International Atomic Energy Agency

Human Reliability Analysis

Presented by: **Tibor Szikszai**
Ri-man Consulting, Hungary
t.szikszai@riman.hu

Joint ICTP-IAEA Essential Knowledge Workshop on Deterministic Safety Analysis and Engineering Aspects Important to Safety, Trieste, Italy 12 – 23 October 2015 (week 1)

Contents

- Introduction
- Classification of human errors
- SHARP procedure
- Pre-accident human errors (latent errors)
- Post-accident human interactions due to misdiagnosis
- Post-accident human interactions: The impact of the available time. Evaluation of time windows
- Human dependencies
- Errors of commission

Introduction

- **The objective of the human reliability analysis is to identify, represent (in the logic structure of the PSA) and analyze (quantify) all human errors impacting the plant safety before and during the accident.**
- **Successive screening processes will help to focus efforts on those that are important**
- **The identification and analysis of human errors in the PSA is a systematic process. The HRA analyst needs to study and understand the PSA models and interact with other PSA team members**
- **Interaction with NPP personnel is essential**

Classification of human errors

- By the time of occurrence

Type	Description	Effect
1 (A)	Human actions before the accident during normal operation	Miscalibrations, misalignments
2 (B)	Human actions that cause the initiating event. (These are often errors of commission)	Initiating events
3 (C1)	Human actions during the accident, following the correct procedures	Non successful response within the time window, errors of omission and commission
4 (C2)	Human actions during the accident that, due to the inadequate recognition of the situation, make it worse	Non response or errors of commission
5 (C3)	Human actions during the accident, trying to recover the situation; for example repairs to equipment	Non-recovery

Classification of human errors

- **By the output of the human error**

  - **ERRORS OF OMISSION**
    - Omits entire task.
    - Omits a step in a task.

  - **ERRORS OF COMMISSION**
    - Selection error
      - Selects wrong control.
      - Misposition of controls.
      - Issue wrong command on information.
    - Errors of Sequence
    - Timing Errors
      - Too Early.
      - Too Late.
    - Qualitative Errors
      - Too Little.
      - Too Much.

Classification of human errors

- **By type of reasons**
  - **Slips,** deviations in manual actions (when you know what you should have done)
  - **Lapses** of memory
  - **Mistakes,** errors of knowledge (decision, diagnosis) where you do not know certainly what you should do
  - **Violations** (circumventions), where the intention was to do something good by 'bending the barriers'. (compare to sabotages, malevolent acts where the intention was bad)

Classification of human errors

- **By basis for human performance**
  - **Routine:** Usual human actions explicitly included in documents
  - **Cognoscitive:** Human actuations that require a cognitive process of understanding and decision making, previous to do an action.

