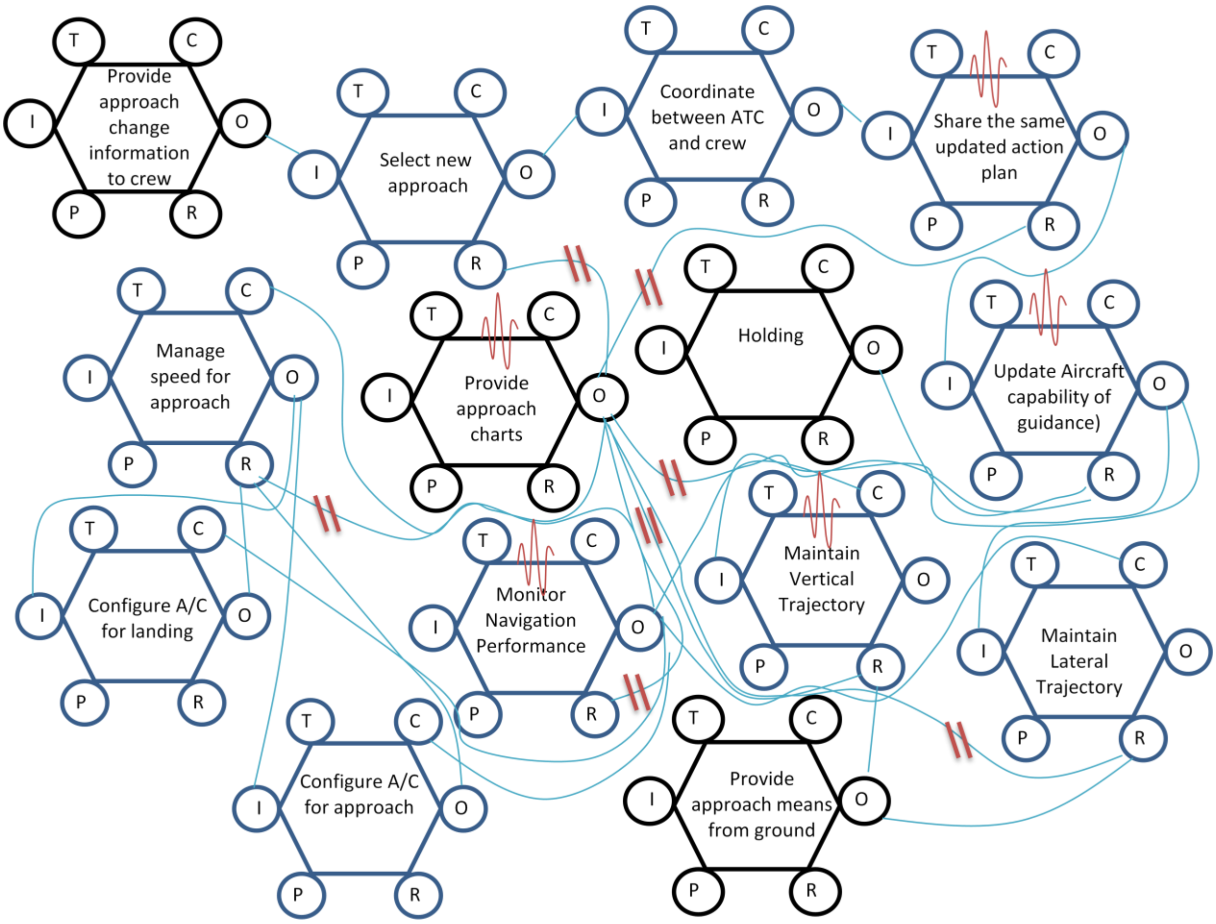

Figure 1. Example of the use of FRAM for Late Runway Change event for one crew

This example shows the performance variability for one crew during the event Late Runway Change. The method proposed by Luigi Macchi was applied to assess performance variability of the function's output. This method is based on two main criteria to determine the potential variability: a temporal criteria (too early, too late, on time) and a precision criteria (accurate, appropriate, inaccurate). The black coloured functions are considered as background function whereas the blue functions are foreground functions. In this example, the crew decided to perform the new approach without the approach chart. During the approach, the chart is used to get information notably about the descent profile (lateral and vertical trajectory that the aircraft must follow), the minimum altitude decision... As this crew disregarded the missing approach chart to perform the new approach, an increased performance variability can be observed on several functions. For example the function "share the same updated action plan", will be detailed later.

