A FRENCH EXPERIMENT ABOUT CREAM

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Abstract

In the field of HRA, new needs like the response to secondary priority alarms or the reliability of field operator actions had stemmed from the development of hazards PSAs. IRSN was looking for a HRA model complementary to models he usually used for level 1 (PANAME) and level 2 (HORAAM) PSA developments in order to take into account the reliability of human actions other than those appearing in the Emergency Operating Procedures (EOPs) or in the Severe accident Management Guide (SAMG).

Generalist, widely used in various domains, international, well documented, CREAM developed by Erik Hollnagel (Denmark) in the year 2000 was a good candidate. Generally classified as a second generation HRA method, CREAM has the ability to identify the importance of human performance in a given context and has a helpful and easy to use cognitive model.

CREAM was tested at IRSN in the framework of a six months final internship in engineering. In order to conclude if CREAM could be an additional HRA tool, about ten human failure events (HFEs) from level 1, level 2 and fire PSAs, already analyzed and quantified with other well controlled HRA methods (MERMOS, PANAME and HORAAM), were selected and quantified. Even if the trial counted a limited number of cases, results were encouraging by the way that no major difficulties were met to model theses different types of HFEs and the order of magnitude of the previous results was verified.

After this test, IRSN recently chose CREAM to calculate the human error probabilities in its first internal explosion PSA level 1. HEFs modeled in the IRSN internal explosion PSA are failures of leak isolation that contribute to the occurrence of an explosive atmosphere. On the French plants, the risk of explosion is taken into account through the implementation of hydrogen detectors in risky rooms, alarms in the main control room and dedicated procedures to identify the source of the leak and to isolate it. The abnormal Hydrogen concentration is supposed to be detected early (12,5 % of the explosion limit) apart from the implementation of the EOPs and the operation of the unit isn't stopped. So CREAM seems more suitable than PANAME for this study. Times responses is an example. PANAME is a first generation time dependent model that needs precise evaluations of the path through the EOPs. Alarm response procedures are simpler than EOPs and time necessary to reach the step that indicate which valve needs to be closed can be the double or the triple in regards with the situation (a tank drain can cause the leak, a maintenance can be underway,…). Conversely CREAM considers the Common Performance Condition (evaluation of the context) "Available time" as "Adequate", "Temporarily inadequate" or "Continuously inadequate". This approach seems more appropriate for the IRSN internal explosion PSA model.

The paper analyses the strong points and the weaknesses of CREAM that have been made out through the test of the method and its implementation for internal explosion PSA model.

Introduction

In the field of HRA, new needs like the quality of the response to secondary priority alarms or the reliability of field operator actions had stemmed from the development of hazards PSAs. IRSN was looking for a HRA model complementary to those he usually used for level 1 (PANAME) (Ref. 2) and level 2 (HORAAM) (Ref. 3 and 4) PSA developments in order to take into account the reliability of human actions other than those appearing in the Emergency Operating Procedures (EOPs) or in the Severe accident Management Guide (SAMG).

Generalist, widely used in various domains and different countries, international, well documented, CREAM (Ref.1) developed by Erik Hollnagel (Denmark) in the year 2000 was a good candidate. Generally classified as a second generation HRA method, CREAM has the ability to identify the importance of human performance depending on the context and has an helpful and easy to use cognitive model.

I. A brief overview of CREAM

CREAM (Cognitive Reliability and Error Analysis Method) (Ref. 1) is HRA method developed by Erik Hollnagel and published in 1998. The purpose of the developer was to offer an alternative to first generation HRA methods which were found fault for poorly taking into account how operators are likely to fail a mission.

CREAM relies on three elements: a classification scheme, a model and a method. In order to be flexible the classification scheme makes use of several connected classification groups from three categories: person related, technology related and organization related. Its fourteen tables[1] are detailed enough to characterize precisely the failure. Unlike a traditional hierarchical classification scheme, a large number of pathways through the classification groups are available. The model, named COCOM (Contextual Control MOdel), focuses on how actions are chosen and has the particularity to consider competence (skills, procedures and knowledge) and control on the same level.

