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Symptom-Based Approach for Dynamic HRA & Risk Management through Holistic Context Evaluation

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Introduction

- HRA is an applied hybrid science on the frontier between PSA, Reliability & Resilience Analyses, HF, DSA, Complex System Simulation, Cognitive Systems Engineering, Psychometrics, Psychology, Ergonomics, Neuroscience …
- HRA is trying to apply what is known from sciences to reflect interactions & interferences within **Socio-Technical System (STS)**, to assess HFE HEP, design & construct fault-tolerant & resilient interactions between

  Human-**Technology**-**Organization**-**Environment** **(HTOE)**.
- HRA is related to PRA that includes at least two quantities:
  - ***severity*** of possible adverse consequence(s),
  - ***probability*** of occurrence of each consequence and
  - *utility*, *casual scenario*, *group of population*,…

HRA thesis, ‘antithesis’ & synthesis

- The scenario's severity is taking into account by expert judgment (guessing) through multiplication of PSFs.
- THERP method gives the **"thesis"** or the aim of *"first generation"* HRA methods: ***to obtain a HEP of identified HFE by reasoning & weighting of internal & external holistic PSFs***.
- HA may be distinguished in two sequential stages – Cognitive (Diagnosis or Decision-making) & Executive (Manual or Response)
  - The *“**unfinished business related to HRA**, which includes identification, specification and fitting of **human cognition model** to define the error potential and context”* of HA (Dougherty, 1993).
  - Hollnagel (1993): the detailed knowledge of HA objective context & its subjective image which exists in human mind is a basis for understanding of **HA in dynamics** *"on a second-by-second basis"*
  - This ***temporal approach*** used in THERP, e.g. Swain's TRC or its ‘improved’ version called the HCR Correlation are **“virtually impervious to context”** (Dougherty, 1993).

HRA thesis, ‘antithesis’ & synthesis

- Dougherty comes up with the idea the change the "first generation“ HRA models such as THERP and HCR with the “second generation” HRA models (1990).
- The **"antithesis"** or the aim of "second generation" HRA methods was *to take into account HA context with its specifics, severity, multidimensional dynamics & holistic PSFs for any individual, group mental/manual response.*
- The most of "first generation" HRA methods made a formalistic substitution of the *THERP's holistic PSFs* or their modifications, with *“contextual factors”* - it does not substantially alter HRA's outcomes.
  - This substitution exemplifies the Dougherty’s observation (1993) & insight of that “the influential and contextual approaches may find themselves **indistinguishable** at the quantification stage because of the paucity of actual data.”

HRA contentions & challenges

- HRA community is discussing & substantiating some contentions & challenges:
- **Description of HA in context**: CREAM, MERMOS, ATHEANA
- **2nd generation HRA**: shift the problem from *quantification of the operator behavior* to the *quantification of the error-forcing context* (CREAM, MERMOS, ATHEANA);
- **Error'** *identification, quantification* (CREAM, MERMOS, ATHEANA) & *reduction* (CREAM);
- **HA Dynamics**: Accident context is a function of time *"on a second-by-second basis"* (not implemented in CREAM); individual dynamics of situation (not implemented in MERMOS);
- **Variability of performance** is *more important than how actions can fail* (not implemented in CREAM)*; some combination between performance-related effects* (MERMOS); *context as a collection of weighted PSFs* (implemented in SLIM by domain expert judgments);
- A structural rather than a functional viewpoint (not implemented in CREAM);
- **Human performance limiting values (HPLV)** (MERMOS);
- **HA Specifics:** The response-related model is necessary (not implemented in MERMOS);
- **Crew**: Context could be different for each crew member (not implemented in MERMOS);
- **Systematic search process** by lists of HFEs, Unsafe Acts & *error-forcing contexts;*

  to identify erroneous actions based on the accident context & **not to** *"subsume the errors identified with the event sequence mostly by historical means"* (ATHEANA).

HRA thesis, ‘antithesis’ & synthesis

- Some of HRA concepts are indisputable, others are result of inertia in group thinking, misinterpretation, judgment biases & business interests.
- To overcome the above challenges with subjective judgment of PSFs, holistic & dynamic human performance in STS, HFE identification, quantification, reduction, data-mining & measuring, a realistic ***symptom-based approach*** to describe of the STS context was proposed (1998).
- The STS holistic/macroscopic context quantification procedure is the first step of a ***Performance Evaluation of Teamwork (PET)*** method that modeling above valuable features for accident analysis in PSA & DSA.
- It relies on combinations of recognizable symptoms for statistical description of the variability of STS performance and gives controllable macro structures of mental processes as cognition and communication.
- **HRA “synthesis“**: *to obtain a HEP of identified HFE in the STS context based on its holistic specific symptoms’ recognition, severity & dynamics for any individual, group mental/manual response. A symptom’s impact is reasoned, measured & weighted by internal & external “glocal” PSFs for it.*

Approaches, explored, unexplored processes & extended definitions

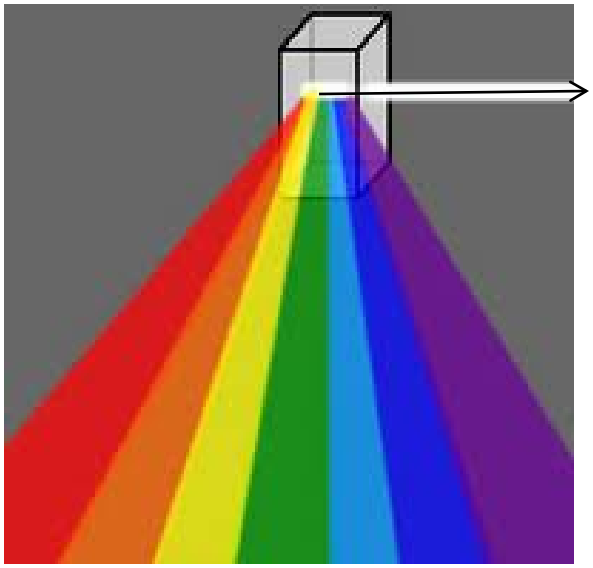
1. Person vs. **System approach** for human error modeling & management
2. PSFs-based vs. **Symptom-based approach** for STS variability description
   - Symptom-based approach in nuclear accident management
   - **Statistical entropy description** of STS
   - Practicality of symptom-based STS description
   - Theoretical issues from **explored** & **unexplored mental processes**
   - Extended definition: STS**Dynamic context**
   - Extended definition: STS **Violated Image of Symptom**

System approach to human errors

- There are two approaches to human errors - the **person approach** and the **system approach**.
  - The first approach focuses on *“the contribution of human errors on the system, their own psychological justification, accusations of forgetfulness, inattention, or moral weakness"* (Reason, 2000).
  - The second approach focuses on *the conditions, situations and context in which a person deliberately and conscientiously performs his/her actions to effectively manage the system and limit the consequences of the risk of its operation*. An extreme statement is **"Human error is never the root cause.“**
- The system approach is preferable and practical for context-based HRA.
  - It isn’t important **"who blundered, but how & why the defences failed.”**
- Human performance needs to be considered as a variability of a whole STS where human interacts with technology, other humans, organizations & environment (**Human error ≡ STS error**).

Decomposition in HRA:
Psychologist's vs. Operator's Point of View

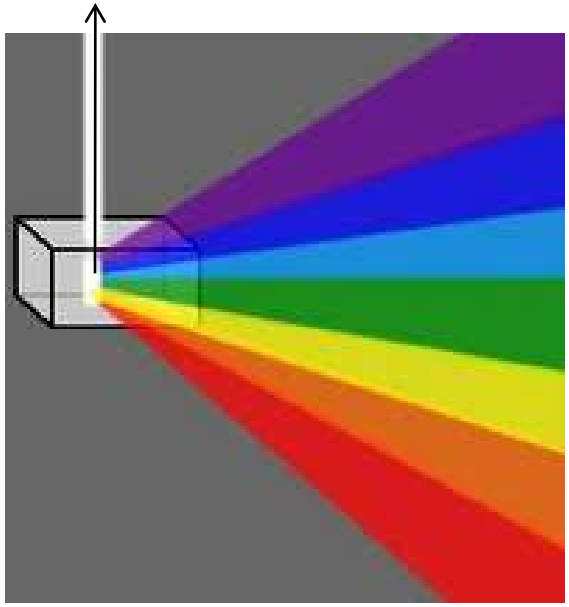
The HRA experience showed that often the approach to the study of HAs & HFEs is unilateral and biased, e.g. psychologists & engineers.



