Human Error Probability in Responding to Alarms (HEPIRA)

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Context

- The human role is key to process safety and the control of risks, necessitating the inclusion and quantification of human actions as part of safety barriers.
- Incorporation of human action as a barrier in risk analysis studies is recognized as an important, though often challenging aspect of the analysis.
- The non-consideration of human actions and interventions as safety barriers is a very conservative approach and could lead to unwarranted expenditures to reduce risks because of additional barriers

A Guide & Manual on the subject was prepared in TotalEnergies. The focus is on the following items:

- Human error probability in responding to safety alarms. Human performance related to other activities is not addressed in this guide.
- Alarms intervening in major accident scenarios

TotalEnergies

COMPANY GUIDE AND MANUAL

GM-GR-HSE-303

Human Error Probability in Responding to Safety Alarms

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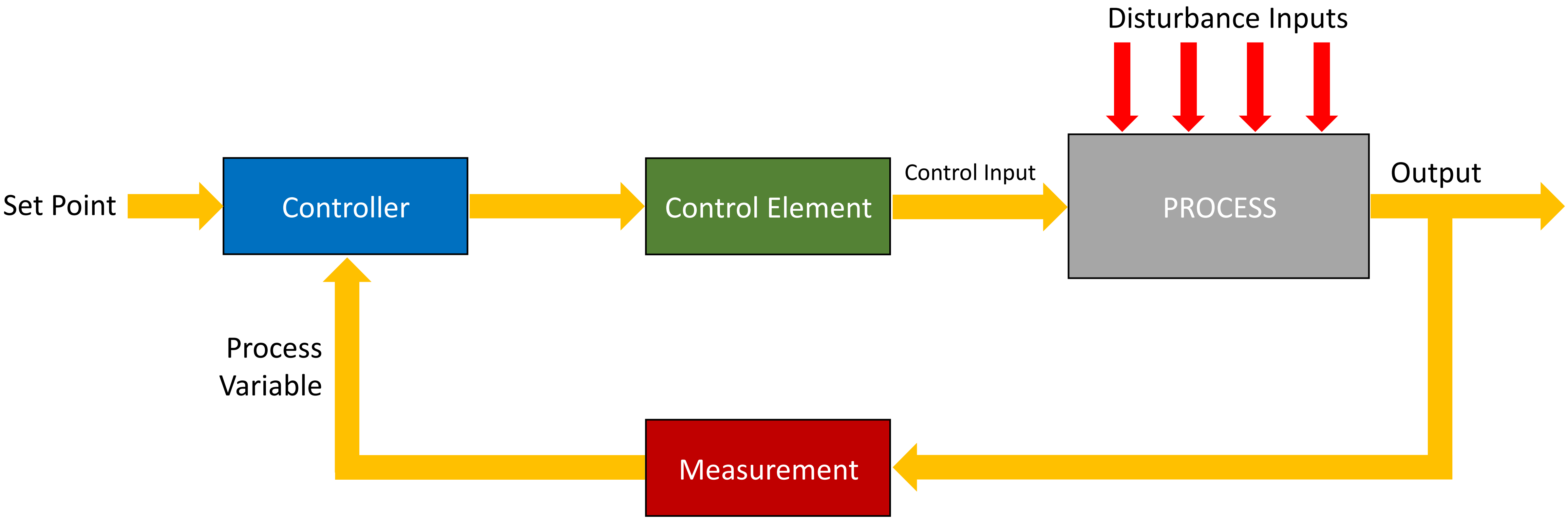
Process control loop

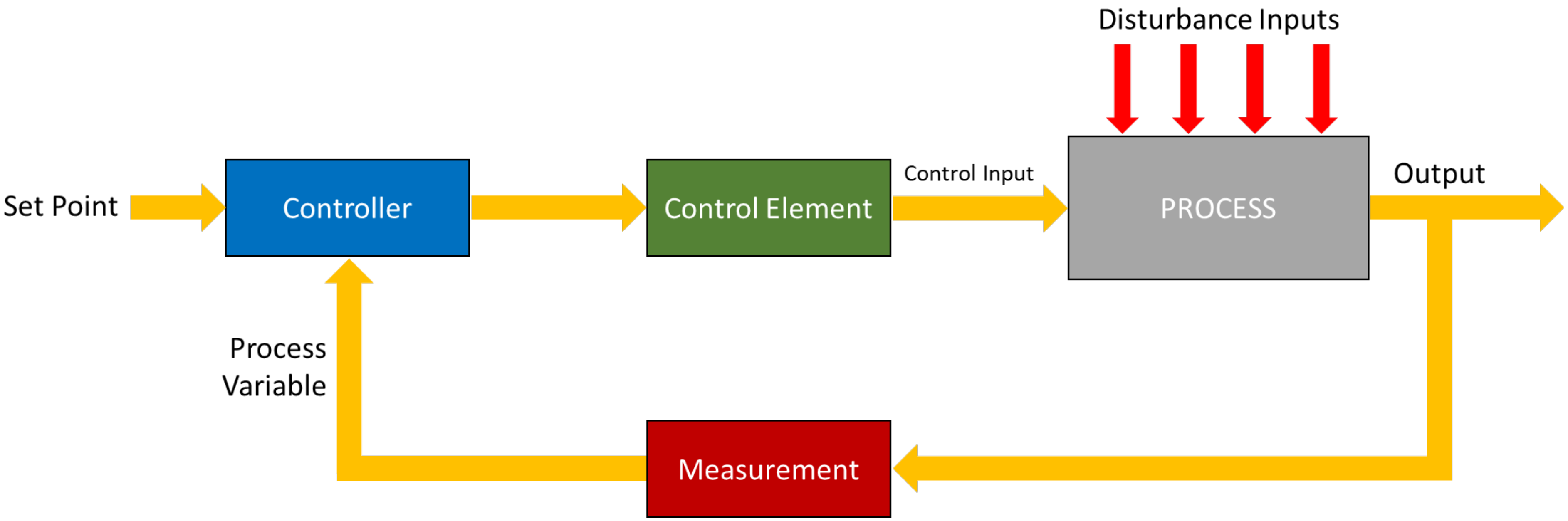
A typical process control loop includes a measurement (via a sensor that can be mechanical or instrumented), a controller (logic solver, relay, mechanical device) and a control element.



