Simulation for training pilots of French nuclear power plants

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Abstract

We here present the simulation training policy for French nuclear reactor pilots. Training sessions are described. Advantages and drawbacks are discussed. The trainers' interactions are commented. Tools for transference of know-how and skills development are presented. As a conclusion, perspective of new training tools are suggested.

1. The context: Industrial facilities and pilots

The operation of nuclear power plants requires a high degree of control, whether in terms of operating or maintenance, and whether in normal or accidental situation. It concerns security and the health of populations, and therefore the possibility to maintain the nuclear sector in the energy market. Nuclear operator must thus be able not only to maintain its know-how but also to update and to adapt to the new requirements, which can intervene at the level of safety or security, regulation or legislation (Buessard & Fauquet, 2002), or economy. These imperatives are of two types:

- External: nuclear safety requirement changes that the operator as the nuclear safety authority keep on strengthening,
- Internal: corrective actions from event analysis essentially done by the operator.

Several domains are worked out to ensure these imperatives. The technical aspect comes in the first place since the industrial purpose is to run a technical system: this dimension receives the design engineers' attention from the construction through the operation to the decomissioning of a plant. The organizational aspect comes in second place, with a permanent desire of analysis and adaptation of the organization taking into account human in any dimension, since the industrial purpose is also to operate a socio-technical system (see for example: Lagrange & Desmares, 1999; Fauquet-Alekhine, 2010a). Many other fields are operated permanently, including those implemented to meet the capacity to develop and maintain expertise (Fauquet, 2003 and 2004): for this aim EDF uses nuclear reactor piloting simulators. Control rooms are reproduced in scale 1 (said "full scale simulators "), and calculators allow real-time simulation of the physical parameters of the installation. The choice of such a teaching tool is motivated by a dual need:

- creating closest situations of the reality of operations,
- leading a team to pilot a complex technical system collectively.

In this perspective, the full scale simulator has demonstrated its added value for nuclear industry and well before that for aviation.

The actors of the simulated situation are the pilot team members and trainers. An operating team of nuclear reactor is generally composed of 15 individuals (case of the 900 MWe reactor type) who operate a pair of reactors and associated equipment. The taking of position is a 3 x 8. The mission of the operating team is to pilot the reactor according to the electricity producing demand from nuclear energy while ensuring the safety of facilities. In the team, four to six people are in charge of piloting, the others being attached to the manipulation of pieces of equipment on the installation directly.

2. Genesis: technical and pedagogical design

2.1.The simulator

There are different types of piloting simulators: full scale simulators and part simulators.
Part simulators represent portions of the control room, and focus on a basic part of the installation that pilots must learn and know before being involved in the whole operating process.

Full scale simulators consist of the control room, replica of the operating reality, a calculator and a control panel from which trainers manage the simulated situation. This panel is closed-glass without color and with digital video system connected to several cameras that allow various views of the control room, with a capacity of zoom such that reading from a sheet of paper is possible. All of the views of cameras are recordable and available later in the debriefing room. This video system presents an undeniable added value and is subject to a strict ethic: any image is deleted after the training session, and the use is limited to the situation actors only.

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http://www.has-sante.fr/portail/upload/docs/application/pdf/2012-01/simulation_en_sante_-_rapport.pdf

2.2.The scenario

The only simulator does not reproduce a work situation in which operating team will be able to evolve in a context which is the most realistic possible, i.e. reproducing the better the reality of industrial operating. The simulator is only a support tool recreating an environment and permitting the interactions between actors and the industrial process. To create a simulated situation, it is necessary to dispose of prepared scenarios that engage actors in action. These scenarios incorporate the input parameters for the simulator calculator and input parameters to deliver to the operating team. This allows to introduce the input data concerning the work situation which each one is about to live on the simulator. It is also the time to propose a technical chain of the process during the simulated situation. The whole is coordinated by the trainers.