Psychological Factors (PSFs)

Human Action Context

Symptoms (CFCs)



Goal
Event
Action
Function
Parameter
Transition
Resource

Violation of **I**mage of **S**ymptom

Symptom-based approach in nuclear accident management

- The symptom-based approach is now usual in nuclear accident management.
- The IAEA NS-R-2 (2000) establishes the following requirements on accident management: *"The training of operating personnel shall ensure their familiarity with the symptoms of accidents beyond the design basis and with the procedures for accident management."*
- Later in IAEA SRS No. 48 (2006) **"symptom/state based procedures"** were justified.
- In IAEA NS-G-2.15 (2009) a **'symptom-based approach'** was also recommended: *"2.14. The approach in accident management should be based on directly measurable plant parameters or parameters derived from these by simple calculations.“*

Statistical entropy description of STS

- The STS dynamic interactions are manifested by interference of symptoms (stimuli with meaning for operator) & the system context could be presented by them on the macro level. If we want to understand the root causes of human errors, we should searched in depth at micro level.
- Macroscopic statistical description of the STS context would help to identify the dynamic and holistic nature of the system's behavior.
- **The basic idea** of the distinction between macro- and microscopic levels is **to change the set of microscopic accessible states with equivalent subsets of macroscopic states** (*bit states*). A certain macroscopic state can be found in many microscopic accessible states.
- This idea follows the ***Shannon theorem (1948) regarding the entropy as the measure of information***, and was the basis for the used, in the *Performance Evaluation of Teamwork* method, ***an analogy of energy and information***. The mental process in the STS is described at each moment by its *microstates* (*quantum states*). This is a specific *quantum state* that represents the most detailed possible STS description.

Practicality of symptom-based STS description and explored models

- As the context characterization and analysis in the HRA is implemented with the assistance of the staff, then it is more practical and natural, firstly, to describe STS context in symptoms used by staff.
- Recognizing each symptom by operator is a mental process involving individual cognition, communication between the group of operators, decision-making, checking and recovery.
- Each symptom has its specific **symptom-influencing factors** (SIFs) that essentially coincide with the used holistic PSFs in HRA.
- If all the symptoms into a given scenario are described with a common PSF then it leads to blur the specific PSF influence on a given symptom, masks the dependencies between the PSFs & increases the results uncertainty.

Theoretical issues and limitations from unexplored mental processes

- Townsend & Schweickert emphasize the need for a theory for connection of *holographic-like behavior*, *separation of selective & non-selective influence*:
  - "***Systems based entirely on holographic-like behavior*** **without any communication among separated processes, are omitted"**
  - *"The selective influence postulate is critical"*.
  - The "empirical tests of selective influence ***separation of selective*** **from** ***non-selective systems*** will likely be tied closely to".
  - *"Factors that influence* **not only durations** but also *outputs of processes* have not been investigated."
  - *"The expectation* (the mean) *of a sum of random variables is equal to the sum of the expectations, which is true for any set of random variables whether or not they are independent*."
- If systems with holographic-like behavior are omitted from exploration of mental processes then <u>the holistic PSFs-based approach for STS context quantification is very questionable!</u>
- In symptom-based approach every symptom is recognized separately & context quantification is based on enumeration of STS accessible states.

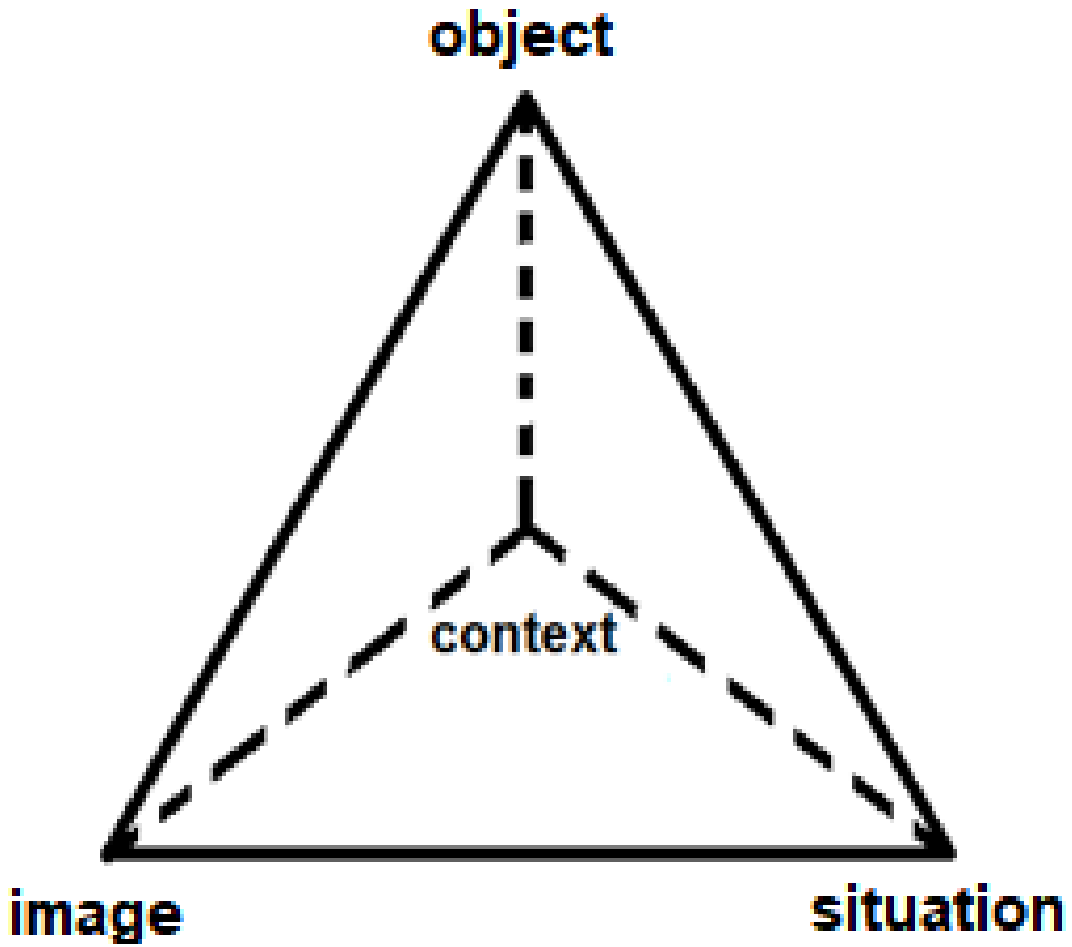
Extended dynamic STS context definition
Additional concepts

- Petkov & Furuta (1998) have proposed a heuristic concept of ***Context Factors and Conditions (CFCs)*** as quantitative factors to indicate *"how symptoms (CFCs) influence context"* in order to study their effects on human performance - *"how context influences actions"* during the accident.
- As well as they consider the context to be a function of time and second argument of the HEP function, while first argument of the HEP is time, i.e. ***HEP=f(context, time)*.**
- Petkov & Groudev (1999) proposed an indirect similarity between material (***"transition temperature shifts"***) and mental processes (***"human performance shifts"***) to measure dynamic deviations of CFCs. The dynamic interactions or *"STS performance shifts"* represent the **dynamic STS context** or dynamic processes in human-technology-organization-environment.
- Matching the object in **situation** is an approximation that could be identified and described as an ***"image"*** or as a ***"signature"*** (Wisse, 2001) of the object in the situation. The concept *"image"* is the imprint of the consciousness and sub-consciousness of the *"human performance shifts"* that affect the person's physical, physiological, psychological and psychosocial ability to make sense, perceive the ***object (STS)*** and to perform action in the STS context.

Extended dynamic STS context definition
General and practical definitions

- Context is defined by psychologists as ***"a state of mind"*** or "*a set of internal or mental representations & operations rather than a set of external elements*".
- In (Petkov, 2004) the context definition was extended as ***"a common state of universe, mind and situation in their relation" – object-image-situation*** .
- In (Petkov, 1999), the term ***"context probability" (CP)*** was coined as **a measure for severity magnitude of error-forcing context.** But this general definition of context is not so practical to be a measure.
- The practical definition of context is: ***a statistical measure of the degree of the STS state randomness defined by the number of accessible states taking place in the STSs' ensemble*.**
- Since the man analyses and operates the machine most frequently by discrete actions, the combination (number, value & tendency) of symptoms (stimuli with meanings), which she/he manages to distinguish, is of greatest importance to him.
- As a measure for symptoms' influence the relative deviation of symptom image is proposed: $\Delta\phi/\phi_o = |\phi_o - \phi_s| / \phi_o$, where the indices denote the two types of values under interest (o – objective, s - subjective; ϕ - denotes image).