Process control loop

For control loops acting as safety barriers (and especially safety critical barriers), several requirements need to be fulfilled in the area of:

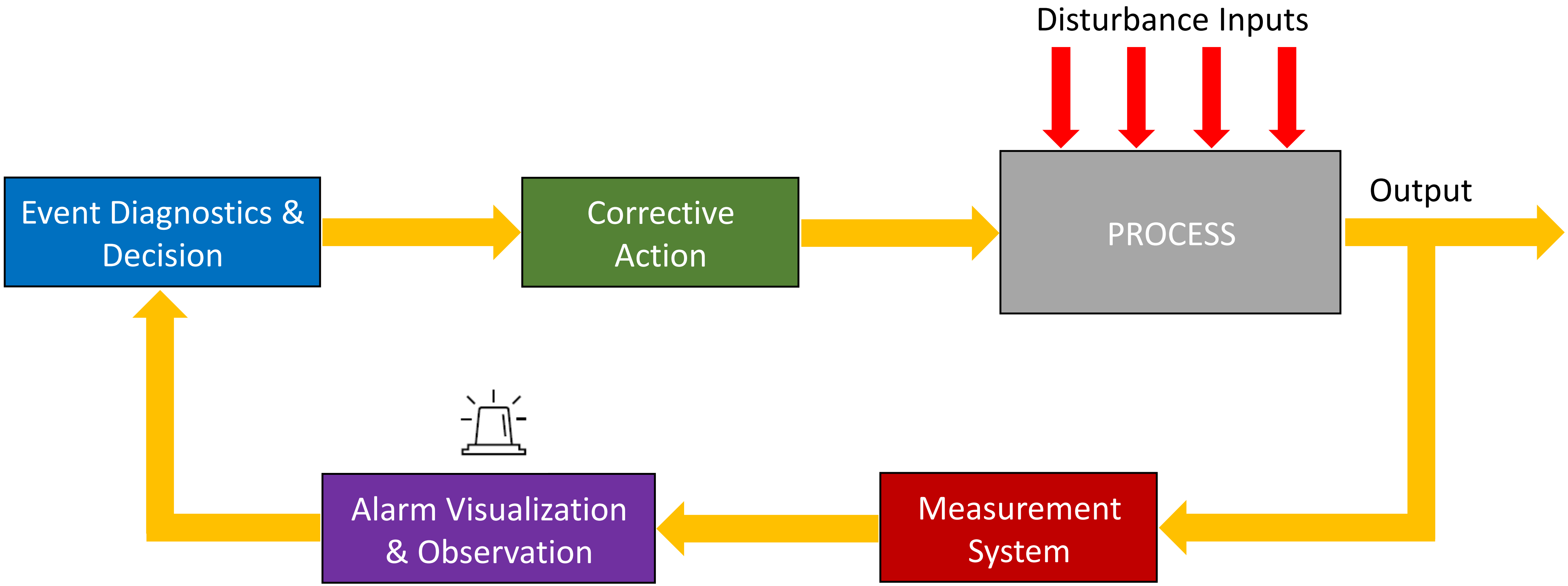
- Independency (from initiating event or other barriers)
- Reliability
- Effectiveness
- Efficiency
- Response Time
- Testability
- Maintainability
- Availability
- Fault tolerance
- Survivability



The performance of instrumented systems is influenced by performance shaping factors such as extreme temperatures, corrosion phenomena, ageing, meteorological conditions,…

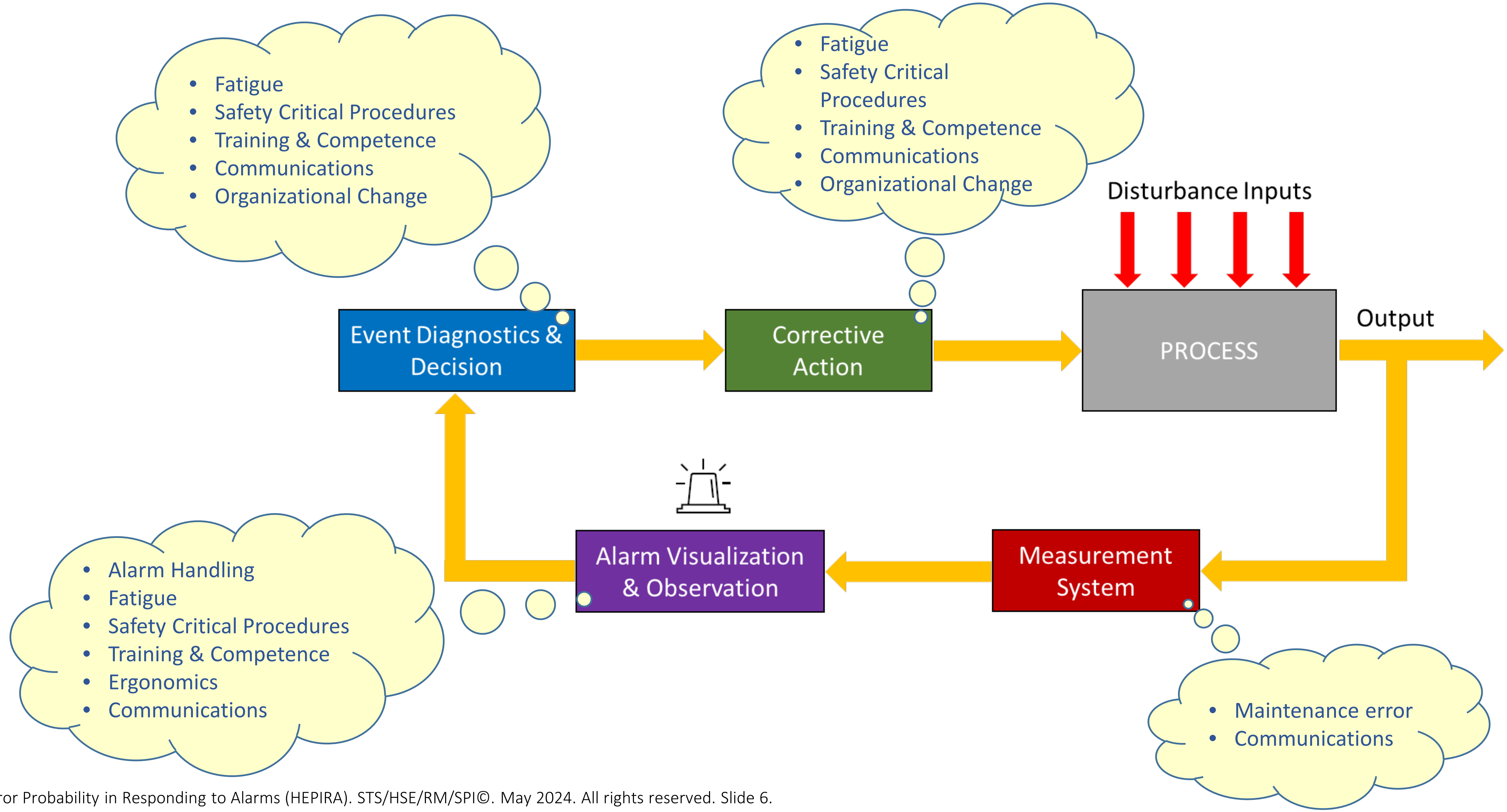
Human response loop

- For operators in a control room reacting to safety alarms, a similar structure can be developed.
- For human performance in responding to alarms, the same requirements as for mechanical/instrumented loops apply: independency, reliability, effectiveness, efficiency, response time, testability, availability, fault tolerance, survivability.
- The effectiveness of human performance in responding to alarms may be affected by numerous organizational and personal factors but also by the environment in which humans are operating.



