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Evaluation of Communication and Decision-making Erroneous Actions Based on Dynamic Accident and Hazard Event Context Quantification

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Disaster Occurrence

- The disaster could be represented as a combination of natural, technological, organizational, mental and physical processes.
- An unbalanced representation of each process can result in:
 - incorrect interpretation of the processes' dynamics
 - incomplete explanation of information
 - imperfect knowledge
 - inability to manage and predict disasters.



External Event Probabilistic Risk Assessment

- Unsafe system states in internal and external event or hazard conditions are reached as a combination of
 - external hazards (earthquake, flood, fire, hurricane, tsunami etc.)
 - hardware failures
 - omissions of required actions
 - commission of unrelated actions



Human Erroneous Actions

- The identification and treatment of significant Human Erroneous Actions (HEA) are of particular importance during both IE and EE.
 - **Violation (Circumvention)**
 - **Cognition error**
 - **Response execution error**
 - **Communication error and**
 - **Decision-making error.**
- Individual processes
- Group processes



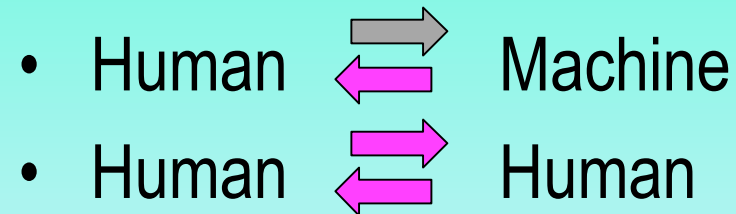
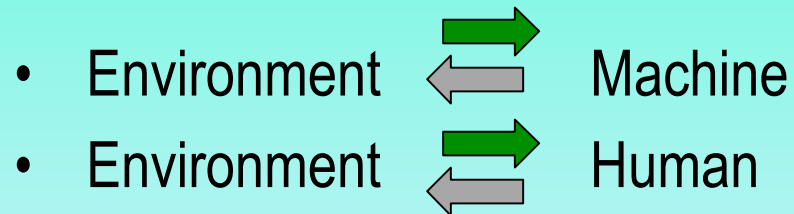
'Second-generation' HRA Method

- A 'second-generation' HRA method has to evaluate the HEA probabilities based on dynamic accident and hazard event context determination
- *Performance Evaluation of Teamwork* (PET) method correlates context and time on a firm probabilistic basis by checking current situation and ensuring that the outcome reflects all temporary and permanent influence factors
- The PET aims at obtaining human error probability (HEP) - individual and crew HEPs



Performance Evaluation of Teamwork

- PET method quantifies context by accounting for all system's accessible states & its subsystems



- PET method uses speeds of their processes for dynamic representation of context probabilities

- **Natural**

- **Technological**

- **Mental**

- **Physical**



Time Response Curves

- The HRA methods try to adjust Time Response Curves (TRC) and results of these simulation-based studies
- They are not applied sufficiently for HRA/PRA purposes due to the fact that TRC is 'virtually impervious to context'
- The speeds of natural, technological, mental and physical processes are determined based on TRCs
- The PET method provides an alternative for integration of TRC into context quantification for dynamic HRA.

