Fukushima Daiichi Nuclear Accident Context Research-in-Depth

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1. Demarcation Lines between HRA and HF

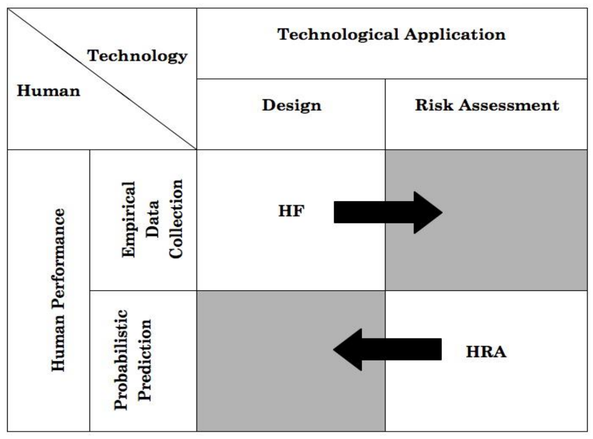
1.1. Theory vs. Practice

Dr. Alan Swain: *The any HRA practitioner has to take into account and adapt the Human, Organization and Technology (HOT) theory but not to wait for the theorists to prepare or regulators to suggest the universal and appropriate HRA method. The theorists may stay on "the height of their belfry" and continue building into their preferable topics and competences without any succeeding to combine them in appropriate HRA.*

- A mechanism for direct extraction of human-machine system (**HMS**) global properties and factors is not discovered yet.
- Theoretical and experimental covering of mental processes is not sufficient.
- Current HRA implementation is limited by the scope of performance shaping factors (**PSF**) for which predictions are available.
- Psychometricans seek to develop mathematical theory of *systems with partial order of the process and sub-processes* but not with *holographic-like behavior* as **contex**t, e.g. accident context.

1.2. Different Research Approaches

- **HF** maintains a strong empirical observation, collection data to generate design improvements
- **HRA** not to be tied closely to the collection of empirical data
- **HF** tended not to predict HEP, relying instead on the findings from specific empirical observations
- **HRA** relies on process expertise to identify HOT problems by human error probability (HEP) quantification



There is nothing to preclude a merger, or at least a convergence, of these two research approaches (PSAM11_16-Th3-5_-_Boring.pdf).

1.3. Dynamic and Statistic Human Action Context Definition

A context description of given situation has to reflect **dynamically**, all specific information for the mind and environment before and after initiating event. This description of the **ensemble of HMS states and/or context factors** must be sufficiently general for the HOT factors of specific control area.

2. HRA Method: Performance Evaluation of Teamwork (PET)

2.1. PET Context Quantification Concepts

The PET method quantifies of context as a probability
Context as ***a statistical measure of the degree of the HMS state randomness*** defined by the number of accessible states taking place in ensemble
The context is a function of time **"on a second-by-second basis"** [**Hollnagel**].

Combinatorial Context Model

The CCM is based on the concept of ***human performance shifts*** in operator's mental model, i. e. on the assumption that the 'context' rate in any situation is proportional to the deviation of the subjective image of past & future from the objective one.

Context Factors and Conditions (CFC)

In the **PAST**, the ***human performance shift*** is between **objective** (*occurred in fact*) & **subjective** (*considered to have occurred by human*): **scenario events (E)**, **safety functions (F)**, **upset trends (UT)** of parameters.
In the **FUTURE** we deal with differences between **objective** (*real*) & **subjective** (*recognized by human*): **safety goals (G)**, such as end states, **transfers (T)**, **human actions (HA)**, etc.

Human Erroneous Actions and Violation Definitions
Violation of Objective Kerbs Method

Qualitative (by Dr. Reason)

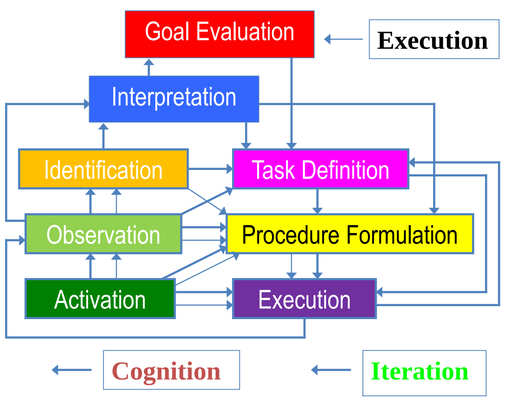
HEA: '*all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome*'
Violation:*'aberrant action' (literally 'straying from the path'…)'*

Quantitative (by VOK)