2.3.The trainer

What the trainer is in ability to do during the simulator run (as during the session debriefing) is highly dependent on his professional experience. The trainers have various career profiles. Some of them are coming from operating professions. Being from these professions gives legitimacy at once in front of the persons in training: This makes more easy technical discussions and this is felt by the trainees, and it allows the trainer to support discussions in debriefing by the narration of experienced examples, full of meaning for the actors, and appreciated because s/he thus facilitates the understanding of the topics discussed. In addition, this provides a certain attraction to the exchange, due to the anecdotal character of the story. For newcomers on a position as an trainer, computer databases containing stories of events will be investigated upstream training sessions. This data base is a enjoyable tool even for the experienced trainer who sometimes would tend to stay on her/his own experience, which, even rich, therefore will take all the benefit of recent operating experience feedback.

2.4.Reference / simuilated situation

From a reference situation, the scenario develops the simulated situation by reducing the variability of the context to emphasize what is necessary to achieve educational goals.

This reduction in variability (i.e. the simplification of the situation simulated from baseline), is fundamental in the pedagogical approach, because it provides the means for the pilots to focus their cognitive resources on some of the difficulties brought by the script directly in connection with the pedagogical objectives. Sometimes, pilots are complaining about being "too far from reality", but this may be a necessity in the first place.

2.5.Training phases

All of which is implemented in simulated situations and debriefing is essentially the work of research by Pastré, Samurçay, and Plénacoste, from 1996 to 2001 (Klein et al.,) 2005. Béguin and Pastré (2002) describe the conceptual perspective of situations of simulations and debriefings (see also Pastré, 2005) which was completed by Fauquet (2007). In short, we must remember that different modalities of work exist on simulator based on the objectives sought; for example:

- initial professionalization,
- recycling,
- accidental procedures,
- development of know-how within specific sessions called “involving situation” (“mise en situation” in French).

The initial professionalization is itself decomposed in different phases: discovery and appropriation of the simulator, basic operation of the facilities, operating in situations with technical failures. This progressive approach is fundamental because it allows to place trainees in good conditions for learning: recent work showed that gradual approach for crisis simulation scenario placed most of trainers in a zone of cognitive disorder (Fauquet-Alekhine et al., 2011a & 2012).

2.6.Training session debriefing and professional practices improvemnt

To achieve these goals, analysis of practices methods are used. This enables to re-examine what is done by the team as what is not done, what have been the thrust or not, with a perspective of potential transformation. This transformation can affect the individual or the collective, but also the work organization in a non-simulated situation.

However, any situation does not necessarily imply this type of transformation. Sometimes, the collective analysis of the work activity points practices recognized as effective by all actors (operators as trainers). The added value is therefore more than a transformation, but also a conscience making contributing towards the anchoring of these professional practices.

In this type of exchange, the trainer leads the trainees to re-examine what is accepted in practice, and encourages pilots to define their personal style. It allows them to (re) become aware of what they are implementing in the work activity, and eventually make it available for others: how to better transfer to others what we are aware about?

The trainer can also lead pilots to speak on the usefulness for him to adopt such a practice. This leads them to become aware of their practices, and possibly to think about them for other situations (Fauquet, 2005a). The consciousness, individual first, broadcasts in the collective to be integrated within a professional style.

The sought effect in the session debriefing is the distancing of the pilots with their action in the simulated situation they lived. To do this, the enveloping position of trainer, distant observer in a simulated situation, is valuable assistance. This situation distancing facilitates the understanding of the pilots’ intellectual approach of the situation, individually and collectively, and must permit the re-work, i.e. allow re-thinking in order to transform. This distancing from the trainer also promotes the observation and analysis of the interaction human-process, interactions between individuals and also the individual and collective contributions (or non-

contributions) to the action in the situation. The result is a potential transformation of the actions, interactions, and contributions.

The debriefing refers to the methods of work activity analysis developed by Yves Clot (Clot et al., 1999, 2000, 2002; see also Fauquet, 2005b and 2006a; Fauquet-Alekhine & Pehuet, 2011b) and is similar by some of its aspects to the Crew Resource Managements done by airline companies.

2.7.The training session structure

Taking a simulation situation by an operating team is carried out on average on 3 days, each day that can be broken down according to the objective of the training:

- A run on the simulator and a debriefing in classroom. The briefing lasted less than 30 minutes. The "run" refers to the fact of taking the simulated situation, with a time length of 2h30 to 3h. The debriefing of meeting lasts 2h30.
- A run of 3h followed by a debriefing of 3h separated by a 30 minutes break.
- A debriefing of 3h followed by a 3h run separated by a 30 minutes break.