As it is the case of several second generation HRA methods, CREAM is able to be applied both for prospective (search for causes) and for retrospective analyses (performance prediction).

The method of HFE quantification counts four main steps: to build a cognitive demand profile, to determine the probable control mode, to identify likely cognitive functions failures and to determine failure probability. Each step is quickly described below.

I.A The control modes

In CREAM, the control modes provide a way to take into account external conditions in a different way from the traditional Performance Shapping Factors (PSFs) and they offer the way of linking the classification scheme and the method.

I.A.1 Description of the control modes

Four control modes are identified:

- scrambled control: complete loss of situation awareness ;
- opportunistic control: the person does very little planning or anticipation perhaps because the context is not clearly understood or because time is too constrained ;
- tactical control: more or less follows a known procedure or rule ;
- strategic control: the operator considers the global context, thus using a wider time horizon and looking ahead at higher level goals.

Control modes have an impact on the probability that an action failure may occur (see figure 1 below).

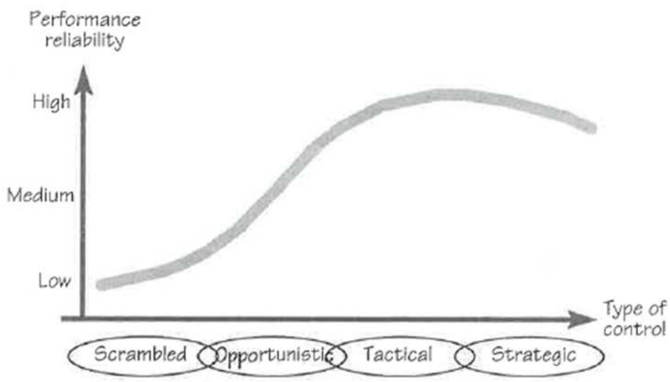

Figure 1. CREAM (Ref. 1): relation between control mode and reliability

[1] Observation, interpretation , planning, temporary person related functions, permanent person related functions, equipment failure, procedures, temporary interface problems, permanent interface problems, communication, organization, training, ambient conditions , working conditions.

II.A.2 Determine the probable control mode

The outcome of this step is the identification of a control mode for the studied HFE as defined on Figure 1 above (cf. I). It is determined through nine Common Performance Conditions CPCs more or less similar to classical common PSFs: available time, number of simultaneous goals, adequacy of training and experience, availability of procedures, adequacy of MMI, working conditions, time of the day, adequacy of the organization and crew collaboration quality.

For each of them a choice between three or four modalities is possible. For example, the CPC "availability of procedures", three modalities are possible: "appropriate" expected to improve the performance reliability, "acceptable" expected to have no effect and "inappropriate" expected to reduce the performance reliability. It is important to notice that is CREAM, CPCs are not considered as independent. So, the number of simultaneous goals has a negative effect on "working conditions" but no effect on "adequacy of the training".

I.B Building a cognitive demand profile

Performing HRA begins inevitably by a qualitative analysis. Prerequisite, this step isn't specific to CREAM but the technical basis of the method should be present in mind. The HFE is analyzed and divided into a list of subtasks that are to be characterized in terms of cognitive activities[2] in order to determine later on whether it is likely that they will be performed correctly. This point is clarified in II.3.

I.C Identifying likely cognitive functions failures

The studied HFE has been divided into subtasks and a type of cognitive activity has been affected to each of the subtasks. CREAM is able to resume the cognitive activities into only a combination of four cognitive functions: "observation", "interpretation", "planning" and "execution" (COCOM model: ref. 1).

If several activities can be resumed to only one cognitive function as the activity "Scan": "quick or speedy review of displays or other information source(s) to obtain a general impression of the state of a system / sub-system" can be resumed to the cognitive function "Observation" (ref 1.), the most complex of them need a combination of two cognitive functions. So the activity "Regulate": "alter speed or direction of a control (system) in order to attain a goal; adjust or position components or sub-systems to reach a target state" (COCOM model: ref 1.) is a combination of two cognitive functions "Observation" and "Execution".