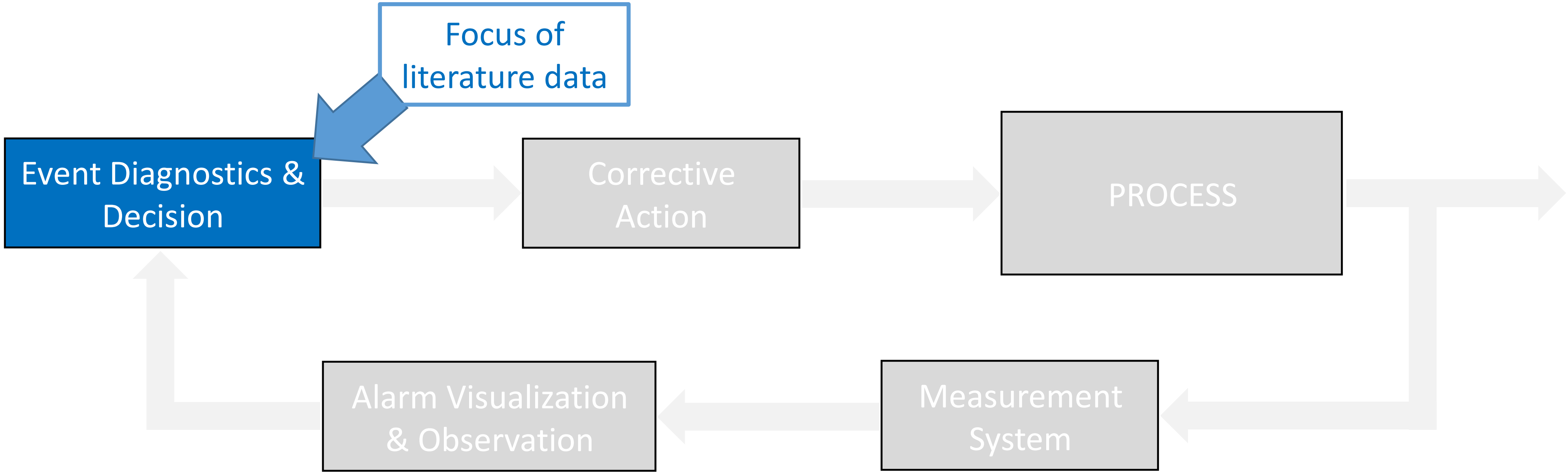
Performance influencing factors

Some of the influencing factors with possible impact on the human response loop are shown in the figure below.



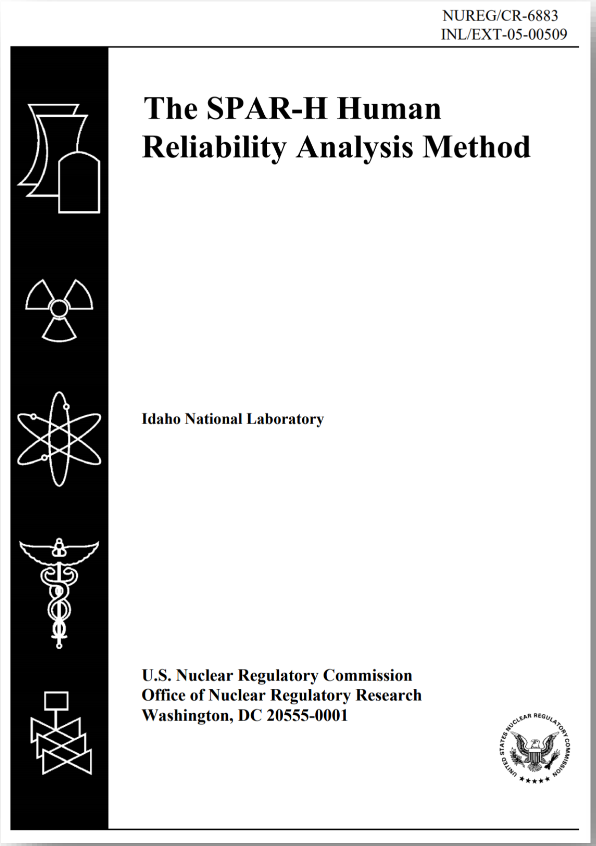
Literature data on human response effectiveness

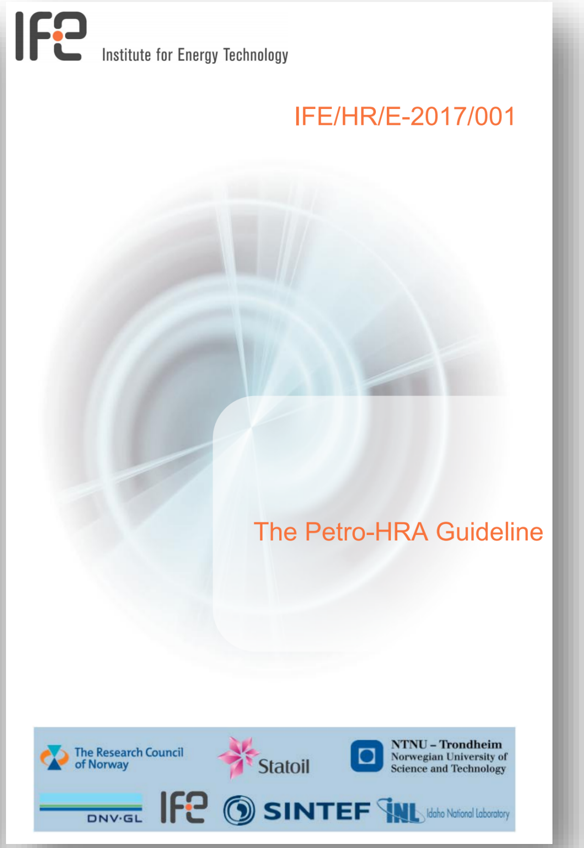
- Data on human error probability are available in literature.
- The human error probabilities reported in literature, expressed as a failure on demand, vary from 10^{-2} to 1.
- However, these data do not reflect the specific circumstances in which humans have to operate and are usually limited to the ability to perform correct diagnostics of a situation and take the right decisions accordingly.
- Other important factors (quality of measurement system, quality of alarm visualization and observation, nature of corrective actions required) affecting the effectiveness of human response are usually not addressed.



Advanced methods

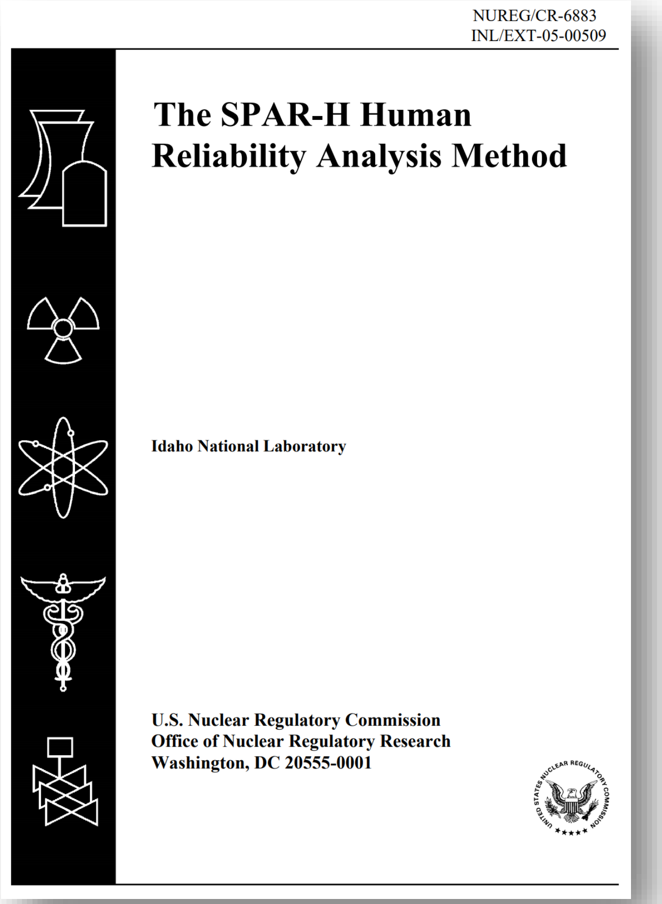
- Advanced methods to address human performance have been developed.
- The application of these methods require a high level of expertise (not very accessible) in assessment of performance shaping factors.
- Two of the most applied advanced methods are SPAR-H and Petro-HRA:
  - ✓ SPAR-H: developed for nuclear energy sector
  - ✓ Petro-HRA: adaptation of SPAR-H for oil & gas industry