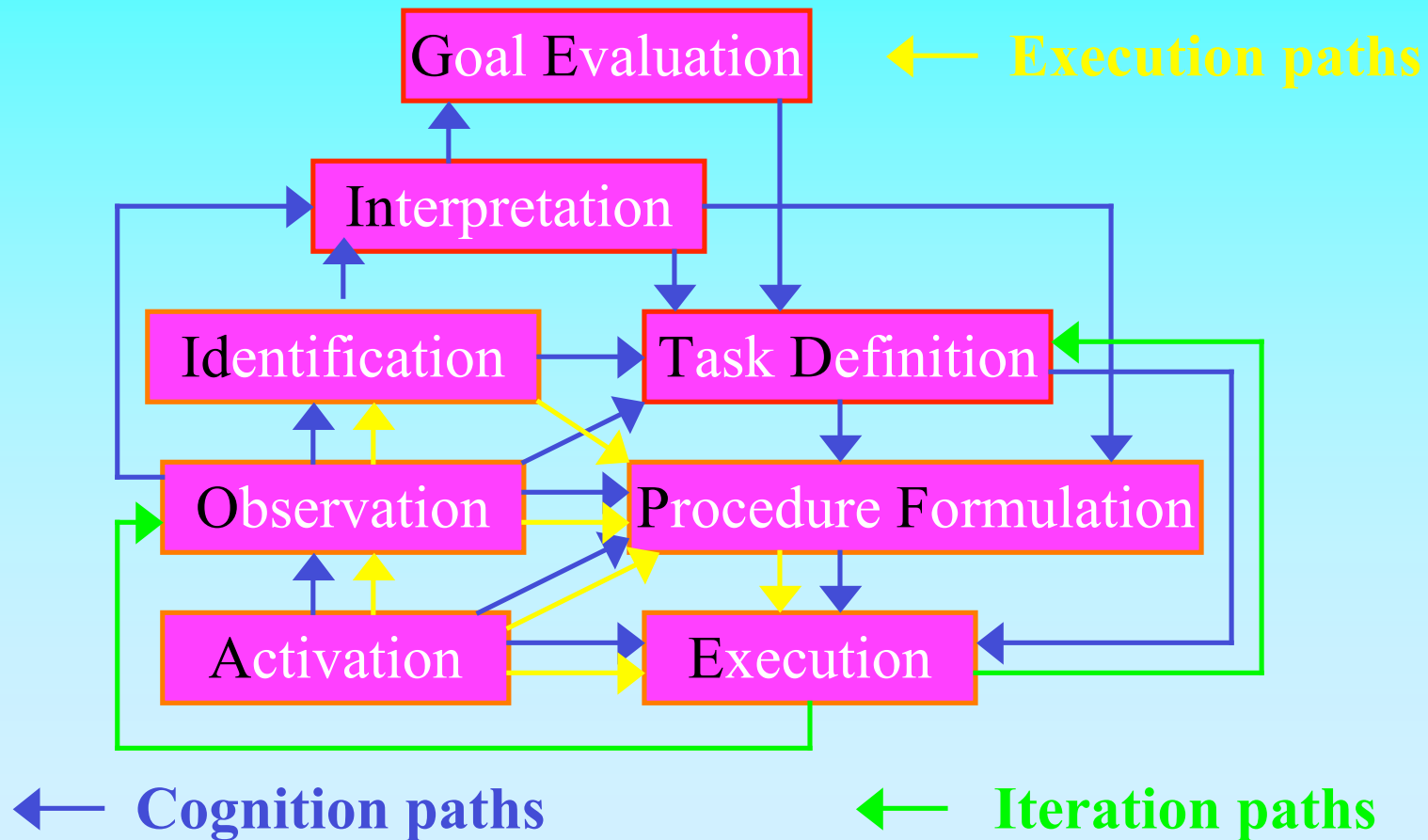


PET Models and Quantifications

- **Context Factors & Conditions – CFC**, used for context quantifications:
 - 1) **Goals**, 2) **Transfers**, 3) **Safety Functions**, 4) **Trends of Parameters**, 5) **Scenario Events** and 6) **Human Actions**.
 - “Second-by-second” context quantification of individual cognition and team communication by consecutive application of the ‘**Violation of Objective Kerbs**’ method in **Combinatorial Context Model**,
 - Cognitive error probability (CEP) quantification of individual cognitive process by the **Rasmussen’s ATRD* Step-Ladder Model**
 - The group decision-making is a superstructure of individual cognition
 - CEP quantification of group decision-making process by the **ATRD* Group Communication Model**
 - The leadership reliability model is not constructed yet.
- * **ATRD** - Analysis of Topological Reliability of Digraphs method