The COCOM model in CREAM combines the advantages of the simplicity and the transparency. For example, for reactor operation, the action of the secondary side operator cooling down the reactor at 56°C/h speed is associated to the cognitive function "Regulate" and the overseeing of the same action by the supervisor is only associated to the cognitive function "Observation".

After this step it is easy to select in the list of potential cognitive function failures the likely cognitive function failure for each sub task identified during the qualitative analysis of the mission. Coming back to the overseeing of the supervisor in the example above, three possible observation errors are identified in CREAM: "observation of wrong object", "wrong identification made (due to e.g. a mistaken cue or partial identification)" or "observation not made".

I.D Determining failure probability

The last step is the quantification of the HFE. Probabilities are issued from a table of nominal probabilities coming from commonly used reference works. Values are adjusted by the effect of the previously determined CPCs. The failure probability of the HFE is the one of the less reliable subtask.

[2] CREAM offers the following list of cognitive activities (ref 1.): coordinate, communicate, compare, diagnose, evaluate, execute, identify, maintain, monitor, observe, plan, record, regulate, scan verify.

II. THE TEST OF CREAM AT IRSN

CREAM was tested at IRSN in the framework of a six months final internship in engineering. The objective of the study was to conclude if CREAM could be an additional HRA tool for the institute. In order to have an idea of the possibilities and the limits of the method, the chosen methodology was to quantify HFEs already analyzed and quantified with other well controlled HRA methods.

II.A The content of the test

HFEs corresponding to a large range of situations had been re-quantified (level 1 internal events HFEs, fire and flooding HEFs, level 2 HEFs). These HFEs were already quantified with the following HRA methods:

- methods in use at IRSN (PANAME for level 1 PSAs and HORAAM for level 2 PSAs)
- methods in use at EDF (MERMOS[5] for level 1 PSAs, MEPEM (derived from MERMOS) for level 2 PSAs, HRA methods included in the EPRI calculator[3] for hazards PSAs).

A slightly different exercise of comparison was also realized: several HFEs from the Halden international exercise[6] (the SGTR part) were re-quantified and results were compared, testing by this way our comprehension of CREAM and the user's effect.

II.B The results of the test

Even if the trial counted a limited number of cases results were encouraging by the way that no major difficulties were met to model HFEs of various nature and the order of magnitude of the results was verified. Some lessons learned from the exercise concerning the modeling of CPCs, the modeling of actions outside the main control room and the dependencies between HFEs are presented in the following.

II.B.1 Development of a guide in order to model CPCs

When working with colleagues, differences appeared sometimes in comparing the modeling of CPCs of one given HFE: it appeared that the modalities of the CPCs were not precise enough to obtain reproducible results. For example the CPC "working conditions": "the conditions under which the work takes place, such as ambient lighting, glare on screens, noise from alarms, interruptions from the task, etc." has three modalities: "advantageous", "compatible" or "incompatible" (Ref. 1). If it is easy to select the modality "incompatible" in case of total loss of electrical power (operators can only use portable lighting), it is often more difficult to choose between the modalities "compatible" and "incompatible". Often alarms ring in the main control room. When can we say that the noise from alarms is "incompatible"; which level, which frequency? In order to improve the reliability of the modelling, we developed a user's guide that gives rules to select a modality for the CPCs. For example, we decided that, for level 1 PSAs, without any further information, in the main control room the working conditions are "advantageous". This represents a kind of basis modeling. Of course a different modality can be chosen, but each time it is the case, the justification has to be written in the user's guide. So the guide grows richer over the modeling.