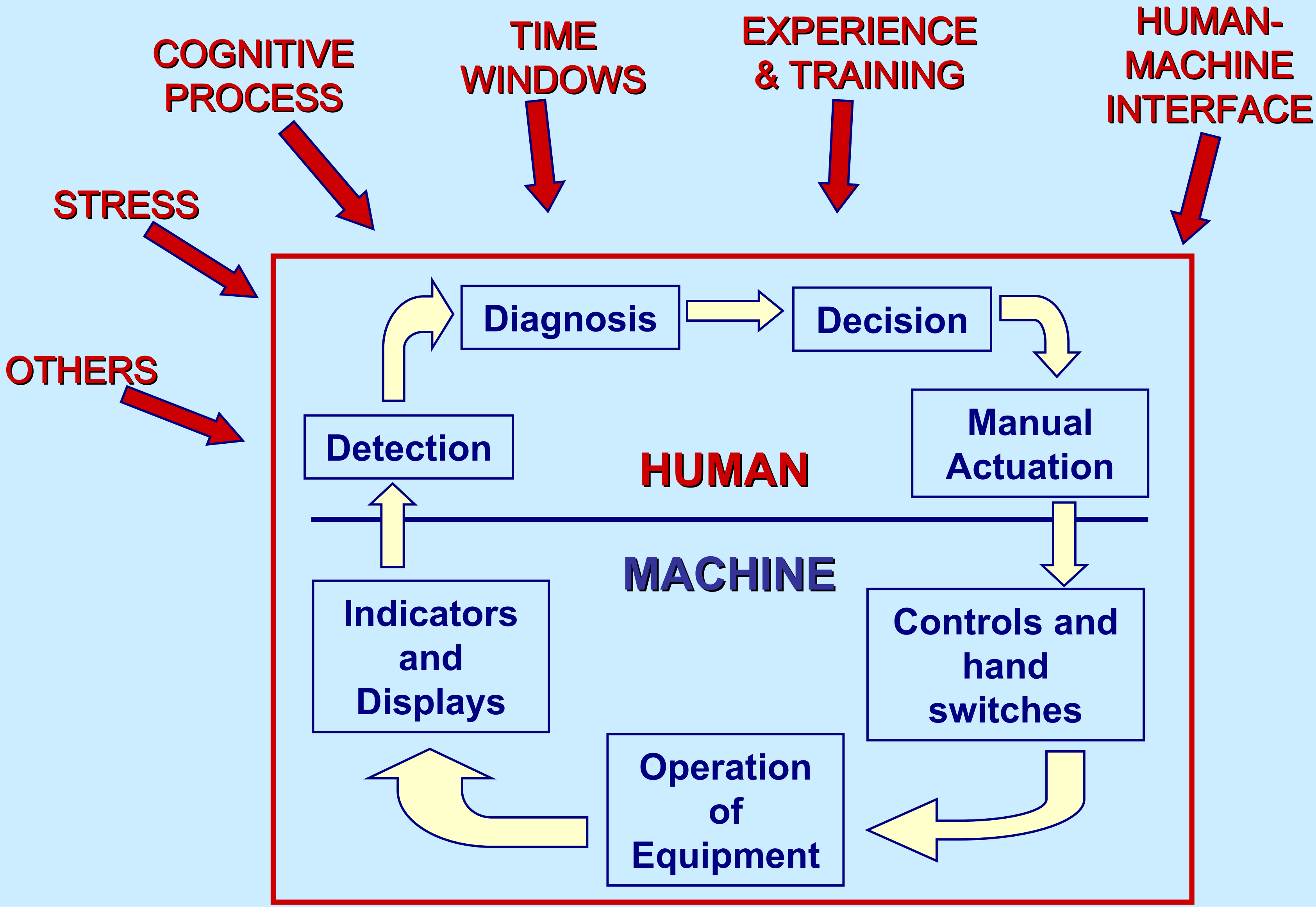
  - **Skill based** (learnt skills)
  - **Rule based** (stored or written rules, procedures etc.)
  - **Knowledge based** (decision making, thinking)

Classification of human errors

- **By basis for human performance**
  - **Routine:** Usual human actions explicitly included in documents
  - **Cognoscitive:** Human actuations that require a cognitive process of understanding and decision making, previous to do an action.

  - **Skill based** (learnt skills)
  - **Rule based** (stored or written rules, procedures etc.)
  - **Knowledge based** (decision making, thinking)

Operator interaction process



Classification of human errors

- **Performance shaping factors (PSF)**
  - **Any factor that shapes (influences) human performance.**
  - **Less than adequate PSF - Higher human error probabilities.**
  - **Categories of PSF's**
    - ✓ External
    - ✓ Stressor
    - ✓ Internal

SHARP procedure

- **SHARP (*S*YSTEMATIC *H*UMAN *A*CTION *R*ELIABILITY *P*ROCEDURE): EPRI-NP-3583**
- **The SHARP methodology can be employed by the analyst as guidance to make assessments of human reliability, suitable for use in a PSA,**
- **Different techniques can be used within the SHARP framework,**
- **Innovation can be employed when current techniques are deemed insufficient for adequately addressing the case under study.**

SHARP procedure

- **SHARP steps**

1. **Definition**

   To ensure that all human interactions are adequately considered in the study.

2. **Screening**

   To identify the human interactions that are significant to the operation and safety of the plant.

3. **Breakdown**

   To develop a detailed description of important human interactions by defining the key influence factors necessary to complete the modelling. The human interaction modelling consists of a representation (e.g., qualitative model), impact assessments and quantification.

SHARP procedure

4. Representation

To select and apply techniques for modelling important human interactions in logic structures. Such methods help to identify additional significant human actions that might impact the system logic trees.