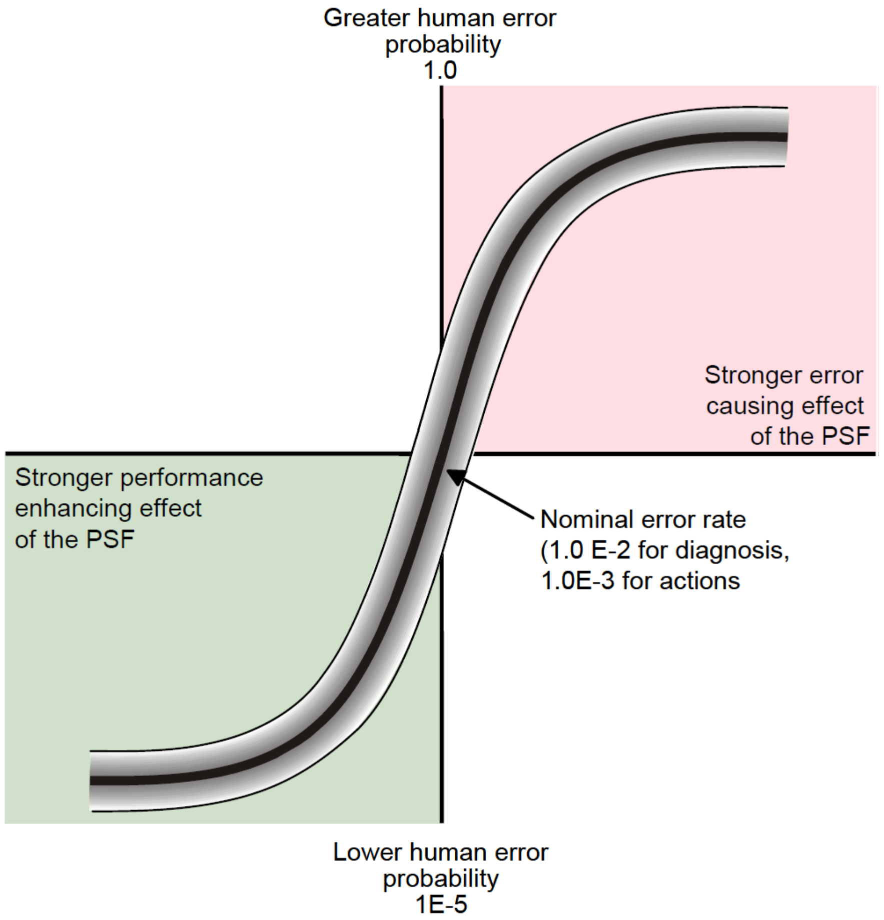
Advanced methods: SPAR-H

- The Standardized Plant Analysis Risk Human Reliability Analysis (SPAR-H) method was developed to support development of plant-specific PRA models for the U.S. Nuclear Regulatory Commission (NRC), Office of Regulatory Research (RES), and has been used to help support the Office of Reactor Regulation (NRR) Reactor Oversight Process (ROP).
- The SPAR-H method presents a HRA method for estimating the human error probabilities associated with operator and crew actions and decisions in response to initiating events at commercial U.S. nuclear power plants (NPPs).
- The basic SPAR-H framework:
    - Decomposes probability into contributions from diagnosis failures and action failures;
    - Accounts for the context associated with human failure events (HFEs) by using performance-shaping factors (PSFs), and dependency assignment to adjust a base-case HEP;
    - Uses pre-defined base-case HEPs and PSFs, together with guidance on how to assign the appropriate value of the PSF;
    - Employs a beta distribution for uncertainty analysis.