II.B.2 Modeling of actions outside the main control room

A field operator doesn't operate on his own decision: the team in the main control room applies EOPs and asks for a local action. CREAM doesn't advise to model two series of CPCs, one to take into account the context for operators in the main control room and one other to take into account the context for operators in local. But both contexts can be different for many reasons. The team in main control room may be overloaded (CPC "Number of simultaneous goals" assessed as "More than capacity") which reduces the reliability of the performance. But the field operator may have only to implement one simple action: start a pump (CPC "Number of simultaneous goals" assessed as "Less than capacity"). On another hand the CPC "working conditions" may be "advantageous" in the main control room (calm and controlled) and "incompatible" in the room the field operator operates (smoke).

To cope with this difficulty we have chosen to model separately the context in the main control room and the one in local: a series of CPCs for the paths through the EOPs (team in the main control room) and another series of CPCs for local actions. The effect is lengthening the modeling but it improves the traceability.

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[3] CBDT / HCR / ORE / THERP.

II.B.3 Dependencies between HFEs

Two or more HFEs can be present on the same sequence of an event tree. In this case the modelling must include the consideration of human error dependencies. It appears that CREAM is quite convenient to take into account dependencies between HFEs by the way that dependencies are considered in the integrated quantification process when defining the control mode of the operators. The modalities of the CPCs are chosen for each HFE and the analyst can take into account the failure of the previous task when fixing the CPCs of the second HFE (or the third one). By the action of the weighting factors, a change in the modalities of the CPCs (degradation of the context) increases indeed the probability of failure of the mission.

III. CREAM chosen to model HEPs for the IRSN first internal explosion PSA level 1

In 2015, IRSN developed its first internal explosion PSA level 1. The specific HEFs of this internal hazard PSA are isolation actions of hydrogen leaks to avoid the occurrence of an explosive atmosphere. Quantification with expert judgment was available for the feasibility study but fairly quickly, the developers were looking for a suitable HRA model for these specific HFEs.

III.A The choice of CREAM

IRSN considers in its study that there is an explosion as soon as the concentration of hydrogen in the air reaches four percent which corresponds to the Lower explosive limit (LEL). An abnormal Hydrogen concentration is supposed to be detected early. The first detection threshold corresponds to a concentration of hydrogen equal to 12,5 % of LEL. The operation of the unit isn’t stopped. The context of the remedial actions is not relating to EOPs but normal operation. But PANAME, the HRA model commonly used at IRSN for level 1 PSAs, is dedicated to EOPs by the way it relies on a large amount of simulations from a full scope simulator where operators had to face reference initiators as LOCA or SGTR and to apply EOPs. Situation is more degraded than that of the incidents happening during normal operation but the procedures are very supportive and the operators are well trained to use them. Moreover PANAME is a first generation time dependent model that needs precise time evaluations of the path through the EOPs. Alarm response procedures are simpler than EOPs but the time necessary to reach the step that indicate which action is needed to stop the leak (generally to close a valve) can double or triple depending on the situation (the origin of the leak can be obvious or hidden, a maintenance can be underway,…). This point could lead to HEPs with a large range of uncertainty. PANAME seemed inappropriate and expert judgment was far from an ideal. For both reasons a trial of CREAM for this project was decided.

III.B CREAM experiment for the internal explosion PSA

III.B.1 Description of the HFEs of the internal explosion PSA

All the French nuclear power plants are equipped with a hydrogen monitoring system. Detectors are dispatched in the risky rooms and information coming from these detectors is centralized on a central panel near the main control room. Three threshold limit values of hydrogen concentration generate visual alarms. The first one consists in an early warning (when 12.5 % of the explosion limit is reached). Since the occurrence of this alarm, operators have to apply a procedure that helps them to diagnose if the alarm is justified or not and, if it isn't false, to select the correct sub procedure to stop the hydrogen leak.

A typical scenario of the internal explosion PSA is as following. An alarm appears in the main control room indicating that the first threshold of hydrogen concentration is reached somewhere on the plant. One operator goes to the hydrogen control panel and scans the hydrogen concentrations retransmitted by sensors. He identifies the location of the leak and he selects the dedicated procedure that indicates which valve to close in order to stop the leak. Sometimes it’s simpler: the operator only has to check that the automatic closure has occurred. On another hand, sometimes he has to ask for a field operator to close a valve locally.