5. Impact Assessment

To explore the impact of significant human actions identified in the preceding Step on the system logic trees.

6. Quantification

To apply appropriate data or other quantification methods to assign probabilities for the various interactions examined, determine sensitivities and establish uncertainty ranges.

7. Documentation

To include all necessary information for getting a traceable, understandable, and reproducible assessment.

Pre-accident human errors (latent errors)

- **Types:** misalignments and miscalibrations
- **Identification & modelling :** In principle, every component that is manipulated is subject to this type of unavailability
- **It is easier to model them all although plant specific defences can be taken into consideration for the initial selection (with supporting justification) Plant specific defences/features need to be taken into consideration when performing the task analysis (e.g. tagging out systems and verifications after manipulations)**

Pre-accident human errors vs. random component failures

- The boundary of these two types of failures has to be perfectly identified so that there is no double counting
- Typical pre-accident human errors are *misalignments during restoration after maintenance/test*. These are dealt with by standard HRA procedures
- Typical pre-accident human errors are *I&C and safety valve miscalibrations (including misalignments during restoration after calibration)*. These are dealt with by standard HRA procedures
- Human errors during maintenance are often difficult to identify. The are normally counted as part of the random failures of components. These are dealt with by standard statistical data processing

Post Accident Human actions: Misdiagnosis

POSSIBLE EFFECTS OF THE MISDIAGNOSES	PSA IMPACT
The human actions required to cope with the accidental situation are not performed	The probability of *affected* HFEs modelled in the PSA is higher because it has to include this contribution: $P(HFE)=\boldsymbol{P_{diag}}+P_{det}+P_{decis}+P_{man}$
The actuation of systems required to cope with the real situation is inhibited	The *affected* system models need to include this HFE under an “OR” gate (top gate)
Actions not required to cope with the real situation are performed which do not impact the situation	No impact in the models but analysis of time windows should be reviewed
Actions not required to cope with the real situation are performed which worsen the situation	Some sequences can be *affected* and may need to be modified
In spite of misdiagnosis the correct actions are performed	No impact in the models but analysis of time windows should be reviewed

Post Accident Human actions: Misdiagnosis

- **Analysis of misdiagnosed scenarios, their probabilities and consequences:**
  - **Prepare a "confusion matrix" which shows the Initiating Event groups included in the PSA in both axis**
  - **Analyse in detail the symptoms/cues that allow the recognition of the accident scenario**
  - **Analyse in detail the instrumentation available/used to recognise the situation**
  - **Discuss with the operating staff and trainers**