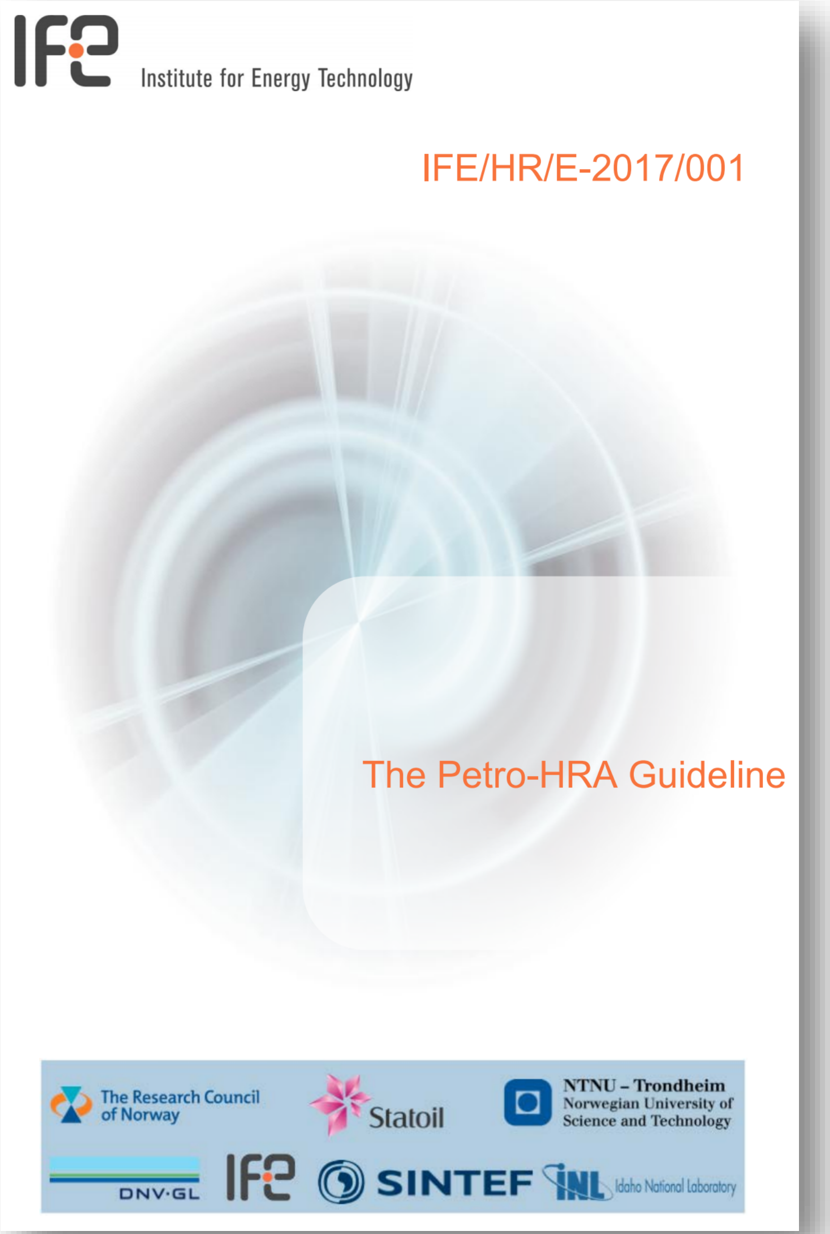
Advanced methods: SPAR-H

- The SPAR-H method is built on an explicit information-processing model of human performance derived from the behavioral sciences literature that was then interpreted in light of activities at nuclear power plants (Blackman and Byers 1994).
- In 1999, further research identified eight performance shaping factors (PSFs) capable of influencing human performance. These PSFs are accounted for in the SPAR-H quantification process.
- These factors include:
  - Available time;
  - Stress and stressors;
  - Experience and training;
  - Complexity;
  - Ergonomics (including the human-machine interface);
  - Procedures;
  - Fitness for duty;
  - Work processes.



Advanced methods: Petro-HRA

- The Petro-HRA method (Institute for Energy Technology, 2017) has been developed in an R&D project called "Analysis of human actions as barriers in major accidents in the petroleum industry, applicability of human reliability analysis methods",
- The aim of the Petro-HRA project was to test, evaluate and adjust a suitable HRA method to post-initiating events in the petroleum industry.
- This project chose the Standardized Plant Analysis Risk-Human Reliability Analysis, or SPAR-H method (Gertman, Blackman, Marble, Byers & Smith, 2005), as the primary method to adjust to the petroleum industry.
- The Petro-HRA method should be used to qualitatively and quantitatively assess the likelihood of human failure. The main purpose of quantitative analysis is to identify which tasks are most sensitive to human error, and which performance-shaping factors have the greatest influence on error probability.



Advanced methods: Petro-HRA

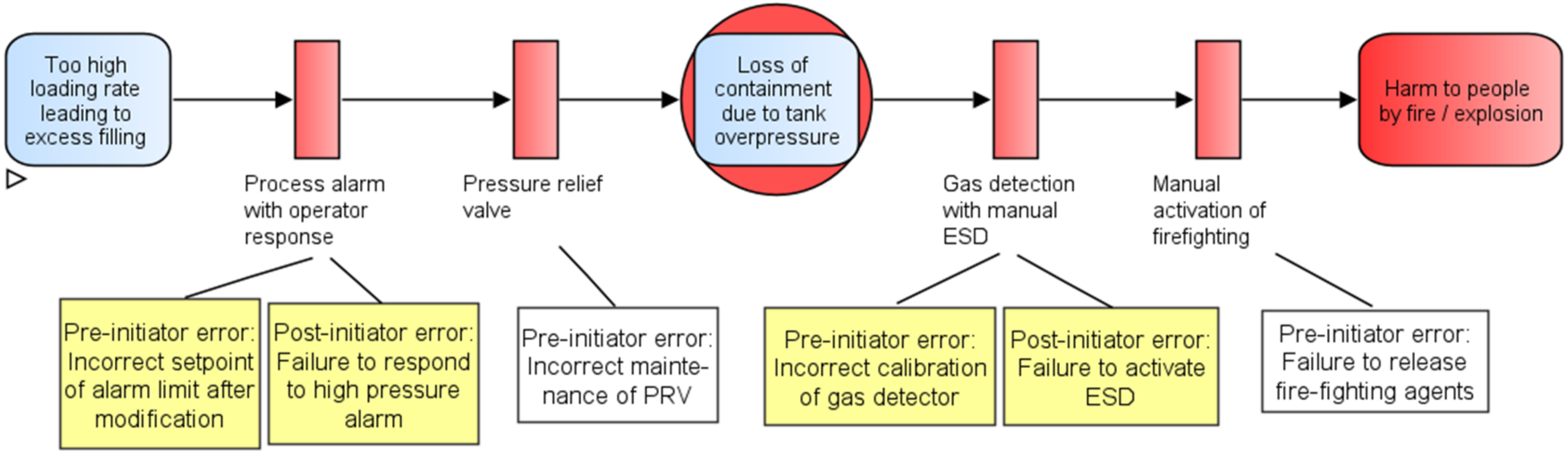
- The Petro-HRA method consists of the following steps:
  - **Scenario definition.** The scenario definition defines the scope and boundaries of the analysis and shapes the subsequent qualitative and quantitative analyses.
  - **Qualitative data collection.** Collect specific and focused data from site visits, interviews and discussions with operators and documentation reviews, to enable a detailed task description
  - **Task analysis.** Describe the steps (i.e. human actions) that are carried out as part of an activity.
  - **Human error identification.** Identify potential errors associated with task steps in the scenario, describe the likely consequences of each error, identify recovery opportunities, and describe the performance shaping factors (PSFs) that may have an impact on error probability.
  - **Human error modelling.** Model the tasks in such a way that when individual tasks are quantified according to Step 6, the model logic can be used to calculate the HEP for the HFE that is then input to the QRA.
  - **Human error quantification.** Quantify each chosen task or event based on a nominal value and a set of PSFs. Check the reasonableness of the HEPs.
  - **Human error reduction.** Develop risk-informed improvement initiatives to reduce the human contribution to risk.

PetroHRA

Petro-HRA PSF summary worksheet			
Facility/installation		**Date**	
HFE ID & description			
HFE scenario			
Analysts			
HEP Calculation			
PSFs	**PSF levels**	**Multiplier**	**Substantiation: Specific reasons for selection of PSF level**
Available time	Extremely high negative	HEP=1	
	Very high negative	50	
	Moderate negative	10	
	Nominal	1	
	Moderate positive	0.1	
	Not applicable	1	
Threat stress	High negative	25	
	Low negative	5	
	Very low negative	2	
	Nominal	1	
	Not applicable	1	
Task complexity	Very high negative	50	
	Moderate negative	10	
	Very low negative	2	
	Nominal	1	
	Moderate positive	0.1	
	Not applicable	1	
Experience/training	Extremely high negative	HEP=1	
	Very high negative	50	
	Moderate negative	15	
	Low negative	5	
	Nominal	1	
	Moderate positive	0.1	
	Not applicable	1	
Procedures	Very high negative	50	
	High negative	20	
	Low negative	5	
	Nominal	1	
	Low positive	0.5	
	Not applicable	1	
Human-machine interface	Extremely high negative	HEP=1	
	Very high negative	50	
	Moderate negative	10	
	Nominal	1	
	Low positive	0.5	
	Not applicable	1	
Attitudes to Safety, Work and Management Support	Very high negative	50	
	Moderate negative	10	
	Nominal	1	
	Low positive	0.5	
	Not applicable	1	
Teamwork	Very high negative	50	
	Moderate negative	10	
	Very low negative	2	
	Nominal	1	
	Low positive	0.5	
	Not applicable	1	
Physical working environment	Extremely high negative	HEP=1	
	Moderate negative	10	
	Nominal	1	
	Not applicable	1	