Object-Image-Situation Context Representation



Qualitative and Quantitative Definitions of STS Error & Violated Image of Symptom

- In order to demonstrate the crucial impact of violations ("circumventions" is used in USA) on the post-accident context, a Violation of Objective Kerbs (VOK) method was also proposed there to account for the probability of aberrant circumstances (prior to or during the initiating event) in cognitive process. The Reason's *qualitative definitions* (1994) of error & violation are:
- ***Errors*** *are "all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome";*
- ***Violations,*** *circumventions, mask or bypass of some conditions are 'aberrant actions.' or* the act or an instance of symptom or condition of being violated; to go around, mask or bypass some conditions.
- the following *quantitative definitions* were proposed for the context quantification purposes:
- ***Errors*** *is probable when the differences between objective & subjective images of context symptom is not zero,* $\phi_{sn}(t) \neq \phi_{on}(t)$*, where zero-context is* $|\phi_{on}(t) - \phi_{sn}(t)| \rightarrow 0/min.$
- ***Violated Image of Symptom (VIS)*** *occurs when the objective image of context symptom* ϕ_n *is changed from* $\phi^1_{on}(t)$ *to* $\phi^2_{on}(t)$ *due to any reason.*

Explanation of extended definition of STS Violated Image of Symptom (1)

- It should be emphasized that the quantitative definitions of error and violation of image of symptom thus formulated are dealt with not only in human performance context, but in the context of the whole STS.
- *Therefore, they have not only a wider, but also more different meaning than definitions of error and violation of Reason.*
- For example, Reason (2000) defines *"procedural violations"* as **an active failures** that *"have a direct and usually short-lived impact on the integrity of defenses."*
- In Reason (2000), the strategic decisions are *"made by designers, builders, procedure writers, and top level management"* refer to **latent conditions** that *"can create longlasting holes or weaknesses in the defenses"* and *"may lie dormant within the system for many years before they combine with active failures and local triggers to create an accident opportunity."*

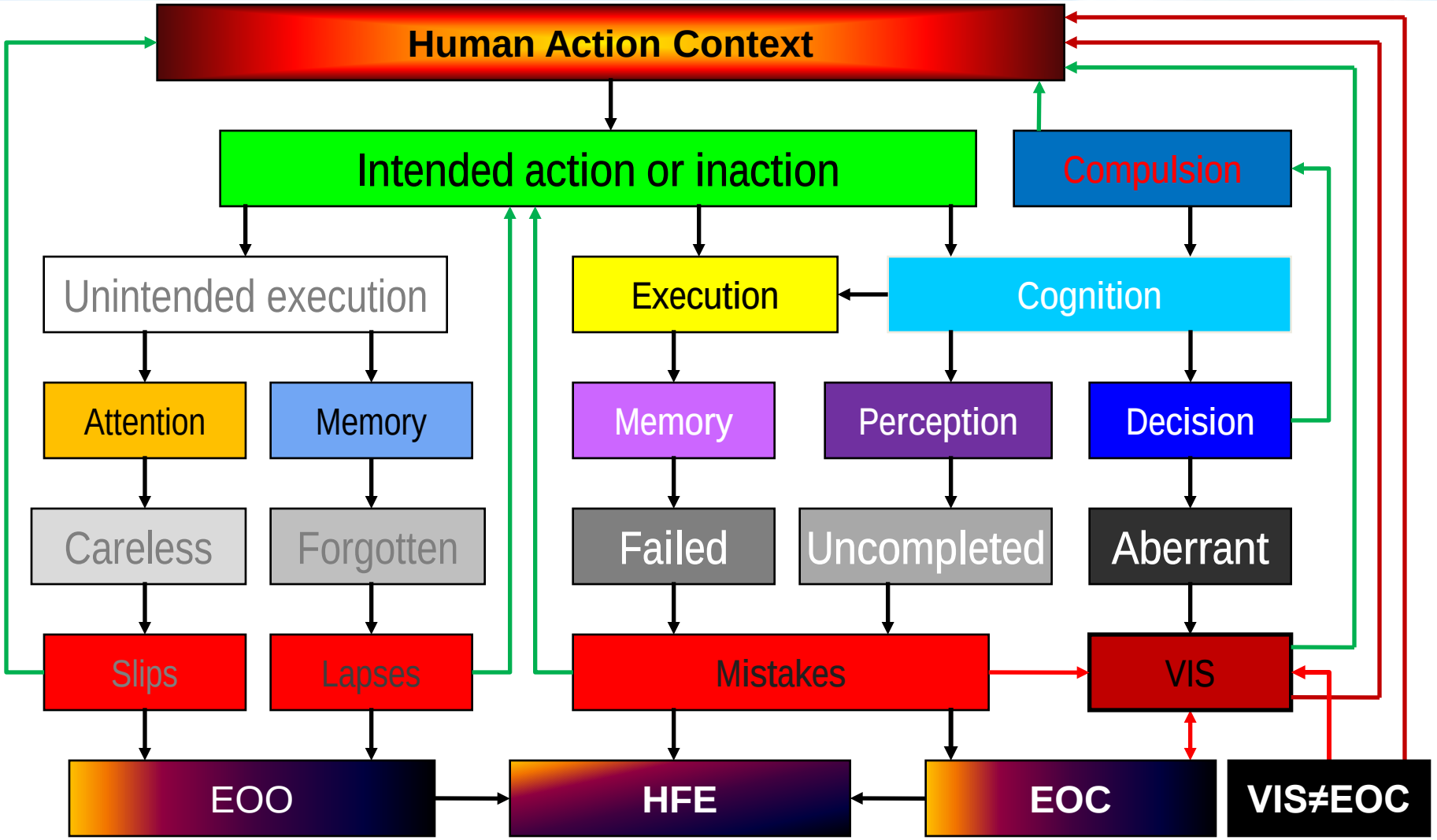
Explanation of extended definition of STS Violated Image of Symptom (2)

- In the PET method, the VIS is considered as a strategic decision and introduces of *"inevitable 'resident pathogens' within the system,"* resulting in a resonant increase in severity of error-forcing context, i.e. the context probability (CP) & human error probability (HEP).
- Taking into account the relativity of time when the strategic decision was made, seconds or years ago, we can conclude that the difference of the PET VIS is that it may be in apparent or latent conditions, but these conditions must lead to a sharp/resonant increase in the *severity of error-forcing context, i.e. CP(t).*
- If we take into account the consequences of the PET VIS, it can be said that they are similar to those of *Error of Commission (EOC)*.
- However, such consequences can occur not only after HAs but also in disturbing the objective image of other symptoms (Event, Parameter, Transition, Resource, Function, Goal), i.e. EOCs are subset of the set of **Violated objective Image of a Symptom (VIS)**.

Examples for Extended definition of STS Violated Image of Symptom

- For example, some **VIS ≠ EOC** during the Fukushima Daiichi NPP #1 accident are the following:
  - **VIS-E:** *SBO - loss of all AC power, the AC power was not restorable*; **VIS-T:** *Loss of DC power*;
  - **VIS-F:** *Containment Failure***.**
- These VIS ≠ EOC, because the violated symptoms are Event, Transition & Function, but they dramatically increased the accident severity & C(t).
- For example, some **VIS≡EOC** during Chernobyl NPP #4 accident are the following:
  - **VIS-A**: *System for emergency cooling of reactor has turned off from the previous shift*;
  - **VIS-A**: *The scram is disabled when two turbo-generators are turned off*;
  - **VIS-A**: *Several manually operated rods are pulled out to increase power, they remain less than 8 of 15 required rods in the reactor core*;
  - **VIS-A**: *The operational reserve of reactivity reaches a value requiring the reactor shutdown, but it is not done*.

Human Action Context & Human Failure Event Taxonomy



Recursion of context and recognition

- Matching the object in situation is approximation of a subjective image to the objective one by comparison of certain symptoms (signals, symbols and signs) that could be identified and described as an image of the object in the situation. These symptoms are **E**, **P**, **A**, **R, F**, **T**, **G &** **VIS**.
- Symptom recognition and cognitive context are iterative & recursive functions. In order to calculate CP, the durations of recognition for any symptom (as CFC) & cognitive disregard durations of VIS are needed. At the next step of iteration of cognitive process, we may use the new duration of symptom recognition based on previous calculation.
- A duration of symptom recognition could be based on measurement or expert judgment about the type of the recognized symptom (skill-based, rule-based , knowledge-based). The times for completion of cognitive process for 'skill-based', 'rule-based' & 'knowledge-based' symptoms would be in correlation 1:5:30 (Ujita et al. 1990).
- A symptom (CFC), after its recognition, could be kept or removed from the operator's context model and his memory depending on the situation. Some unimportant symptoms could be disregarded after their recognition by analogy with hypothesis that Rodin (1987) labeled 'cognitive disregard'.