It must be kept in mind that a simulated situation has meaning only by combining adapted run time/debriefing time, where " adapted " implies that debriefing time should give time to discussion for what is done during the run. In other words, believing that a good simulated situation is one that favors the time of the run on simulator is an mistake.

3. Extension: studies, assessment and maintenance training

Beyond initial training, development and learning of new methods (Fauquet-Alekhine, 2011c), the simulator is a place of study (see Le Bot, 2004; Fauquet, 2004b, 2006b; Fauquet-Alekhine, 2010b; Fauquet-Alekhine et al., 2011a and 2012): when professional practices are established and anchored in the professional gender, any organizational modification or change proposed by the management may be studied and assessed prior to application. It concerns the implications of such decisions in terms of potential consequences on the key parameters such as safety, security, and production. For example, what is the influence of such additional alarm, what consequence if using such standard of communication, what added value with such technical change for the quality of the industrial operation an dfor the safety?

Training, study... and of course evaluation! Since more than ten years, the capacities of the workers trained to operate reactors are subject to initial assessment, but validation of capacities renewal is implemented only since 2005. It is a matter of capacities validation, not skills validation. It is clearly agreed in the pedagogical requirements that skills cannot be validated in simulated work situation. Validation of skills is therefore for the hierarchy of the persons concerned. On this point, it should be noted the difficulty encountered by the company to implement this system of continuous assessment: management decision has been confronted at the beginning of the Human Performance Program to a tough opposition to a certain category of personal strongly assisted by union trades. One of the lessons from this situation is that, to avoid this kind of conflict, the integration of the ongoing evaluation by the simulation must be very quickly integrated into the training organization, otherwise taken daily rehearsals can delegitimize the simulator as an assessment tool.

Progress induced by simulator training was consequent enough for the Nuclear Production Division of EDF management to recently make two major decisions, heavy from organizational and financial standpoints, but successful in terms of skills development. At the end of the 1990s, while the nuclear power plants of EDF had several simulators on less than five French sites, it was decided a new distribution and the staffing of each of the twenty French nuclear sites of a full scale operating simulator: the investment has been considerable. Then in 2006, the head management chose to expand this educational action in other professions than operating and piloting. While there were full scale mock-ups for intervention and maintenance personnel, it was decided to rig each nuclear plant of a full scale maintenance simulator in so-called "chantier école " structures: a space of more than 200 m^2 reproduces an industrial environment integrating different pieces of equipment for intervention such as ventilation, pump, valves, capacity, exchanger...with or without fictive radiation protection measures.

Quantifying the results induced by such actions is difficult because they are always part of an action plan. What can be rated is the result of all of these joint actions. To give just one indicator, since 2006, the number of automatic scram for French nuclear power plants has been reduced by more than 20%, which is considerable.

4. The advantages and disadvantages (limits)

4.1.The several-days training session

Among the benefits of training on several consecutive days, we can point:

- The existence of a time of integration from one session to another, a time of reflection. The briefing, taking place just before the simulator session is beneficial for any learning. The production of the previous session remains present in the trainees' mind and is reactivated by the trainers at this particular time. This re-actives the pilots' attention on items selected in the debriefing during the day before.
- The possibility of a progression on these days; for example:
  - D1 is to analyze a given problem according to "solving problem " method and to identify the areas for progress,
  - D2 is to try to implement what was decided in the previous debriefing.

- D3 is to work the transposition to another situation,

This time of briefing just before the run on simulator helps anchoring new practices thought during the debriefing of the day before.
From the standpoint of learning and transference in non-simulated operating situations, a several-days simulator session is a real added value.

4.2.Fast kinetic and freeze option

The simulator also allows to vary the kinetic of physical phenomena in two senses: for the dilution process that would take several hours for example, the trainer is able to accelerate the simulation to fit the scenario in time limit for a run of 3 hours; similarly, for something fast, it is possible to "freeze" the simulator, i.e. freeze the industrial process in the state so that the pilots can take the time to think about what is going on, and the consequences of their actions or their non-actions.