Post Accident Human actions: Misdiagnosis

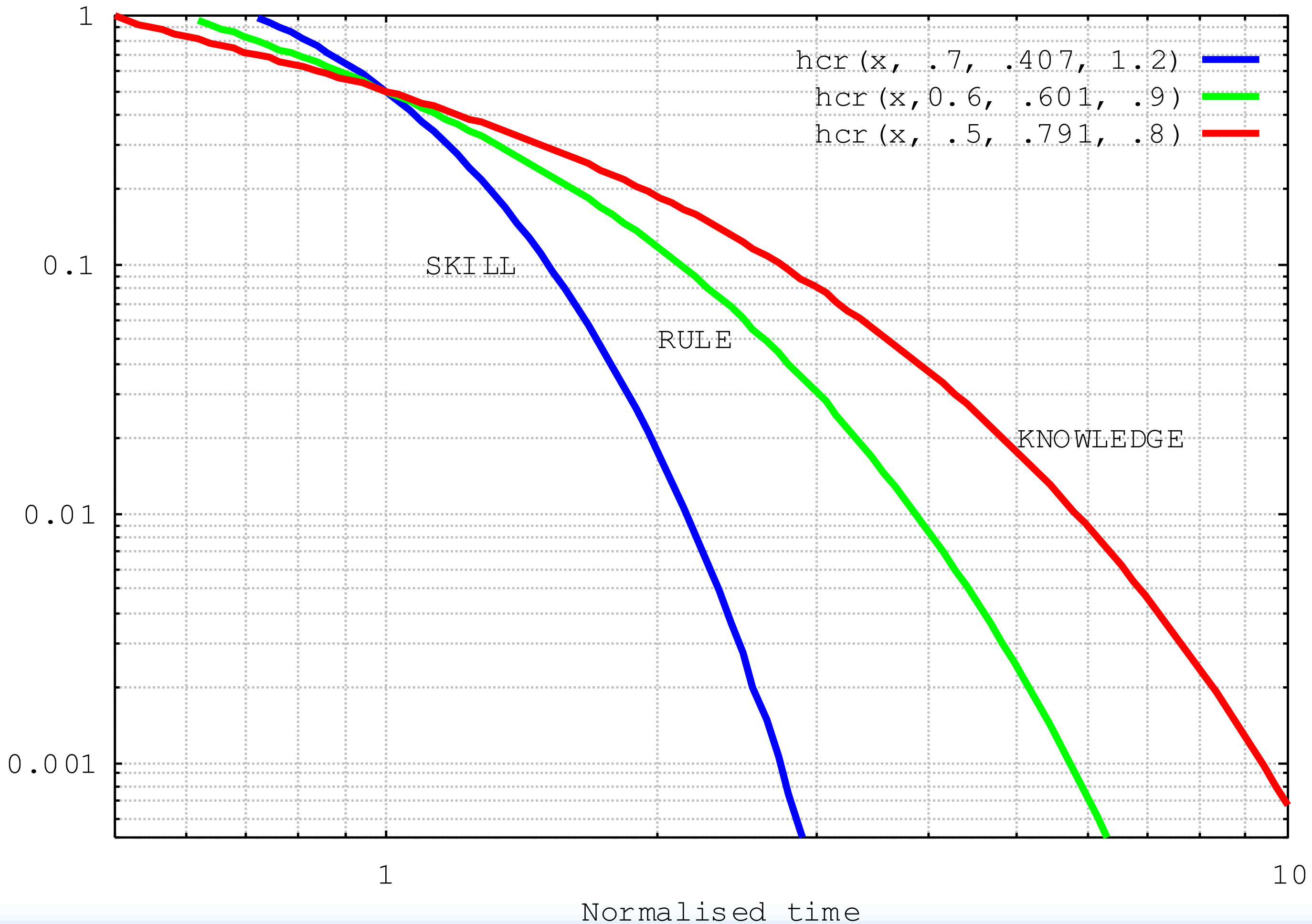
REAL / DIAGNOSED	SMALL LOCA	STEAM GENERATOR TUBE RUPTURE	SMALL STEAM LINE BREAK (IC)	OTHER INITIATING EVENT
SMALL LOCA	***********	P_1	P_2	P_3
STEAM GENERATOR TUBE RUPTURE	P_4	************	P_5	P_6
SMALL STEAM LINE BREAK (IC)	P_7	P_8	************	P_9
OTHER INITIATING EVENT	P_{10}	P_{11}	P_{12}	************

Post Accident Human actions: Misdiagnosis

- **Revisit confusion matrix and screen out all incredible confusions. Justification needs to be provided and transparent**
- **Use a structured expert judgement approach to calculate the probabilities of the identified confusions**
- **The possibility of recovery (re-diagnosis) needs to be taken into account in the analysis**
- **For the identified confusions, analyse the emergency procedures in detail to identify 'what can go wrong', e.g.:**
  - ✓ Systems required to mitigate accident are inhibited (impact on system fault tree models)
  - ✓ Actions are taken which are not required and change the course of the sequences (impact on event tree models)