Performance Evaluation of Teamwork Procedure

- The PET procedure for evaluation of context, cognition, communication and decision-making probabilities consists of eight steps:
- 1st step: A 'second-by-second' description of the scenario by tracing a timeline.
- 2nd step: Determination of numbers of the STS macroscopic outer symptoms - ϕ_n. (ϕ_{sn} & ϕ_{on}) that are determined in the scenario (s - subjective; o - objective).
- 3rd step: Specification of the initial and boundary conditions.
- 4th step: Calculation of dynamic context deviations by the formula:

$$\left|\phi_{okn} - \phi_{skn}\right| = \Delta\phi_{kn}, \left|\phi^{v}{}_{okn} - \phi_{skn}\right| = \Delta\phi^{v}{}_{kn}, n = 1...N, k \neq j \quad (1)$$

- where *n = 0, 1, 2...N* are indices (*N* is the number of symptoms).
- 5th step: Calculation of *CP(t)* for cognition of each crew member:

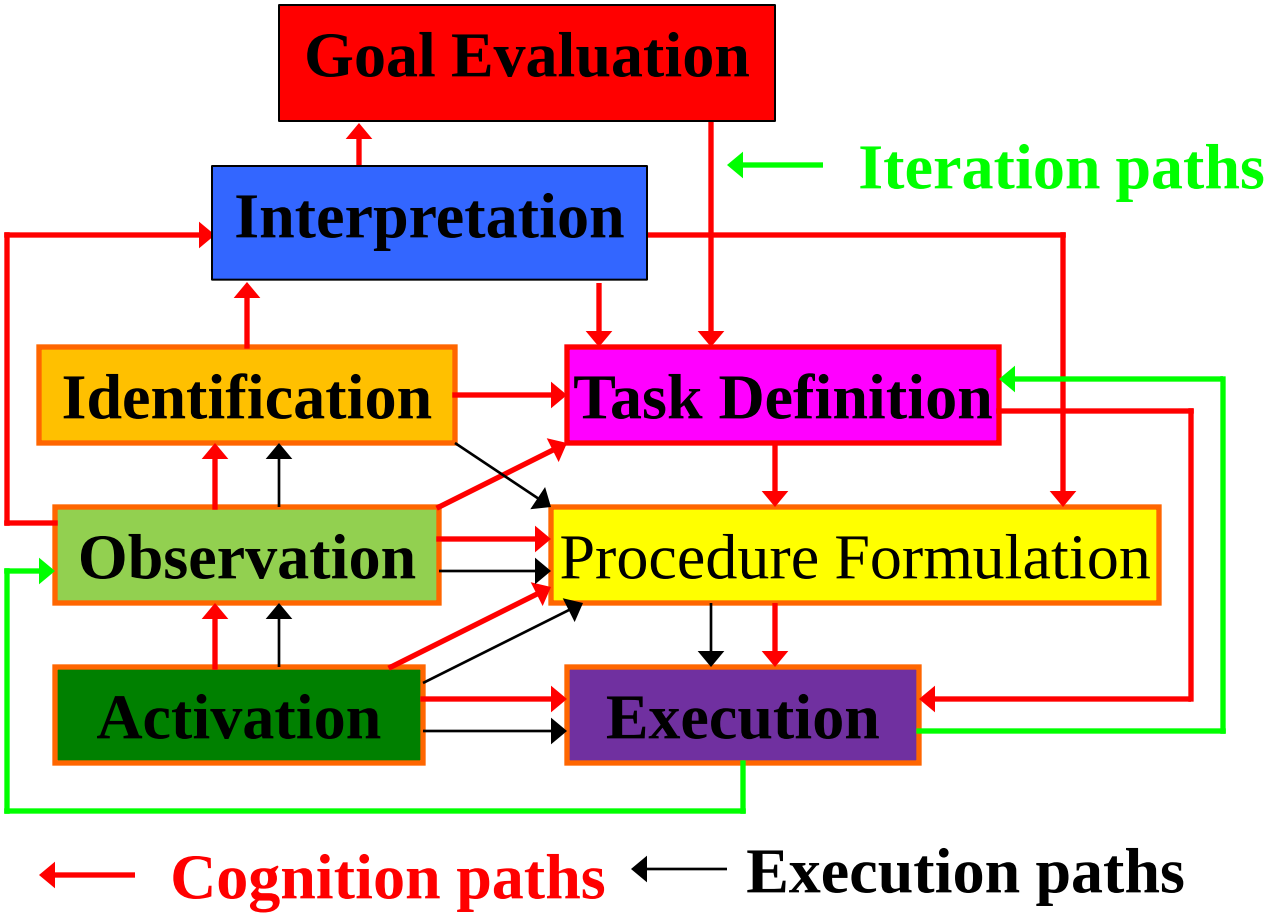
$$CP(t) = \frac{Number\_of\_unknown\_STS\_accessible\_states}{Number\_of\_possible\_STS\_accessible\_states} \quad (2)$$

- 6th step: Calculation of mutual *CCP(t)* between the crew members:

$$CCP_{kj}(t) = \mathrm{CP_j(t) - CP_k(t)}, \mathrm{k \neq j} \quad (3a)$$

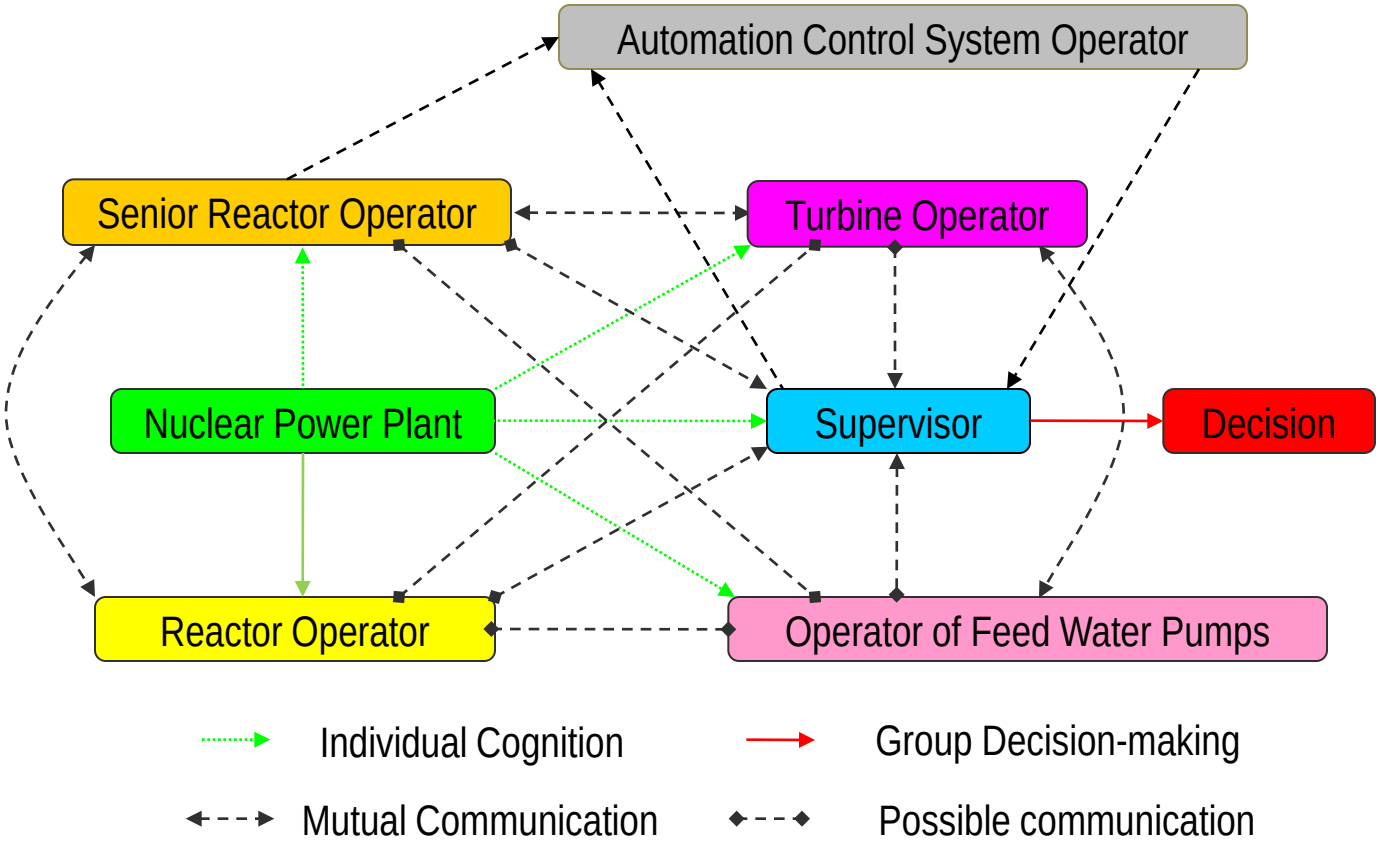
- 7th & 8th steps: Calculation of individual CEP(t) & crew CEP (t) by digraph models.