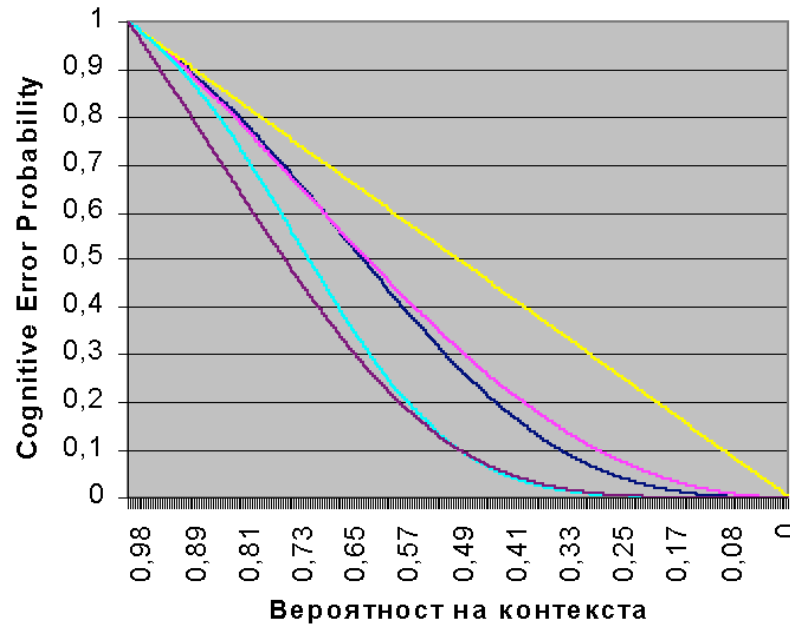


Rasmussen's ATRD Step-Ladder Model

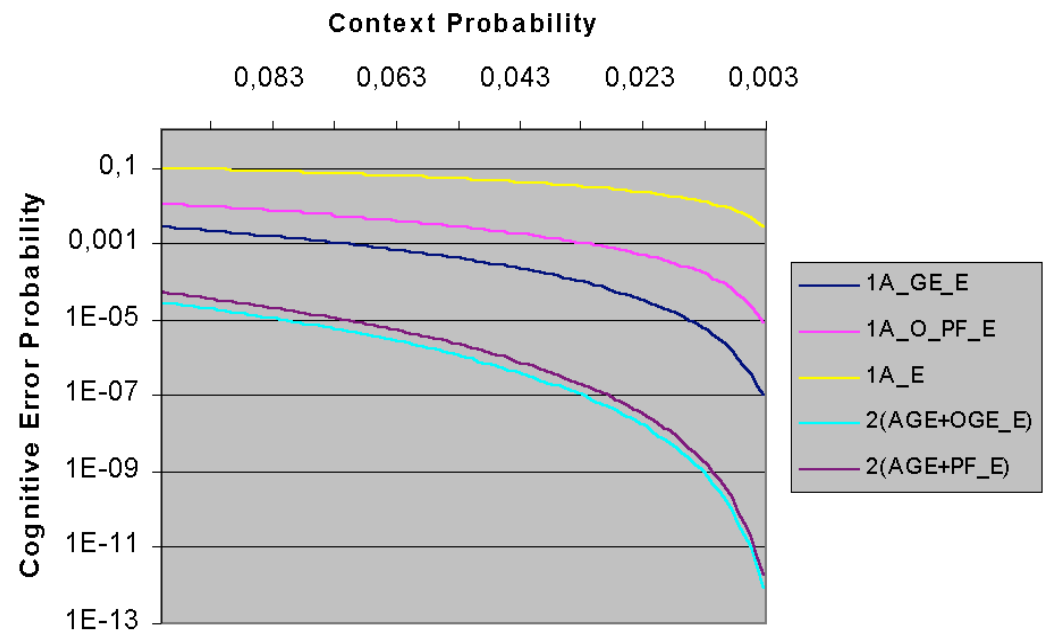




ATRD Step-Ladder Model Results



Smaller Context Probabilities



Bigger Context Probabilities

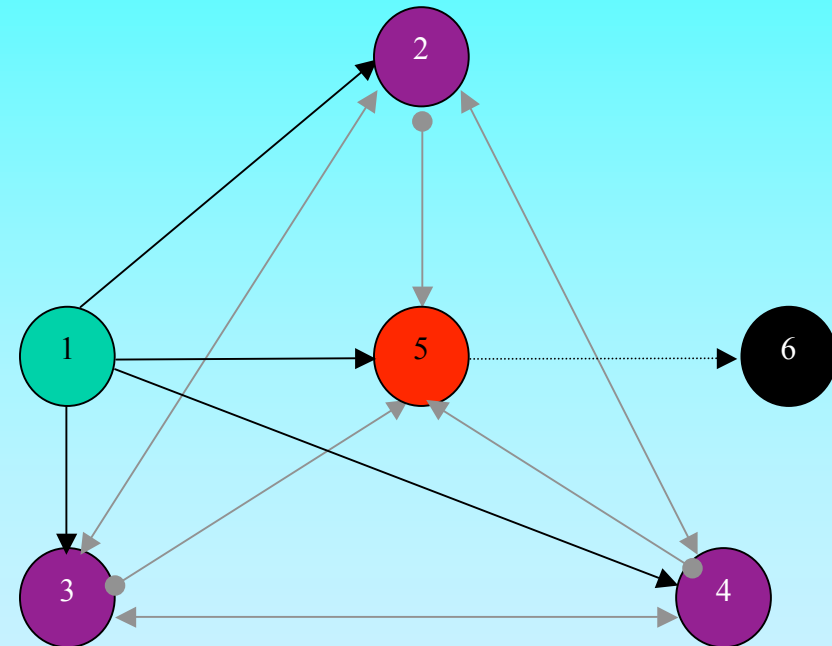


ATRD Group Decision-making Model

4-Group Communication Reliability Model

Legend:

- 1 - Environment