III.B.2 The exploratory phase

Firstly, CREAM was tested with only one single HFE. During the CREAM internship (cf. paragraph II) an excel calculation sheet had been developed to support the quantification. It contains the three tables necessary for a HRA modelling with CREAM: a table for assessing the CPCs, a table for selecting the generic function failures and a table for selecting the generic failure types. The calculation sheet is users friendly. After the qualitative analysis of the task, the tool support the modeling by the evaluation of the context of the task (modalities of the CPCs), fixing a cognitive activity to each step of the task and assigning the likely cognitive function failure to each of them. At the end, the Excel calculation sheet provides a failure probability for the HFE.

Two developers of the internal explosion PSA model and a HRA analyst participated to the trial. In order that they feel confident to realize the test, a quick training was provided to the developers less familiar with CREAM than the HRA analyst. The objective wasn't to obtain a complete consensus on the failure probability for the HFE but to appreciate if all the characteristics of the task (response to an alarm) could be addressed in CREAM. The results of the exploratory quantifications were convincing to carry on with CREAM.

III.B.3 Considerations about the user's effect

The difficulties about the CREAM user's effect identified during the internship study re-appeared. Developers of the internal explosion PSA approached the HRA method with a fresh eye but the conclusions were the same: the definitions of the modalities for the CPCs are not precise enough to obtain reproducible results.

The assessment of the CPC "Availability of procedures / plans" raised a lot of discussion. The definition for the CPC in the method is: "The availability of prepared guidance for the work to be carried out, including operating / emergency procedures, routines, & familiar responses" (Ref.1). It wasn't easy to choose between the modalities: "Appropriate" and "Acceptable". Obviously operators are warned about the risk of explosion and they know the dedicated procedures but can normal operation procedures (response to a lower level alarm compared to that of a classical initiator like LOCA or SGTR) be compared to EOPS? Responses "Appropriate" and "Acceptable" are both possible: it's a user's of CREAM.

To go further: is it only a weakness of CREAM or is it a weakness of most of the context defined HRA methods? The question is open but in any case, this kind of difficulty can easily be overcome with the implementation of a user's guide as presented in paragraph II.B.1.

III.B.4 A fictive example

The validation of the internal explosion PSA level 1 is still in progress. In order to have an idea of the integration of CREAM modeling in the project a fictive example is presented in the followings. The fictive scenario is consistent with the typical scenario presented in the paragraph III.B.1 above: a leak from a singularity on a pipe in room B1 is revealed by the failure of the exhaust fan in the room. The mission time (explosive atmosphere) is 20 minutes; the first threshold of hydrogen concentration is reached in 3 minutes and the second one in 7 minutes.

The hydrogen concentration increasing, a red alarm appears in the main control room indicating that the first threshold of hydrogen concentration is reached in room B1. As it is the case for any HRA method, the first step of the modeling is task analysis. Using CREAM, at this step, it is important to identify the main sub-tasks that, if failed, will lead to the failure of the mission. In the example, the three following sub-tasks are selected:

1. Identifying hydrogen alarm and apply the orientation procedure ;
2. Selecting the correct procedure to manage the leak in room B1 ;
3. Closing the valve to stop the leak.

The second step is the evaluation of the context through the assessment of the CPCs. The CPC ''working conditions" is considered as "incompatible" because the situation is stressful. The alarms that correspond to the second level threshold (new alarm) and the third level threshold (alarm for the total evacuation of the room B1 building) of hydrogen concentration will appear while operators are applying the procedures to manage the hydrogen leak. The CPC "number of simultaneous goals" is considered as "more than capacity" because operators in the main control room have very little time to apply the procedures and to supervise field operators in local. Both CPCs reduce the performance. The CPC "availability of procedures/plans" is considered as "Adequate": it improves the performance. Other CPCs are considered as "neutral" so without negative or positive effect on the performance.