Rasmussen's Step-Ladder Model



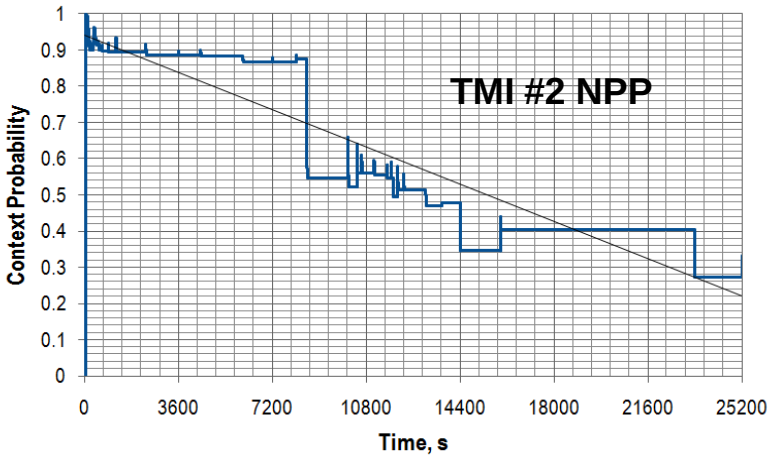
The paths follow the results of study of Hiroshi Ujita (1992)

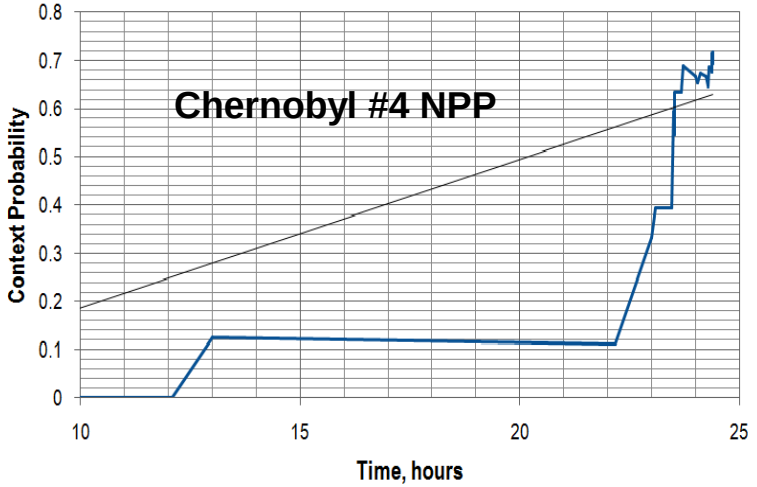
PET Crew Communication Model

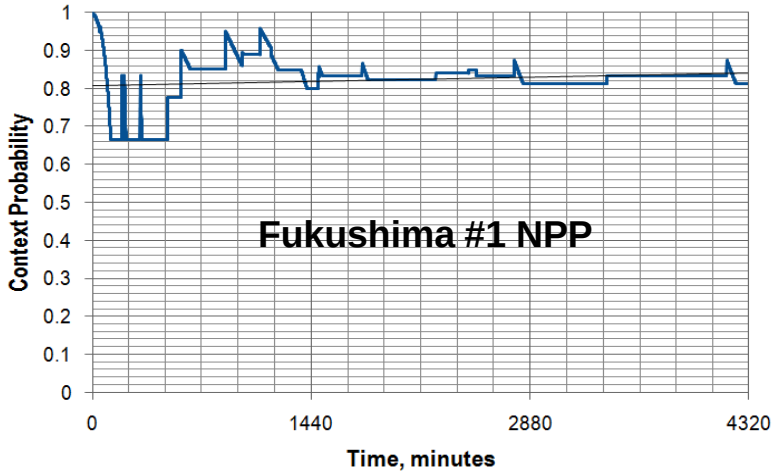


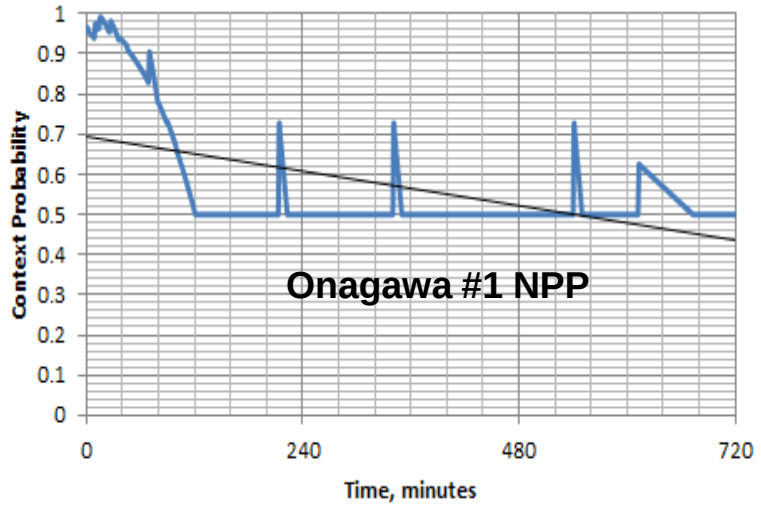
The group model follows the study of Kazuo Furuta & Shunsuke Kondo (1992)

Comparison of Context Probability for TMI#2, Chernobyl#4, Fukushima#1 & Onagawa#1 NPPs

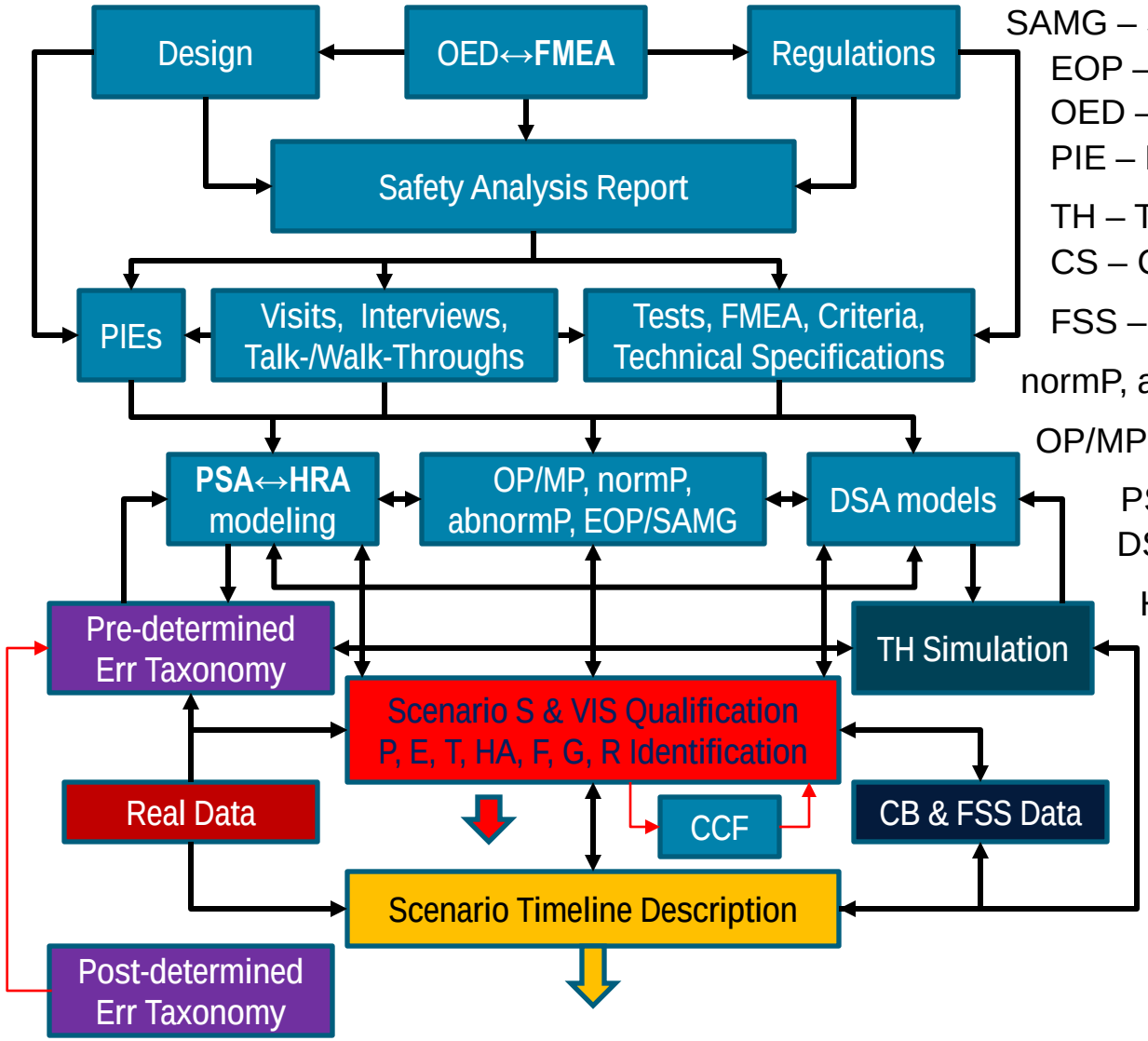








PET Scenario's Timeline Description & Symptom & VIS Qualification



SAMG – Severe Accident Management Guideline
EOP – Emergency Operating Procedure
OED – Operational Experience Data
PIE – Postulated Initiating Event