If the benefit of such functionality of the simulator (adjust the kinetic of phenomena) is immediately visible, it must not be forgotten the possible drawbacks this can induce. Increasing the speed of the physical phenomena does not allow pilots to work the result of slow kinetic. For example, the reality of operation induces long waiting periods during which the vigilance may diminish to the point that the installation check-up by the pilots loses efficiency: a pilot must be able to work this problem and this is not done if the simulator is accelerated. By contrast, freeze the simulator does not allow a pilot to work and try to catch up with the immediate consequences of an inappropriate action. Also, vary the kinetics of physical phenomena is not appropriate for the sessions called "involving in situation". They are adapted to the simulator sessions at technical learning phases (see section 2.5).

4.3.Transference

To help trainees, trainers follow the training evolution from one to another by a FAP system (“Fiche d’Aide à la Progression” in French), a support sheet for improvement written jointly by trainees and trainers. They are individual, given to each, and must ensure continuity of training on the simulator. For some training, a contract of collective transference is written at the end of the 3 days. This document is the property of the operating team. Trainers help in its drafting. It gathers all the important points observed during the session: good practices of the team on which they can rely in their activities on a daily basis and the work axes to improve. Must only appear on this document the facts and findings observed and recorded by the team. The team must feel free to use it or not. Some teams incorporate the contents of this document in their team project, or use this document as a specific theme on a day dedicated to the organization analysis of the team.

4.4.Physical separation

The physical separation between trainers and operating team offers several advantages: it promotes the involvement of actors in the situation, allows a dialogue between trainers without disruption or interference with the actors of the team, and encourages taking notes for the trainers.

4.5.Trainers’ background

One of the counterparts for an trainer coming from an operating or maintenance profession is that s/he can be engaged in technical discussions during the debriefing. The difficulty is then to know how to keep the distance necessary to not fall into such a trap. However, the solution cannot be the opposite, i.e. choose trainers who do not have such experience, as the job requires access to a legitimacy which will then not be acquired a priori. There is a need for the trainer not coming from the operating professions to know a minimum of the technical basis of these professions. S/He can win legitimacy by the use of techniques or methods appropriate to help actors to analyze their practices by her/his questioning. The fact that s/he is not skilled in the art of the professions gives opportunity for a relevant and productive questioning of the trainees.

4.6.Trainers’ training

When used by professionals of training, the training simulator is a remarkable tool. But as we have seen, the technological tool is effective only in connection with scenarii designed and built according to specific pedagogical objectives taking into account specific precautions. There is therefore a need of competence. Having this competence is a real strength for the organization but working without it can very quickly become a dangerous disadvantage: first risk can be the deconstruction of know-how, of collective, even the implementation of bad practices. Because even without being incompetent, trainers can generate results that escape initially until their return via undesirable event analysis.

5. Prospective conclusions

Proposing to conduct teams to work in simulated situation contributes to make work activities where practices are re-questioned, re-thought for a new individual and collective development. This point is fundamental for the management of industrial risky systems when research shows that management generally tends to migrate to areas of less secure operation than provided originally the designer. This type of migration, well described by De la Garza & Fadier (2007), can be induced, among others, by ignorance of some risks, constraints of exploitation and production, and a tolerance of the organization to accept exceeding certain limits (the normalization of deviation suggested by Vaughan, 1996 and 2005). Situation on simulator allows to re-examine the relevance of the terms of actions implemented by the actors in such a socio-technical system.

However, the operator faces a problem of investment, because the simulators, technical objects driven by calculator, are very expensive to purchase and to maintain. Technological developments are yet to reduce this cost and open new perspectives. Some developers

have designed hybrid systems that combine the pilots' work environment (real size control panels) and virtual image (the panel do not have any actual button but is itself a large on-touch LCD screen that duplicates the buttons and configurable indicators by simple contact on the screen). In parallel the Serious Games are developed which immerses the trainee in a completely virtual world representing the most closely as possible the reality of exploitation, or, on the contrary, presenting a definitely decontextualized environment. The cost reduction is considerable because there remains only the calculator of the simulator, the technical object becoming obsolete. The question which must be asked is what is lost with such systems from the point of view of the integration of the know-how, because professional practice is not incorporated anymore in the same way (Fauquet-Alekhine, 2011c). This field remains to be explored.

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