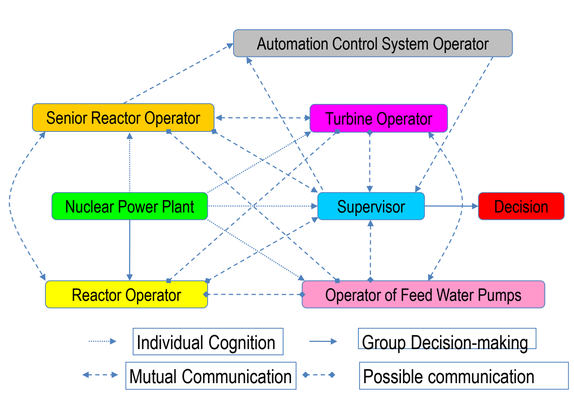
Cognitive [executive] error is probable when $\varphi^{C}_{si}(t) \neq \varphi^{C}_{oi}(t)$ [$\varphi^{E}_{si}(t) \neq \varphi^{E}_{oi}(t)$].
Violation occurs when the objective image of factor ***i*** is changed from $\varphi^{1}_{oi}(t)$ to $\varphi^{2}_{oi}(t)$.

2.2. PET Cognition and Communication Models

Step-Ladder Model



Crew Communication Model



2.3. PET Straightforward Procedure for HEP Quantification

1. *Determination of HMS outer parameters (CFC)* - φ_k, k=1…K.
2. *Determination of initial & boundary conditions* of **cognition/communication**:
   - initial - $\varphi_{sk}(\varphi_{s2k})$ and final $\varphi_{1ok}(\varphi_{s1k})$, *non-violated*, and $\varphi_{2ok}(\varphi_{s2k})$, *violated* values of contextual parameters.
3. *Determination of context deviations:* $|\varphi_{ok}-\varphi_{sk}|=\Delta\varphi_k$ ($|\varphi_{s2k}-\varphi_{s1k}|=\Delta\varphi_k$)
4. *Enumeration of accessible states,* for all C_i, (i=1…Ω):

$$C_i = (\Delta\varphi_1,\ldots,\Delta\varphi_k,\ldots,\Delta\varphi_K)_i$$

5. *Calculation of probabilities – **Context Quantification Formula**.*

$$C(t) = 1 - \frac{\prod_{n=1}^{N}\left[\phi_{sn}(t)+1\right]}{\prod_{n=1}^{N}\left[\phi_{2on}(t)+1\right]} = 1 - \frac{\prod_{n=1}^{N}\left[\phi_{sn}(t)+1\right]}{\prod_{n=1}^{N}\left[\phi_{1on}(t)+1+\Delta_n\right]} = \frac{\prod_{n=1}^{N}\left[\phi_{1on}(t)+1+\Delta_n\right] - \prod_{n=1}^{N}\left[\phi_{sn}(t)+1\right]}{\prod_{n=1}^{N}\left[\phi_{1on}(t)+1+\Delta_n\right]}$$

6. *Determination of communication context.*
7. *Calculation of individual cognitive error probability* - **Step-Ladder Model**.
8. *Calculation of team cognitive error probability* - **Crew Communication Model**.

3. HRA Research-in-Depth in Retrospective Accident Study

The PET context quantification makes HRA researchers suspicious because this approach is practically 'empty' from psychological point of view (HOT factors are presented indirectly). They think that it is an obstacle for thorough investigation of each PSF/HOT factors.
The holographic approach gives more real perspectives for HRA research-in-depth and understanding the role of each HOT factor in accident context.

3.1. Retrospective HRA in Emergency Situation

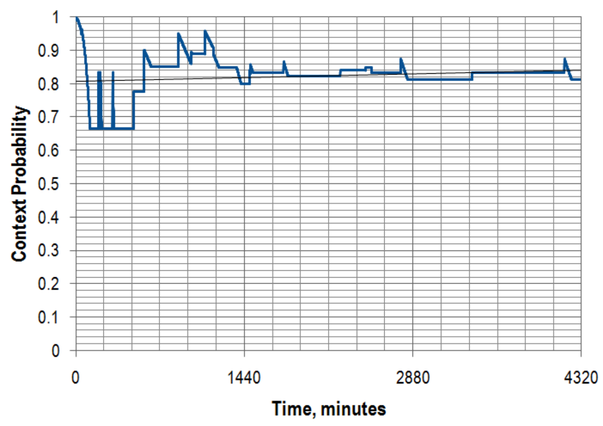
The aim of a retrospective accident study is to build up a path of probable cause-effect relationships by working backwards from the observed effects.
The retrospective HRA in emergency situation is connected with the questions:

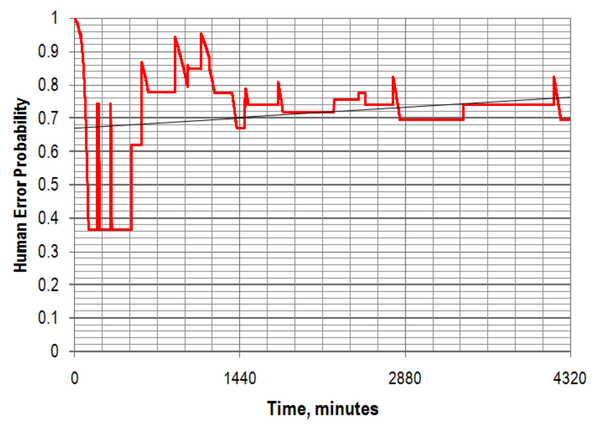
- What is to be explained?
- When, where, how and why did the failures occur?

Regardless of the place, moment and agent, the performed human erroneous action (HEA) could be divided into three basic types that determine the reliability of human performance: violation/circumvention, cognitive/decision-making error and executive error.

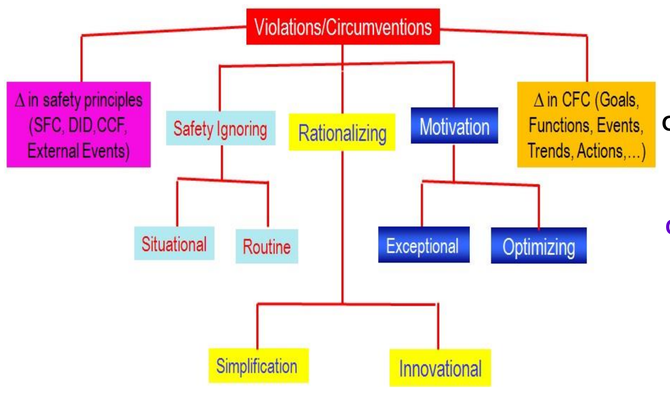
3.2. Retrospective HRA of the Fukushima Daiichi Nuclear Accident

min	JTC outset	Violations - Context Factors and Conditions
0÷T	11.03-14:46	**V1-T**: The circuit breakers and disconnectors in switchyard were damaged by earthquake because the Fukushima Dai-ichi NPS is designed for magnitude 8.2 (Tohoku earthquake with magnitude 8.9)
56÷T	11.03-15:42	**V2-T**: DG on a basement submerged by Tsunami because the Fukushima NPS designed for 6.51m - total station black-out for Units 1-6 up to March 18th
494'÷T d	11.03-23:00	**V3-E**: Doses increased in turbine building - potential leaks via steam lines (MSIVs, SDS-C, stop valves, etc.)
584'÷1174'	12.03-00:30	**V4-F2**: Decay heat is being removed only through isolated condenser. Assumed to be inefficient after 00:30 JTC 12 March due to tanks depletion
584'÷2529'	12.03-00:30	**V5-F4**: Possibility of 600kPa in CV dry well (Design basis: 427 kPa)
984÷1372'	12.03-07:10	**V6-UT**: Reactor level was 0 mm and continued to drop
1490÷ Td	12.03-15:36	**V7-UT**: Hydrogen Explosion

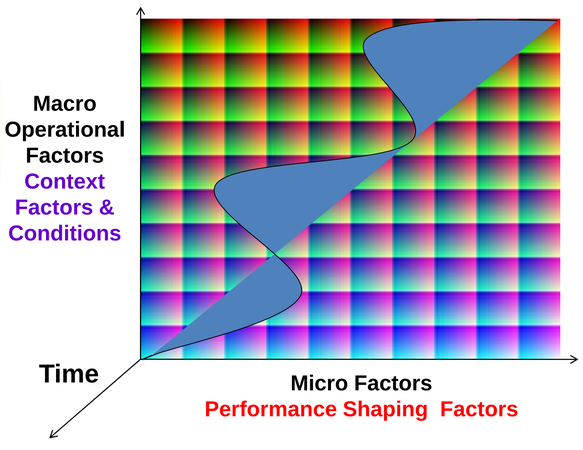




General Classification of Violations



HEP Objective Context Image



4. Conclusion

The risk resonance context based on combination between external hazards, equipment failures and violations has to be monitored and analyzed.
All macro factors (violations and CFC) should be investigated based on relevant micro factors (PSF, HOT factors, HF).

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