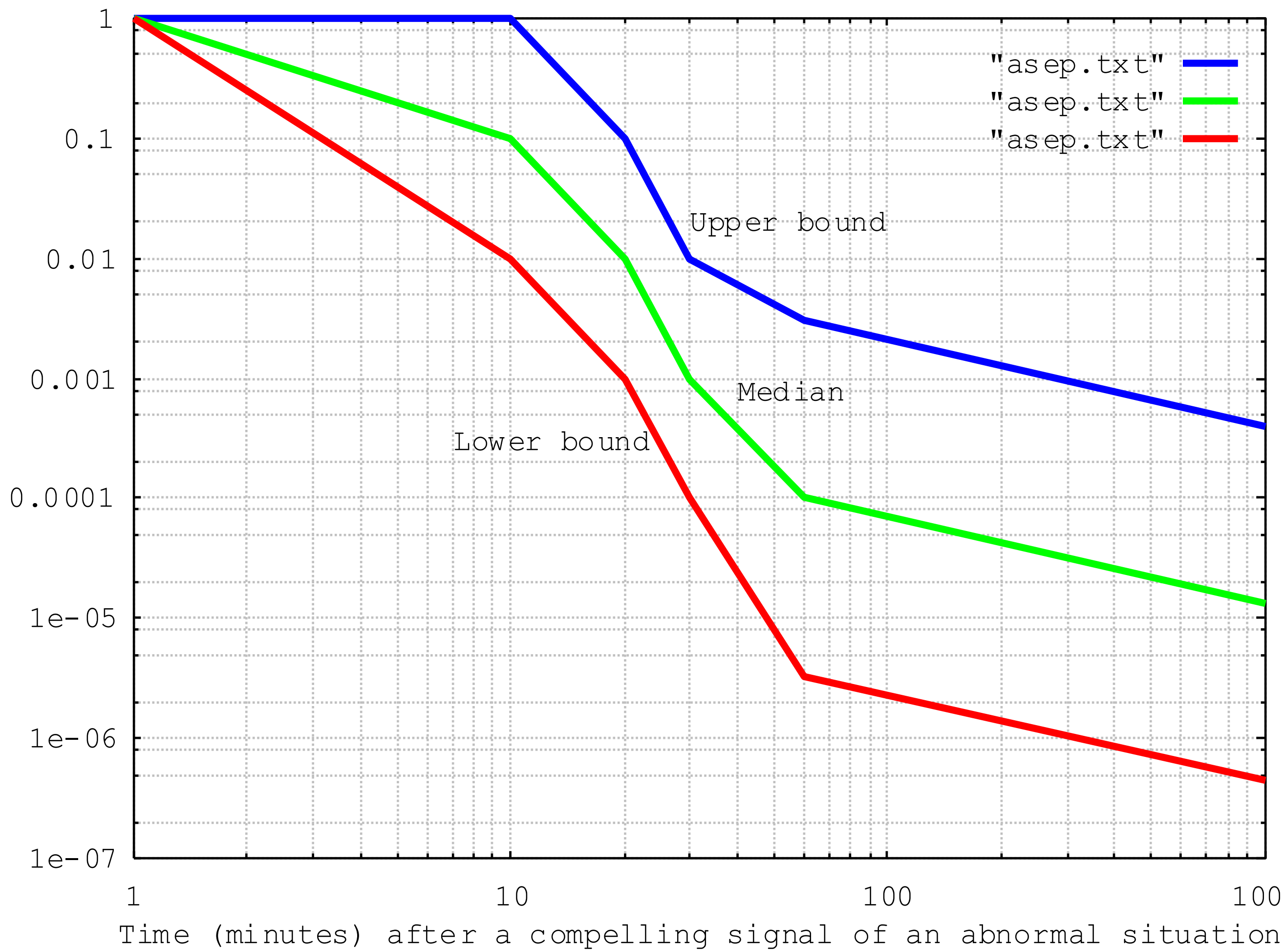
Post-accident human interactions: The impact of the available time. Evaluation of time windows