- 2 – First Operator
- 3 - Second Operator
- 4 – Third Operator
- 5 – Single Decision-maker
- 6 – Decision



Note: The links between decision-maker and operators are not relevant to the reliability of one-step decision-making process (**information pouring**).



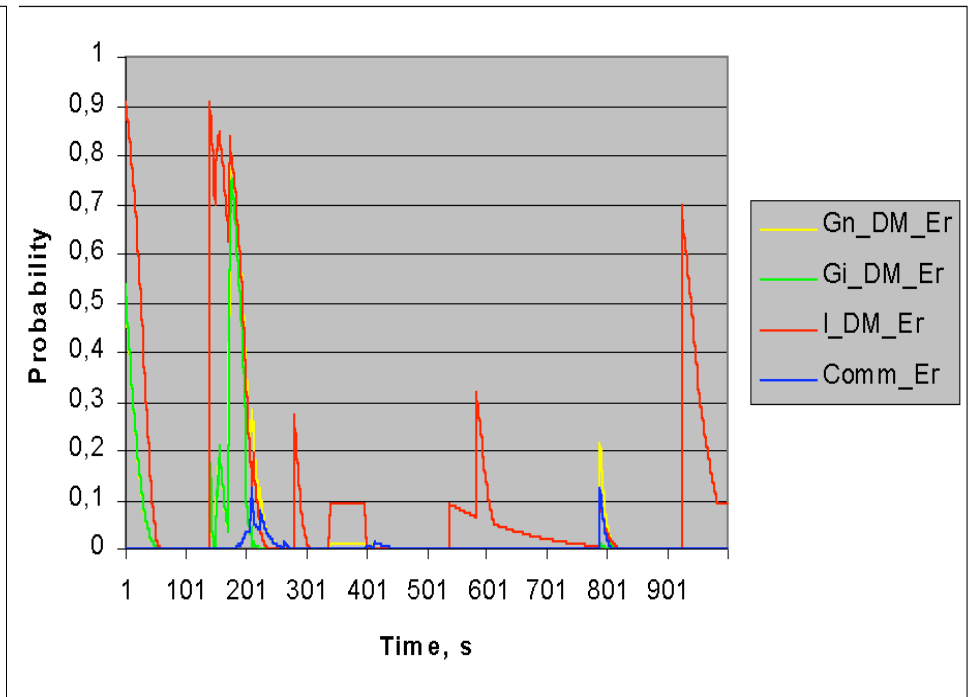
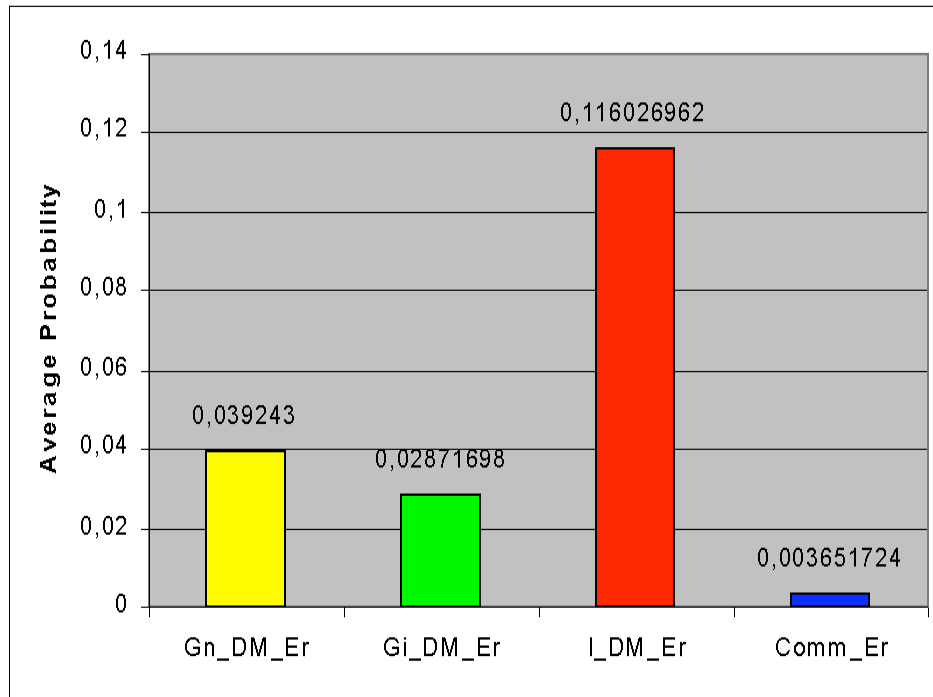
PET Criteria for HEA