Then the COCOM model is applied. An "activity type" is associated to each of the subtasks that had been selected. The subtasks "1" and "3" are considered as "Execute" while Subtask "2" as "Observe". At the end, the likely cognitive function failures are selected on the list of the possible failures of "execution" and "observation". In the example, taking into account that operators have very little time to operate, the failure "missed action" is selected (HEP: 3.10^{-2}). The effect of the CPCs reduces to 9.10^{-2} the HEP of the mission.

III.B.5 Considerations about the time modelling

The first difficulty met in PANAME concerning the precise evaluation of the time necessary to stop the leak is not a problem with CREAM. The time available to carry out a task is considered both in the CPC "Available time" and in the choice of the likely cognitive function failure.

For the assessment of the CPC "Available time", the analyst chooses between: "Adequate", "Temporarily inadequate" or "Continuously inadequate". This qualitative way of evaluation is convenient for the HFE "stop the hydrogen leak during normal operation" where the delay can vary from simple to triple. If badly marked, the CPC "Available time" contributes to increase the failure probability of the HFE.

In CREAM, another way to take into account the available time is the selection of the likely cognitive function failure. In the case of the internal explosion HFEs, one recurring subtask is "closing a valve to stop the hydrogen leak". For the cognitive activity, the obvious choice is "Execute" which only corresponds to "Execution" in the COCOM model (one of the simplest cases of the model: see Ref.1, p.248). CREAM offers a choice of five possible execution errors. Two of them deal with delays: "action performed at wrong time, either too early or too late" (basic value: 3.10^{-3}) or "missed action, not performed" (basic value: 3.10^{-2}), the best choice for us (action that was not done within the time interval allowed).

Notice that in any case the analyst can affect a probability of failure of "1" if he considers that the time available is really too short for the operator to operate.

III.B.6 Results

Around thirty different HFEs of the internal explosion PSA model were quantified with CREAM. They correspond to five different missions that represent five different ways of hydrogen leak and five different remedial actions (room, valves, procedures, main control room or local actions). The mission times vary from 2 minutes (which is very short in normal operation) to 272 minutes.

No particular difficulties have been encountered for the modelling. HEPs vary from 1 to $1.2.10^{-3}$. An HEP equal to "1" means that the time available was obviously too short to stop the hydrogen leak.

In the application of CREAM for the internal explosion PSA level 1, only four on nine CPCs vary (i.e. marked other than "average"): "working conditions", "MMI and operational support", "simultaneous goals", "available time". However these variations allow HEPs to vary from $4.8.10^{-1}$ to $1.2.10^{-3}$ (the HEPs that equal "1" are issued directly from the qualitative analysis).

In only one case, the procedure was considered "inappropriate"; a large part of high failure probabilities correspond to a short time to manage the situation.

Another positive aspect in the use of CREAM for the quantification of the HEFs of the internal explosion PSA model was the list of generic failure types. They seemed to be at the right level compared to the sub tasks of these specific HFEs, as "identify the faulty sensor among others on panel", "selected the right procedure in list" or "close the correct valve"...

IV. CONCLUSION

CREAM is considered by IRSN, as a complementary HRA method, to model HFEs that do not cope with the main HRA models: PANAME when operators apply the state oriented procedures and HORAAM when the national crisis organization is gathered to support the team on the unit.

Because of its HFEs dealing with alarm responses and stopping hydrogen leaks, actions implemented during normal operation, CREAM was chosen to model the specific ones of the internal explosion PSA level 1. It proved appropriate by the way that CREAM offered a correct ranking of the HFEs taking into account the variety of the procedures and the remedial actions: from the main control room or in local, that of the context: possible recurring alarms disturbing operators and of course that of the mission times.

In addition, in the framework of the ten years periodical safety reviews, IRSN plans to use CREAM to obtain an against-expert analysis for the assessment of EDF (The French utility) internal explosion PSAs and more generally hazard PSAs that contain normal operation HFEs.

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