- **HCR – Human Cognitive Reliability**

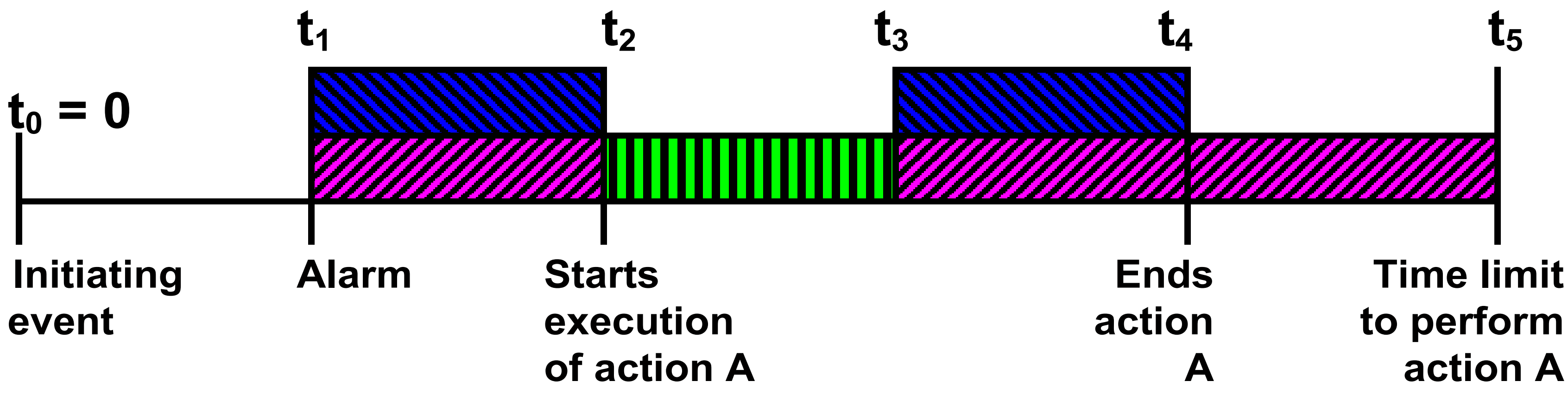


Post-accident human interactions: The impact of the available time. Evaluation of time windows

- **ASEP Methodology (Swain, 1987)**



Example of actions with several steps and lengthy or local actuations



t_{local} = Local manual actuations = $t_3 - t_2$

$t_{(A)}$ = Available time = $t_5 - t_1 - t_{local}$

$T_{1/2\ (A)}$ = Median time for decision = $t_4 - t_1 - t_{local}$

Time and manual part of the action - recovery and dependence levels

TIME AFTER RECOGNITION OF AN ABNORMAL EVENT	PERSONNEL AVAILABLE TO COPE WITH THE ACCIDENT	DEPENDENCE LEVELS CD = Complete HD = High MD = Moderate LD = Low
0-1 min	one reactor operator (RO)	
≈ 1 min	one reactor operator (RO)	
	shift supervisor or deputy	HD with RO
≈ 5 min	one reactor operator (RO)	
	experience senior operator	HD with RO
	shift supervisor	LD to MD with others
	one (several) assistant operator(s)	Plant/situation specific basis
≈ 15 min	one reactor operator (RO)	
	experience senior operator	HD with RO
	shift supervisor	LD to MD with others
	shift technical advisor	LD to MD with others for diagnosis and major events. HD to CD for detailed operations
	one (several) assistant operator(s)	Plant/situation specific basis

Human dependencies

- **Examples of coupling mechanisms**
  - **Same person**
  - **Same crew**
  - **Same procedure**
  - **Same procedure step**
  - **Similar action**
  - **Close in time**

Human dependencies

- **Levels of dependency(*)**
  - **Complete**: If action A fails, action B will fail
  - **High** dependency
  - **Moderate** dependency
  - **Low** dependency
  - **Zero** dependency: Probability of failure of action B is the same regardless the failure of or success of task A

(*) NUREG/CR-1278 (THERP), Chapter 10

Human dependencies

- **Examples of dependencies to be considered in HRA**
  - **Between pre-initiating event human actions**
  - **Between post-initiating event human actions**
  - **Between sub-tasks involved in the same action**
  - **Between errors and recoveries**
  - **Between pre and post initiating event human actions**

Errors of commission

- **omissions:** failure to perform required actions
- **commissions:** performance of inappropriate actions ... that aggravate a scenario
- **two types of EOCs**
  - **slips: inadvertent, unintentional**
    - ✓ align train A instead of train B
  - **mistakes: inappropriate decisions**
    - ✓ terminate safety injection because criteria appear to be satisfied
- **evidence suggests slips are easier to recover (detect and correct)**
  - **mental model is correct**
  - **incorrect situation assessment tend to bias the interpretation of plant feedback following an EOC, tendency to confirmation bias**

Errors of commission

- The EOC modeling is still an issue to be resolved.
- This is one of the on-going development areas of HRA
- Other on-going development areas are:
  - analysis of decision performance
  - data and quantification
  - computer-based displays / “soft” interfaces
  - organizational factors