The characterisation of the output of a function is made following two main steps:

- The characterisation of the aspects of each function: characterise each aspect of the function using time and precision criteria
- Associate the quality of the output to a value of the potential variability (damping or increasing potential) in order to ease the analysis.

The following table present the detailed possible characterisation of the output.

		Temporal characteristics		
		Too early	On time	Too late
Precision	Precise	**A**: Output to downstream functions is precise but too early	**B**: Output to downstream functions is precise with the right timing	**C**: Output to downstream functions is precise but delayed, reducing available time
	Appropriate	**D**: Output to downstream functions is appropriate but too early	**E**: Output to downstream functions is appropriate with the right timing	**F**: Output to downstream functions is appropriate but delayed, reducing available time
	Imprecise	**G**: Output to downstream functions is imprecise and too early	**H**: Output to downstream functions is imprecise but correctly timed	**I**: Output to downstream functions is imprecise as well as delayed, reducing available time

Table 1. Output characterisation for function (Macchi thesis, p.73)

Once each output characterisation is done for one function, each one is associated to a value. This value represent the potential of damping or increasing the performance variability in the system. The potential for damping performance variability can be : +1, +2 or +3 whereas the potential for increasing performance variability can be: -1, -2, or -3. The median of the quality of the aspect determines the quality of the output of the function. The example below show the output characterisation for the function “share the same updated action plan”.

Share the same updated action plan		Quality	Value
Input	ATC clearance obtain	E	+2
Preconditions	Communication between crew members (CRM)	E	+2
Time		/	/
Resources	Briefing procedures	H	-2
	Approach chart	H	-2

Control	Cross-check between crew members	H	-3
Output	**Updated briefing, cross-check and task allocation done**	**H**	**-2**

Table 2. Performance variability for one function: Share the same updated action plan

The output of the function has been qualified as (H, -2), meaning that the output of the function is imprecise and on time (H) and is associated to a medium potential for variability increase (-2). In the instantiation of the model, this function allows the crew to share the information according to the new approach (task allocation, type of approach, minimas...). In the particular context of the experiment, as the crew had no approach chart, they had to rebuild the required information for approach. New information is based on an approach chart for another type of approach. This induced a workload increase (augmented cross-check and calculation of distances) leading the crew to forget a check-list even if the overall performance of the approach was maintained. In this example the late runway change requested by ATC did not induce a change of action plan for the crew, they stuck on the first planned approach even if it increases workload and induces performance variability. This source of performance variability may create vulnerabilities, i.e. unexpected outcomes that can create events, incidents or accidents. The proposed barriers could be for example, an organisational one, using a better coordination between ATC and crew (ATC gives precise heading and altitudes) or a planning system designed to allow a rapid change of approach.

Expected results with the use of FRAM: determine for a use case the performance variability to assess the vulnerabilities or potential risks that can be identified. A step further is to propose design solution to maintain performance variability of functions that can be at risk. FRAM is used at a local level for risk assessment.

2nd way: Global approach: FRAM for risk assessment by merging results coming from various sources.

Context: This research has collected a huge amount of wide-ranging data from multiple sources:

- Scientific knowledge on fatigue and aircrew resources variability: cognitive and physiological variability due to fatigue, consequences on performance and activity, strategies used by pilots to manage fatigue (Petrilli, Dawson)
- Pilots experience: strategies for fatigue and activity management
- Focus groups: selection of use cases relevant in case of aircrew resources variability
- Task analysis: scenario in full flight simulators with 2 types of situations (rules and knowledge based)

Use of FRAM: FRAM can be used to represent a global approach of performance variability gathering all the data collected. The data collected were collected according to two main topics, the detection of an incapacitation and the following recovery. These two aspect where studied in order to know the current indices used for detection by pilots and the recovery means i.e. the strategies pilots used to manage the incapacitation and its consequences on the situation. The first results indicates that there are six main needs or functions identified for incapacitation management:

- Identify the incapacitation: detect the incapacitation
- Assess the crew state: determine the type of incapacitation, its seriousness
- Evaluate the consequence on the situation: evaluate the consequences of incapacitation on mission, on crew activity
- Decide the action plan or Compensate/mitigate: maintain current flight plan or rerouting
- Execute the action plan: inform ATC, cabin crew, passengers, flight operations and reorganise activity for the new action plan

- Control the action plan: evaluate if the action plan allows to recover the situation and if actions are appropriate to the expected result.