TH – Thermo-Hydraulic Simulation
CS – Computer Simulator

FSS – Full Scope Simulator

normP, abnormP – Normal/Abnormal Procedure

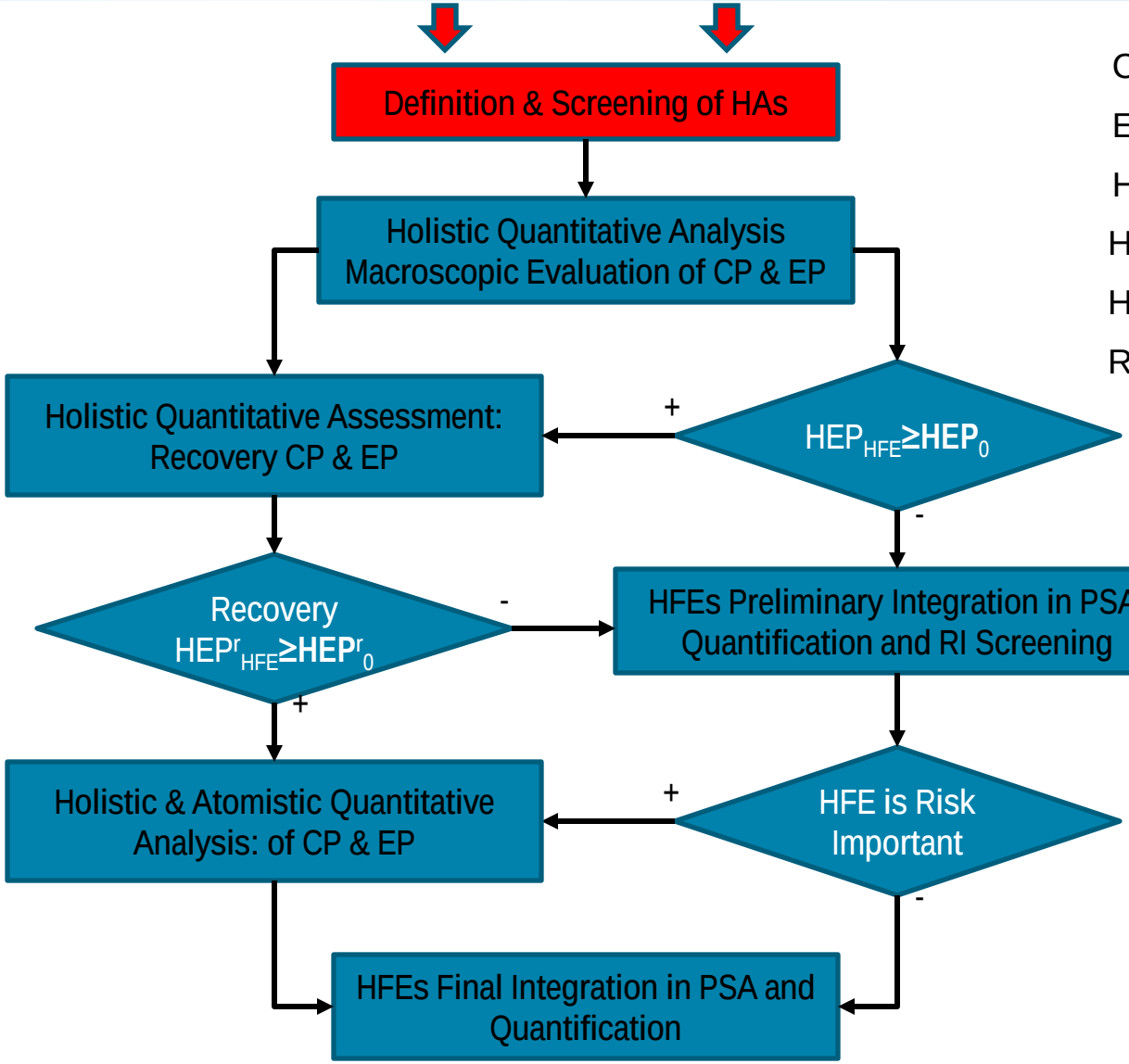
OP/MP – Operational/Maintenance Procedure

PSA – Probabilistic Safety Assessment
DSA – Deterministic Safety Assessment

HRA – Human Reliability Assessment

VIS – Violation of Image of Symptom
S – Symptom/Stimulus:
P – Parameter (Trend)
R – Resource *E – Event*
T – Transition *G – Goal*
HA – Human Actions or Tasks
F – Function (safety, efficiency)