- The PET erroneous action of **cognition** or **response execution** is probable when the subjective image of $CFC_n(t)$ is different from the objective image of $CFC_n(t)$ [Cognitive Error Probability (CEP) & Executive Error Probability (EEP)]
- The PET **violation** occurs when the objective image of CFC_n is changed from $CFC_n(t)$ to $CFC_n^v(t)$ for of any reason
- The erroneous **decision-making** probability is the crew CEP
- The probability of **communication** error could be calculated as a difference between individual CEP of decision-maker and the crew CEP



PET Results for Internal Event 'Steam Generator Tube Rupture' Training Scenario

Average & Dynamic Group (with natural and initiated communication), Individual Decision-Making and Communication Error Probability (Case with Violations)








Simulator Applicability for EE HRA

- The simulated technological system can be manipulated outside - close to its design limits;
- Rare events can be replicated and repeated at will;
- The objective and subjective data about plant, individual operator and crew could be collected;
- Simulators are sensitive to dynamic impacts on plant equipment, technological processes and personnel.



Study of Operators' Actions During External Event by Simulator

-  How does simulator model the influence of an external hazard on technological processes?
-  How does simulator model the consequences of external event on human mental, psychological and physiological processes?
-  To what degree do simulator limitations reduce the possibility for external events modeling and spread uncertainty in human performance evaluation?



Subjective vs. Objective Reality

- The simulator training is a complex exercise that imitates reality, but never repeats it.
- Even when a scenario with really occurred sequence of events and operator actions is played, considerable differences between real and simulator operator's behaviors are observed.
- The differences are due to deviations in **subjective** operators' perception (**face fidelity**) and **objective** simulator reproduction (**simulator accuracy**) of reality.
- These deviations are more obvious in external impact scenario rather than in internal events.



PET Experimental Design for Modelling EE Simulator Training Scenarios

- On the FSS by retrospective PET/HRA to collect database about relations in normal operation, IEI and EE accident scenarios between CFC_i , CP_i and measured stress (S_i)
- On the real plant by retrospective PET/HRA to collect data in normal operation and any accident conditions (IE and EE) and to quantify CP_j (CFC_j) and to measure the stress (S_j)
- On the FSS by variation of CFC to match the same context CP_j (CFC_j) as on the real unit and to measure the stress (S_k)
- Any error probability (EP_p) of prospective HRA could be extrapolated based on its retrospective value (EP_r) as

$$EP_p = EP_r \cdot (S_j/S_k)$$



Conclusions 1

- Currently applied HRA techniques use general team context that is static, specific for each HEA in accident and based on expert opinion. The results authenticity and treatment of such approach are questionable.
- The PET method strives to overcome these drawbacks by dynamic and individual evaluation of context & error probabilities.
- Comparison of individual and group decision-making results demonstrates the advantage of teamwork. The crew could compensate for individual errors and violations.
- Initiated communication (required by procedures and accident plans), together with the natural one, reduces crew communication and decision-making error probabilities in internal and external accident events and hazardous conditions.



Conclusions 2

- The use of full-scope simulator data for the internal and external event PRA/HRA could be preferable or not. The results can be subject to comparison or choice discussion.
- At any rate, it is obvious that the simulators are the best place for inventing, testing and refining the post-accident HRA methods.
- If any HRA technique is not applicable for simulator exercise explanation, it is quite unbelievable that it would be applicable for HRA in general.