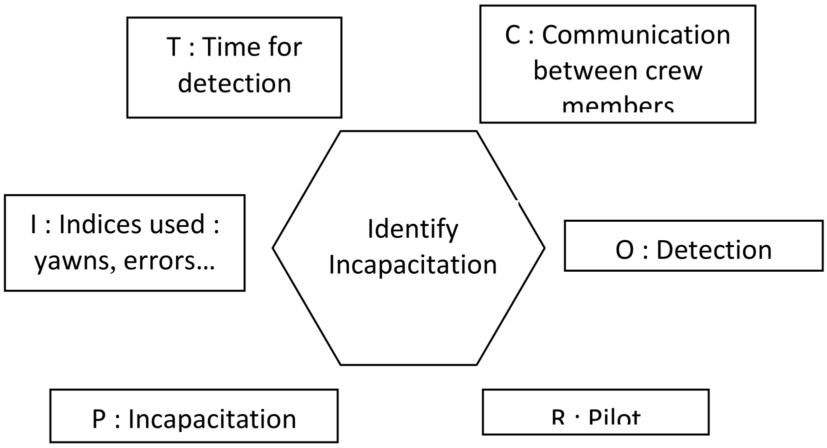

Figure 2. Example of the function Identify Incapacitation

Each need or function can be analysed using both dimensions: precision and time. The analysis of performance variability can be performed using data collected and potential vulnerabilities that have been identified.