PET Screening, Holistic & Atomistic Quantitative Assessment & Integration in PSA



CP – Context Probability

EP – Error Probability

HEP – Human Error Probability

HA – Human Action or Task

HFE – Human Failure Event

RI – Risk Importance

Holistic Dynamic Context & Error Probabilities

CP – Context Probability

EP – Error Probability

HEP – Human Error Probability

HA – Human Action or Task

HFE – Human Failure Event

a - appearing

r - recognition

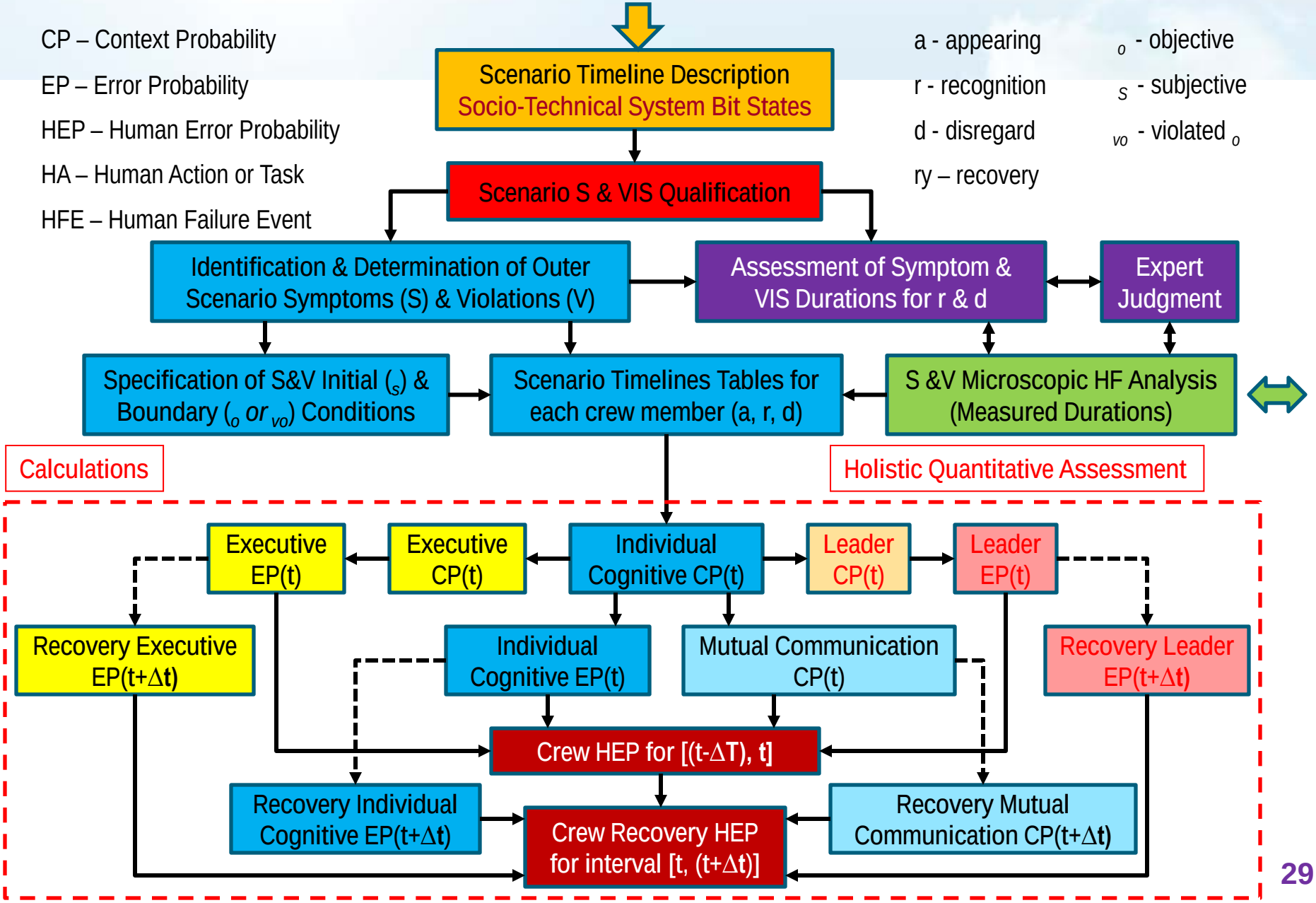
d - disregard

ry – recovery

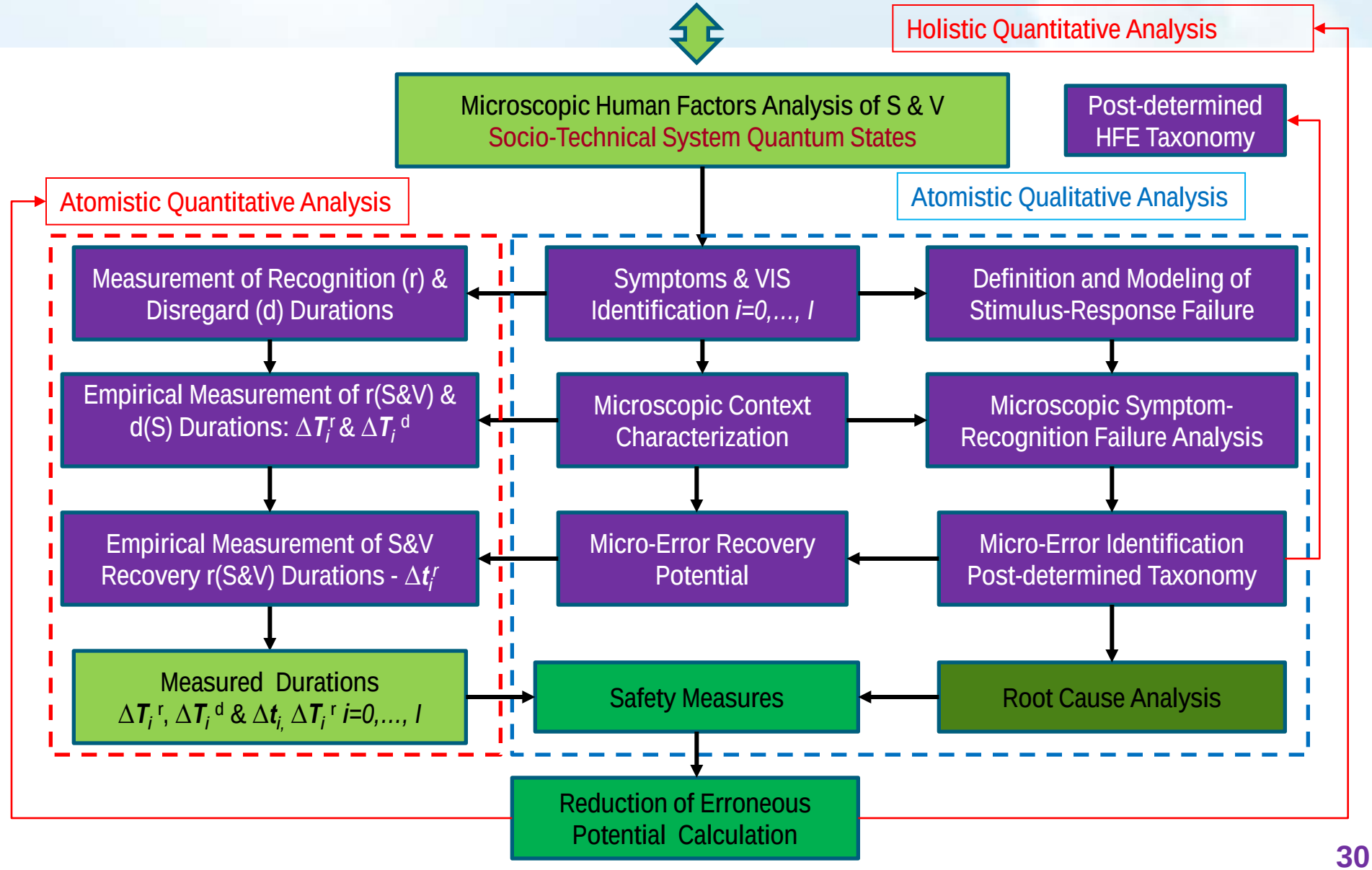
$_o$ - objective

$_S$ - subjective

$_{vo}$ - violated $_o$



Atomistic Error Potential Reduction & Root Causes



HRA for Bulgarian Kozloduy NPP

HRA for PSA Level 1 of Kozloduy NPP Units 5 & 6 follows IAEA Safety Series No 50-P-10:

1. Getting to know the NPP and collecting information;
2. Identification of HAs (pre-accident HA and post-accident HA);
3. Incorporating HAs into the PSA logical model (HA modeling);
4. Assigning HEPs (Screening Preliminary Analysis);
5. Analysis of dependencies;
6. Detailed qualitative and quantitative analysis of pre-accident HA;
7. Detailed qualitative and quantitative analysis of post-accident HA;
8. HA analysis when performing recovery actions (identification, modeling and quantitative assessment);
9. Documentation of the completed HRA and the results obtaining.

- In **detailed assessment** of HEPs for full power operation, the CBDTM methodology is used in the EPRI HRA Calculator and its software.
- In low power and shutdown operation (where the CBDTM methodology is not applicable, i.e. where EOPs for full power are not applicable), the detailed values for the diagnostic part are obtained according to ASEP Table 8-2 or Figure 8-1 of NUREG/CR-4772 or EPRI HRA Calculator

HRA for Bulgarian Kozloduy NPP
Type A Human Actions

The model does not include unavailability for:

- an item whose status is signaled by its own signaling (acoustic or light) or checked for a period of less than 24 hours;
- probable human errors that may affect the performance of an item resulting from repair or testing because these errors are included in the failure probability the item itself in the database;
- all components that receive an automatic return to normal operating status after actions that did not require removal of the power supply of this component;
- all items whose performance is tested functionally after any change in their condition.

*The identification of **pre-emergency HA** is performed on the ASEP approach NUREG / CR-4772.*

HRA for Bulgarian Kozloduy NPP
Type B Human Actions

- The same methods and approaches are used for their assessment as for manual operations type C1.
- For the purposes of this analysis, the value of the initiator and / or contribution to some of the existing initiators is calculated on the basis of the HRA event tree.
- HAs leading to initiation of IE are modeled as part of the initiator frequency.

HRA for Bulgarian Kozloduy NPP
Type C1 Human Actions

- HAs of the C1 type are modeled in ET or as base events in FT. In modeling, these actions are divided into two parts:
  - *diagnostics part* and
  - *manual part.*
- The diagnostic part is placed highest in FT or ET, at the same top event for the system to which it refers. If an action refers only to a single system, it is assumed that it has been modeled in the FT for this system and should no longer be modeled.
- Screening analysis:
  - The ASEP method is used to evaluate the diagnostic part of C1 type operations at low power and shutdown;
  - The THERP method is used to evaluate the manual part of Type C1 operations.
- Detailed analysis:
  - The detailed values for the manual part of the **Type C1** operations in full power, low power operation and shutdown are obtained by developing models (human error trees) and calculating THERP methodology.
  - The selection of **detailed analysis** actions is based on the contribution of MCS containing Type C1 type HAs. All HAs involved in the MCS with a contribution greater than 1.0% in the damage frequency of the area for each initiator

HRA for Bulgarian Kozloduy NPP
Type C2 Human Actions

- The inclusion of this type of action in the PSA model is only necessary in cases where the operators do not have *Symptom-Based EOPs (SB EOP)* and have to diagnose the initiator before taking any action.
- At the time of this analysis, Kozloduy NPP units 5 & 6 have SB EOPs only for full power operation. For this reason, operators of this type have been analyzed in PSA at low power and shutdown operating states where full power SB EOPs are not applicable.
- The determination of the **screening** initial values for type C2 operations is based on the NSAC-60, Oconee PRA, Unit 3.
- For detailed quantitative assessment of **Type C2**, used EOPs corresponding to POSs 5÷14 are event-based. Within PSA-1, only the time interval up to 1 h is analyzed as the time available to detect the misidentified accident events or actions taken in these operating states of the unit are much greater than those at full power, due to the slow development of the accident processes.
- Confusion matrices have been developed by the crew according to the criteria called "up to 15 min“ - for each event that had to be performed within a time interval of 15 minutes to 1 hour from the start of the emergency process.