HEPIRA

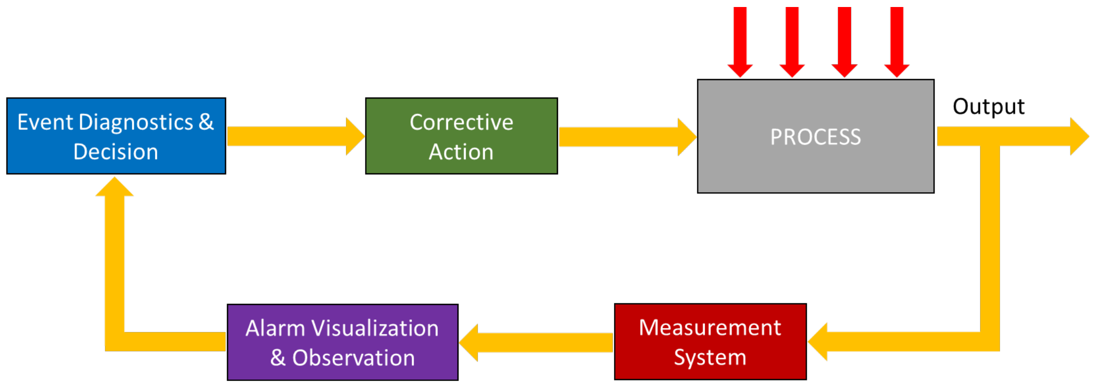
- Existing methods for assessment of human error probability are or very coarse (use of generic literature data, addressing part of the human response loop) or very complex (SPAR-H, Petro HRA).
- A pragmatic method, addressing all components of the human response loop, is needed for assessment of human error probability.
- As a response to this need, HEPIRA was developed in TotalEnergies.
- HEPIRA is a procedure for quantitative evaluation of the human error probability by operators in responding to process and fire & gas alarms, as part of a safety barrier.



The safety barriers in yellow are within the scope of the HEPIRA method.

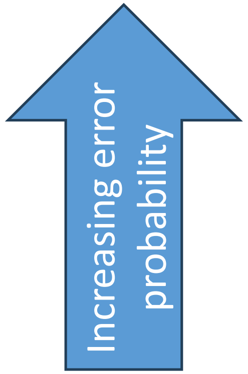
HEPIRA

- HEPIRA proposes a procedure based on the verification of specific conditions affecting the human error probability in responding to alarms. These conditions are verified using several questions related to:
  1. The quality of the measurement system
  2. The quality of alarm visualization and alarm observation
  3. The effectiveness event diagnostics
  4. The effectiveness of decision making
  5. The effectiveness of corrective action



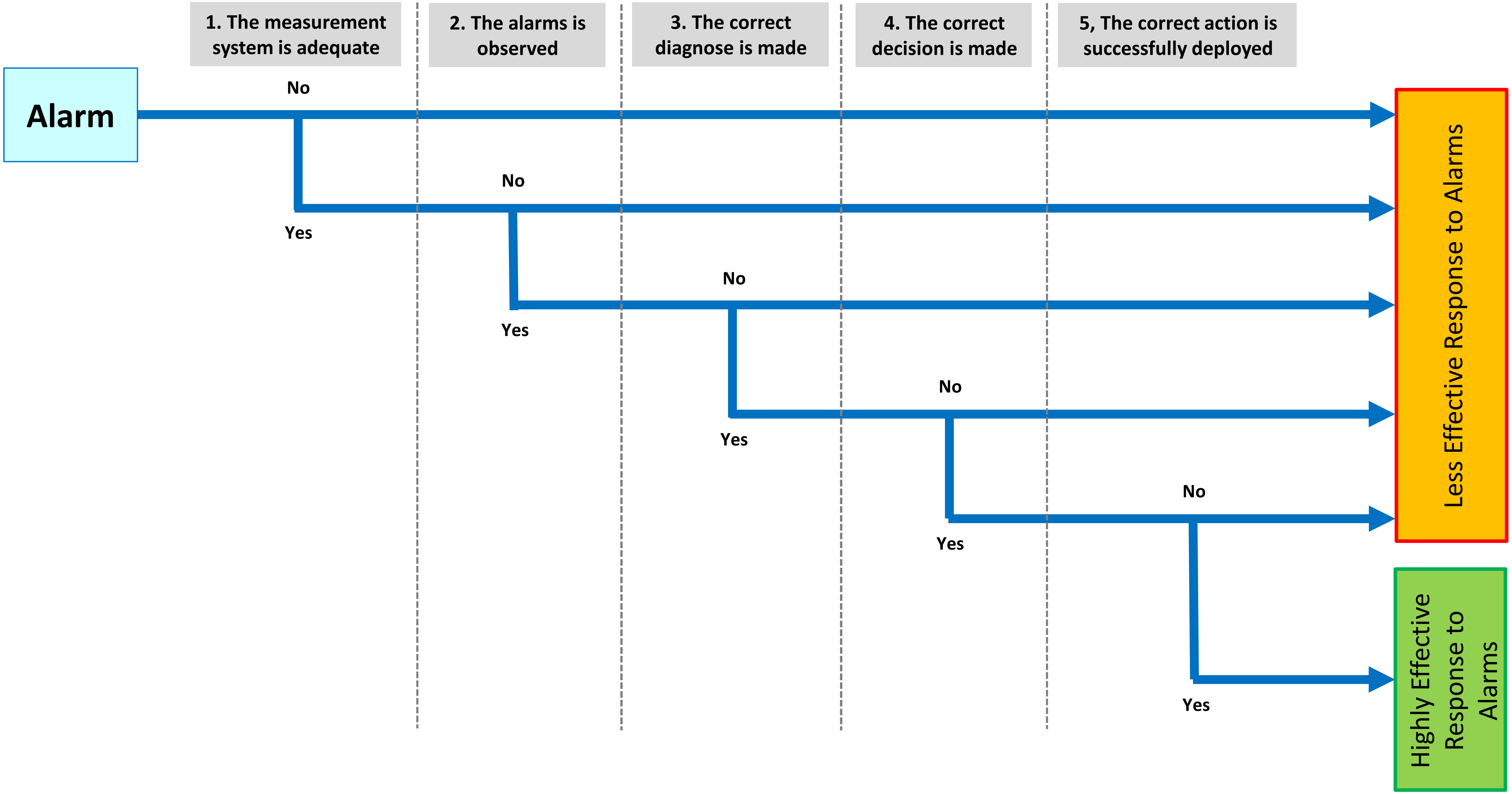
- A criticality level was associated with each of the 26 conditions following the definitions in the table below.

Criticality of Condition	Description
Critical (C)	This condition is a must. Without this critically important condition, no credit can be given for human response to alarms
Major (M)	This condition has a major impact on the effectiveness of human response
Important (I)	This condition has a high impact on the effectiveness of human response
Significant (S)	This condition might affect the effectiveness of human response significantly



- As a function of the status of these 26 conditions, a quantitative evaluation of the PFD of the human response loop is made.