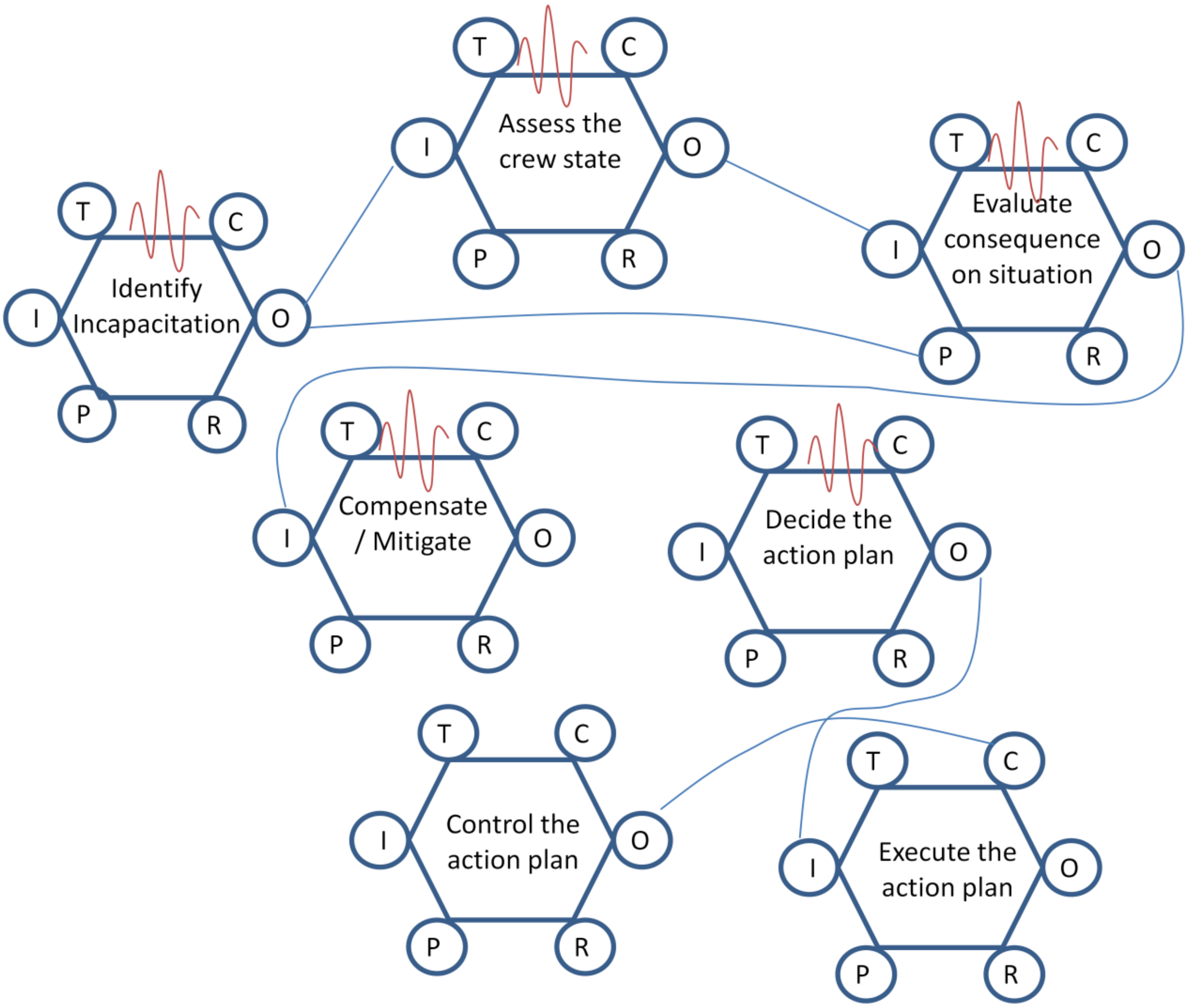

Figure 3. Analysis of an identified vulnerability for the function Identify incapacitation: Aspect Time: high variability in detection time

This example shows a global approach of risk assessment for incapacitation management. During the data collection phase, one of the vulnerability identified is the time needed to detect incapacitation that can vary dramatically depending on multiple factors such as the flight phase, the workload, the familiarity level between crew members... The figure 4 shows that if case of a performance variability of the function "identify the incapacitation", 4 other functions can be impacted (assess the crew state, evaluate consequence on the situation, compensate, mitigate, decide the action plan). In a risk assessment perspective it means that in order to maintain the variability in acceptable limits, a design mean should be used to help the crew to identify the type of incapacitation and reduce the time needed to detect it. Moreover means can be proposed to help the crew to manage the consequences of the incapacitation on their activity. So, this representation allows showing the consequences of the potential performance variability on the overall incapacitation management making a link between the dimensions detection and recovery.

Use of FRAM: FRAM can be used to present the results of this research in order to ease the comprehension and improve the identification of the main vulnerabilities that must be recovered. Moreover it may allow to identify performance variability leading to other vulnerabilities identification.

Discussion

Both approaches proposed in this paper can be considered as complementary. The first one aims to analyse data in order to determine performance variability for experienced crews who are tired vs. crew who are not tired (according to a sleepiness scale results used during the experiment). Once assessed, this performance variability allows determining potential variability that has to be managed proposing design or training solutions. The current limit encountered using FRAM is the time needed to perform the analysis for each crew and combining all the results in an instantiation that can be used to find barriers. A proposed solution could be the use of an Alta Rica tool, a tool that is already used in risk assessment analysis at a functional level for the aircraft. Today this tool does only include system failure probabilities but can be combine to a human factors approach. A specific tool for FRAM must be created (already discussed by the FRAMily members). Another limit is the transition between the performance variability identification and the barriers identification. Currently, a few things are written to help finding a methodology applicable to barriers definition.

The second way for using FRAM is more global and allows presenting all the information collected during this research and the risk assessment process that is performed. Using FRAM allows putting on the same representation the information gathered and the vulnerabilities identified taking into account the normal activity of the system (a specific scenario may not be necessary to represent all the data gathered). According to the state of the art, FRAM has not yet been used as a global approach as it always rely on specific scenario to perform instantiation. It is not established for now in this research if it is possible to use FRAM in a general manner with no precise scenario but an incapacitation one and if it can then be “plugged” with specific scenario on failures, weather event...

For this research both approaches can be relevant even if some methodological issues have to be solved, issues that can be discussed with other FRAM experts.

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