HRA for Bulgarian Kozloduy NPP
Type C3 Human Actions

- Type C3 HAs are not identified and analyzed at the PSA model development. They are identified after obtaining the Minimal Cut-Sets (MCS) only in case this is necessary. The main factor of this type of action is the time to perform the recovery action.
- Initially, a selection of primary events (including those triggered by HAs) that can be recovered are selected from the MCS list after the last iteration of the calculation. The selection is made from those primary events that contribute more than 1.0% to the frequency of core damage.
- The quantification of the recovery action is a Boolean sum of the diagnostic and manual parts. It is not recommended to do two or more recoveries in the same MCS because of the hidden dependence.

HRA for Bulgarian Kozloduy NPP

Dependencies & special feature for PSA Level 2

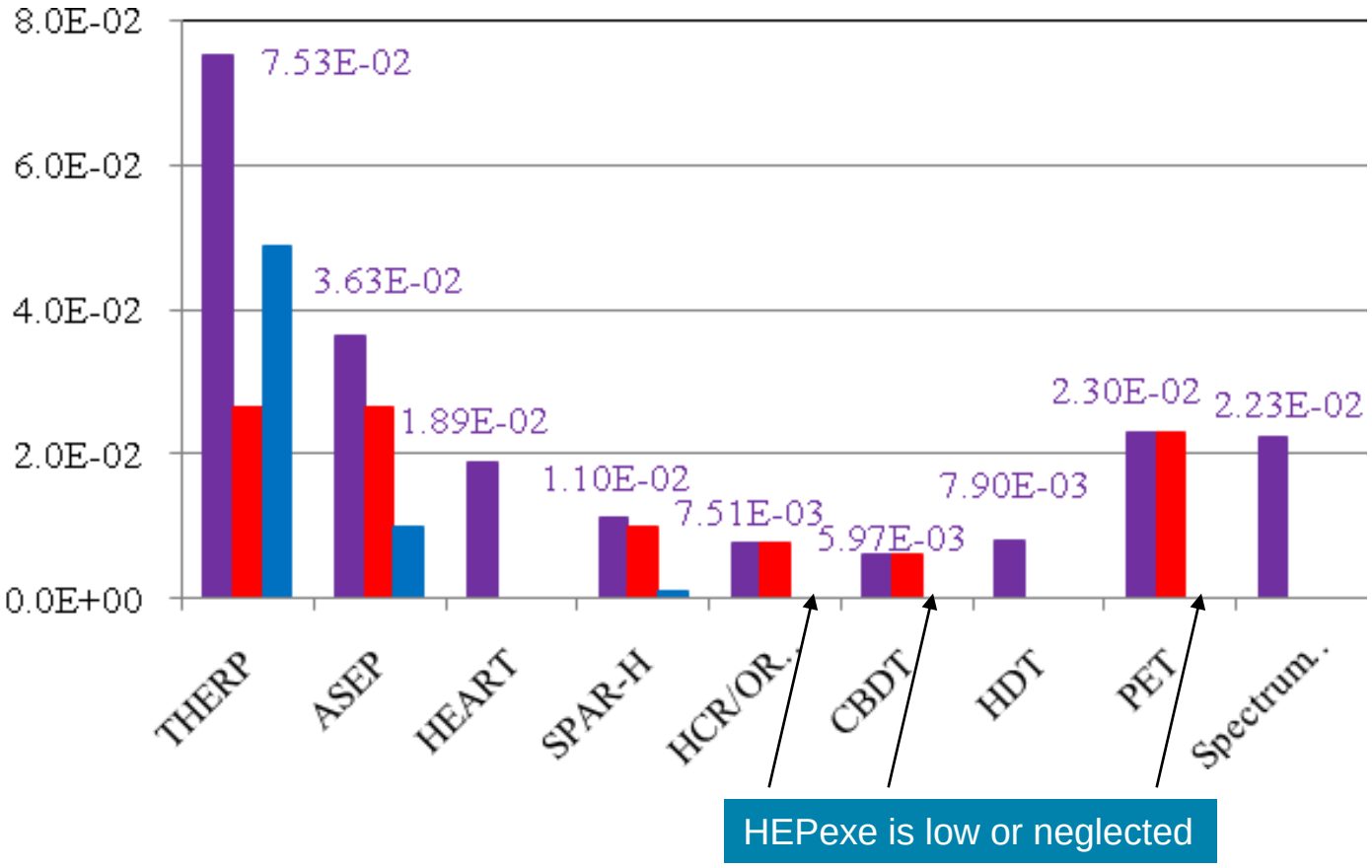
- Dependencies are determined as shown on figure below (NUREG-1278).
- Main dependencies between actions modeled in PSA-1 & PSA-2 - two cases:
  - Between operations common to PSA-1 and PSA-2, such as the recovery action of core cooling. The difference is that the time available in PSA-2 is much more than PSA-1, there are many more symptoms that help identify the need for appropriate responses, and the presence of SAMGs provides further guidance in the current crisis situation.
  - A key point is to determine whether the corresponding PDS gives a sufficiently accurate imagination of an adequate assessment of the situation in the context of the task or of the PSFs.
- There may be a gap between the EOP & SAMG where there is a potential for operators not to be fully confident about the actions they have to take.
- The analysis of HAs that may influence the process of development of the severe accident in PSA-2 should take some account of dynamic changes in order to assess the possible delay for the next actions.
- Treat failure probability as a function of available time, or to use a definition of a minimum HEP for HAs whose available time is several hours or 24 h.
- The EPRI HRA calculator has been used for the HRA.

Comparison of 8 HRA methods for Kozloduy NPP

'Closing of Unclosed Steam Dump Valve to Atmosphere'

- This accident occurred in Unit 6 of the Kozloduy NPP on March 21st 2010 at 23:05h and led to reactor scram and safety systems actuation after 9 years of successful operation without scrams.
- The unclosed SDV-A of 3rd SG was closed in 5 minutes and no damages to reactor core and plant occurred.
- **Test, Evaluate & Compare** HEP for the cognitive part of post-accident action by a spectrum of **eight** HRA methods*: THERP, ASEP, HEART, SPAR-H,* HCR/ORE+THERP, CBDT, HDT & PET
- **Apply** the HRA methods to NPP operating crew performance based on standard PSA model assumptions for real & simulated cases with their detailed boundary conditions
- **Give** the significant differences in the scope, approach, and underlying models of these methods
- **Develop** an understanding of the performance, strengths and weaknesses of the HRA methods, along with ways to improve them

THERP, ASEP, HEART, SPAR-H, HCR/ORE+THERP, CBDT, HDT & PET Comparison



Insights

- The PET, as a HRA method, applies a realistic procedure for dynamic symptom-based context evaluation of cognition and communication, and context-sensitive digraph models of cognition, communication and decision-making.
- The PSA modeller is responsible for appropriate determination of the Initiating Event progression and needed actions based on thermal-hydraulic simulations or full-scope simulator training exercises.
- The HRA modeller is responsible for correct definition of symptoms, violated images of symptoms and determination of the durations of their manifestation, recognition and disregard, action and recovery implementation. It is preferably to measure them but guess or judgment could be acceptable only as a first approximation.
- The correct distribution of roles in modelling, limitation of expert guesses and possibility for experimental verification & validation supposes that PET could be applied with higher degree of confidence.

Conclusions

- The intermediate use of symptoms for dynamic context evaluation gives better opportunities for the systematic identification, qualitative and quantitative interpretation of time-dependent HFEs during the accident and for improving of emergency response planning and/or severe accident management.
- The data use of thermal-hydraulic calculations & full-scope simulator are a valuable option for optimization of time to implement emergency measures and actions to ensure safety during the DBA and DEC/BDBA based on joint deterministic and probabilistic criteria.
- The PET is a prospective emerging HRA method for dynamic, context-based, retrospective and prospective analysis and data-mining that could provide the PSA studies with HEPs for any specific action/task based on state-of-art simulations in order to avoid expert guesses.
- The detailed and qualitative data of accident reports are the best source for validation and verification of HRA methods.

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Technical Meeting
on the Development of the Safety Report on Human Reliability Assessment for Nuclear Installations

THANK YOU FOR YOUR ATTENTION!

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