HEPIRA: conditions impacting human error probability



HEPIRA: possible situations

The following situations were identified:

Case	Event triggering the alarm	Action in the field
1	*Simple and easy to understand* *(situation that doesn't involve multiple alarms and/or troubleshooting and does not cause a high-stress situation)*	Not required
2		Required
3	*Not easy to understand* *(involving multiple alarms and/or requiring troubleshooting and causing a high-stress situation)*	Not required
4		Required

For each of these situations, relevant questions to understand the status of the conditions is given in the following table.

HEPIRA: questions

C: Critical **S**: Significant
M: Major **I**: Important
NR: Not relevant

			Case 1	Case 2	Case 3	Case 4
1. Measurement System	1.1	The alarm system (sensors) is robust and independent from the BPCS?	S	S	S	S
	1.2	The alarm system is integrated in the BPCS but the initiating event is linked to a different controller on BPCS and the alarm system is independent of other protection layers to manage the event?	C	C	C	C
	1.3	A quality HAZOP study is available including the evaluation of adequacy & appropriate location of sensors/alarms?	C	C	C	C
	1.4	There is a high quality and formalized Management of Change process covering changes in instrumentation (hardware, settings)?	I	I	I	I
	1.5	The measurement system is reliable (not exposed to frequent false alarms) and aligned with operational goals (fit for purpose)?	I	I	I	I
	1.6	There is a dedicated program for testing and maintenance of critical alarms?	M	M	M	M
2. Alarm Visualization & Observation	2.1	The alarm system and control room layout are adequately and ergonomically designed using good industry practices?	S	S	S	S
	2.2	Operators are periodically (re)trained in understanding and working with the alarm system?	M	M	M	M
	2.3	There is a high-quality process for managing bypassing of alarms and for management of modifications pertaining to the alarm visualization (hardware, settings)?	M	M	M	M
	2.4	Qualified operators are continuously present in the control room?	C	C	C	C
	2.5	The configuration of the alarm system (noise, light, vibration level) and the organisation of the alarm management (fatigue, distraction) allows for rapid observation of this alarm?	M	M	M	M
3. Event Diagnostics	3.1	Operators have extensive knowledge of the process and are trained individually and collectively to react adequately to this process deviation?	M	M	M	M
	3.2	If the event is triggered by error of an operator, the diagnostics following the alarm are performed by a different operator?	NR	NR	C	C
	3.3	If the event is triggered by error of an operator and the diagnostics need to be performed by the same operator, will he be able to correctly interpret, diagnose and recover the situation?	C	C	NR	NR
	3.4	There is an Alarm Management/Prioritization System or a decision aid system to treat complex situations and to guide operators?	NR	NR	M	M
	3.5	Operators are trained in using the Alarm Management System?	NR	NR	M	M
	3.6	The physical environment allows rapid diagnostics (fatigue, noise, light, vibration, distraction)?	M	M	M	M
4. Decision Making	4.1	The chain of command is well defined, communicated and understood?	I	I	I	I
	4.2	The physical environment allows rapid decision-making (fatigue, noise, light, vibration, distraction…)?	I	I	I	I
	4.3	There is time and the possibility to discuss the situation with other operators/supervisors/managers to take appropriate action?	NR	NR	M	M
5. Corrective action	5.1	The Process Safety Time is fully defined and understood and is at least twice the time needed for effective intervention and longer than 2 minutes?	C	C	C	C
	5.2	The Process Safety Time is very long (hours)?	S	S	S	S
	5.3	There is sufficient time to discuss the intervention strategy with others?	NR	I	NR	I
	5.4	There are sufficient resources (people, systems) to manage the situation in the field?	NR	C	NR	C
	5.5	There is a dedicated program for testing and maintenance of systems (access, intervention) needed to manage the situation in the field?	NR	I	NR	I
	5.6	The corrective action or the conditions under which these actions need to be performed are: simple, moderately complicated or complex ?	NR	S	NR	S

Case 1	The event triggering the alarm is a simple and easy to understand event (not a complex situation involving multiple alarms and/or requiring troubleshooting and not causing a high-stress situation) and does not require action in the field.
Case 2	The event triggering the alarm is a simple and easy to understand event (not a complex situation involving multiple alarms and/or requiring troubleshooting and not causing a high-stress situation) requiring action in the field.
Case 3	The event triggering the alarm is a complex situation (involving multiple alarms and/or requiring troubleshooting and not causing a high-stress situation) but does not require action in the field.
Case 4	The event triggering the alarm is a complex situation (involving multiple alarms and/or requiring troubleshooting and not causing a high-stress situation) and requires action in the field.

Assessment of Conditions Impacting Human Response Effectiveness

HEPIRA

Human Error Probability In Responding to process Alarms

For guidance, contact E. Janssens (els.janssens@totalenergies.com), O. Iddir (olivier.iddir@totalenergies.com) or D. Roosendans (dirk.roosendans@totalenergies.com)

Case 1: The event triggering the alarm is a <u>simple and easy to understand event</u> (not a complex situation involving multiple alarms and/or requiring troubleshooting and not causing a high-stress situation) and <u>does not require action</u> in the field

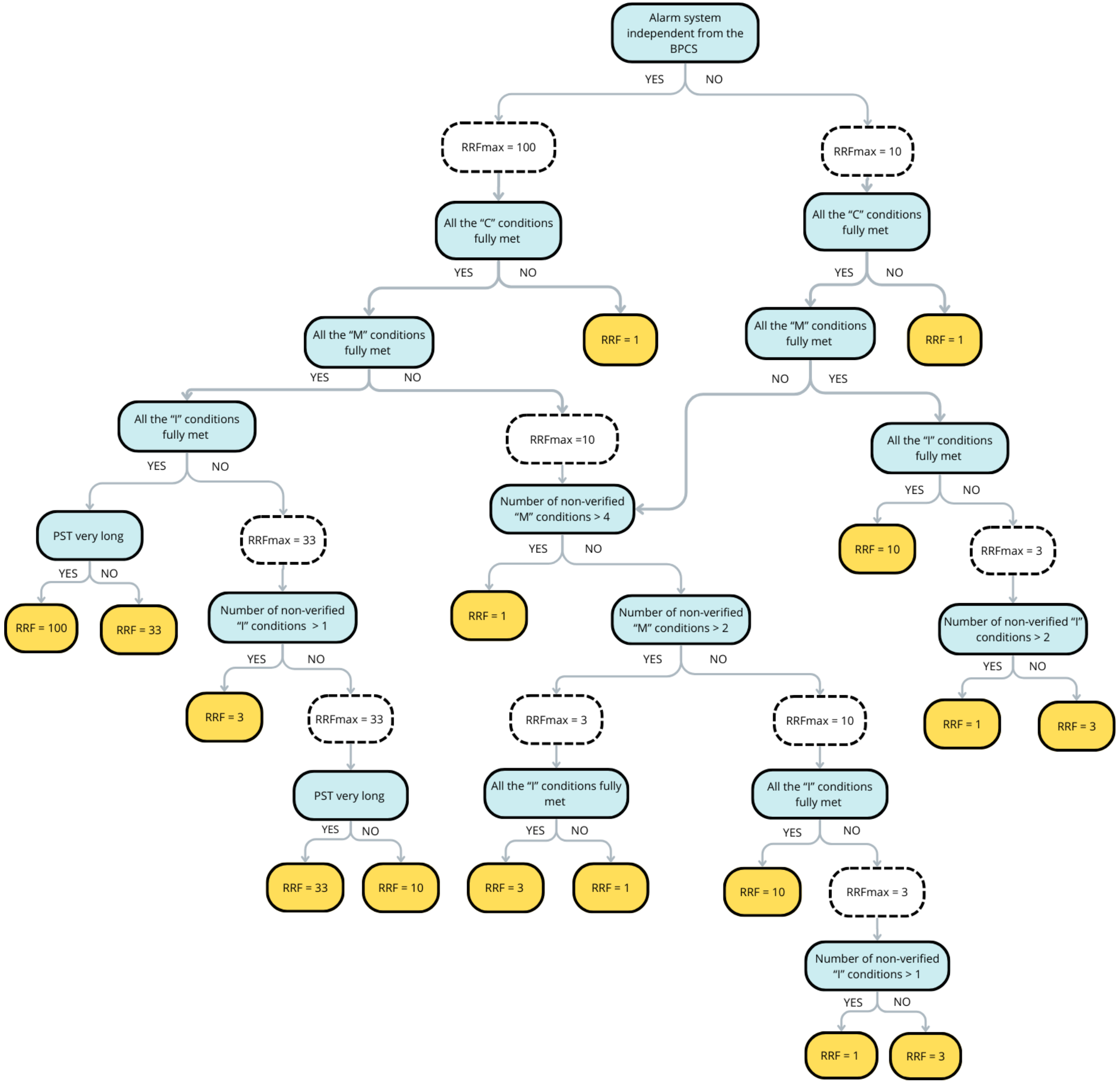
Description of safety barrier loop:

	Use of the tool: answer the below 18 questions and click the button at the end of the list to calculate the appropriate PFD	Comments
1.1	The alarm system (sensors) is robust and independent from the BPCS? ○ No ○ Yes, but not proven ◉ Yes, and proven ?	Proof = Formal documentation from E&I that the alarm system is independent from the Basic Process Control System
1.2	The alarm system is integrated in the BPCS but the initiating event is linked to a different controller on the BPCS and the alarm system is independent of other protection layers to manage the event? ○ No ○ Yes, but not proven ◉ Yes, and proven ?	Proof = Formal documentation from E&I validating the independence between alarm (sensor + CPU + BPCS input card) and initiating event, as well as the independence from other protection layers
1.3	A quality HAZOP study is available including the evaluation of adequacy & appropriate location of sensors/alarms? ○ No ○ Yes, but not proven ◉ Yes, and proven ?	Proof = HAZOP report, as well as lay-out evaluation of adequacy & appropriate location of sensors/alarms
1.4	There is a high quality and formalized Management of Change process covering changes in instrumentation (hardware, settings)? ○ No ◉ Yes, and proven ?	Proof = MOC procedure including instrumentation changes
1.5	The measurement system is reliable (not exposed to frequent false alarms) and aligned with operational goals (fit for purpose)? ○ No ◉ Yes	
1.6	There is a dedicated program for testing and maintenance of critical alarms? ○ No ○ Yes, but not certified ◉ Yes, and certified ?	Proof = Performance standard for critical alarm
2.1	The alarm system and control room layout are adequately and ergonomically designed using good industry practices? ○ No ◉ Yes	

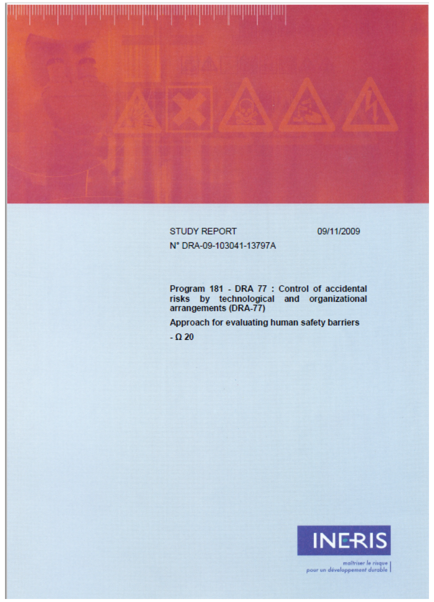
Risk reduction factors for Case 1

Case 1

The event triggering the alarm is a simple and easy to understand event *(not a complex situation involving multiple alarms and/or requiring troubleshooting and not causing a high-stress situation)* and does not require action in the field.



Comparison with Omega20



Reference: *INERIS - Démarche d'évaluation des Barrières Humaines de Sécurité - Ω 20 (2009)*

- Why this comparison ?
  Need for calibration of HEPIRA method

- Why Ω20 ?
  - Philosophy close to GM : Human response = detection + treatment + action
  - Gives Risk Reduction Factor estimation of (1 ; 10 ; 100) based on following influencing factors
    - ❖ DETECTION: complexity of event & operator presence
    - ❖ DIAGNOSTIC: quality of information and support for diagnostic
    - ❖ ACTION: stress level & complexity of corrective action
  - INERIS method recognized by French authorities for quantitative evaluation of human safety barriers

- 4 HEPIRA cases tested
  -> Convergence of results between the 2 approaches

Ω 20 extract for detection (passive)

4.3.1.1 "PASSIVE DETECTION"

Downrating	Characteristics of the work situation
0	Information clearly perceivable and identifiable: Information available in a hierarchical way (for example: a dedicated visual and sound alarm clearly distinct from the other types of alarms) giving the condition of the system, regardless of the environmental conditions (night, fog, …) and which would be capable of preventing or hindering perception of this information. AND Total availability of the operator: The operator is present in the location where the information is available and he/she may interrupt any other current activity. The working conditions are favorable to maintaining a good vigilance level.
- 1	Information perceivable and identifiable with moderate difficulty: Information available in a non-hierarchical way in the midst of a limited number of other pieces of information. AND/OR Availability of the operator: The operator is present in the location where the information is available and he/she may be led to managing an acceptable number of other tasks at the same time without questioning his/her perception capabilities.
- 2	Information difficult to perceive and identify: The information embedded in other pieces of information or information which is difficult to detect (localization of the information is not adapted to the activity of the operator, perception which may prove to be difficult, notably under certain environmental conditions or within the scope of the progression of the scenario). OR Low availability of the operator: The operator is seldom present in the location where the information is available or else he/she is present randomly, in an unpredictable way, or he/she may be led to managing a significant number of tasks at the same time.

Conclusion – Aim & benefits HEPIRA

- Harmonize Human Error Probability in Responding to safety and fire & gas Alarms estimation in company Process Hazard Analyses
  -> provide more homogeneous LOPA & SIL allocation results

- Pragmatic and less time consuming than other HRA techniques
- Bridging the gap between HRA and PHA

- Raise awareness of PHA participants of performance shaping factor influence on human safety barrier reliability
- Highlight & mitigate the relevant areas that negatively influence human actions
- A qualitative review of the 26 questions enables the identification of opportunities to reduce operator error by optimizing the entire loop (measurement system, alarm visualization, event diagnostics, decision making, corrective action)

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danke
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