LAYERS OF PROTECTION ANALYSIS FOR HUMAN FACTORS (LOPA-HF)

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ASSE Symposium on

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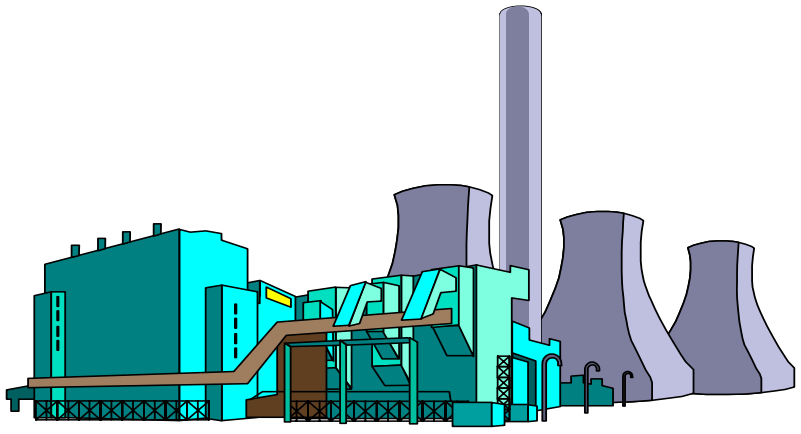


PREMISE

- Plethora of human error classification schemes and human factors models
- Importance of human error contributions to accidents in process plants is well recognized
- Large body of knowledge on human errors/factors
- Few companies have applied it to their existing plants
  - or designs for new ones

WHY NOT?

CONTRIBUTING REASONS

- Language of human factors not understood
- Potential benefits not recognized
- Cost of studies
- Acceptance of a culture of blame
  - i.e. fix people, not the process
- Discomfort with a field that sounds “touchy-feely”

“Most human beings have an almost infinite capacity for taking things for granted.”

Aldous Huxley

CONTRIBUTING REASONS (CONTD.)

- Absence of
  - human factors framework to which plants can relate
  - simple and straightforward methods
  - how to fix human factors problems

CONTRIBUTING REASONS (CONTD.)

- Field seems so broad it appears overwhelming
- Existing safety programs viewed as adequate
- Perceived to benefit only safety
  - not productivity, operability, quality, etc.
- Value not convincingly demonstrated

“Minds are like parachutes; they work best when open.”

Lord Thomas Dewar

CONTRIBUTING REASONS (CONTD.)

- Plants do not have the time or resources
  - overwhelmed with other programs
  - thinly staffed
  - operating in a highly competitive environment
- No imperatives, or motivating factors
  - contributions to financial performance
  - regulations

PATH FORWARD

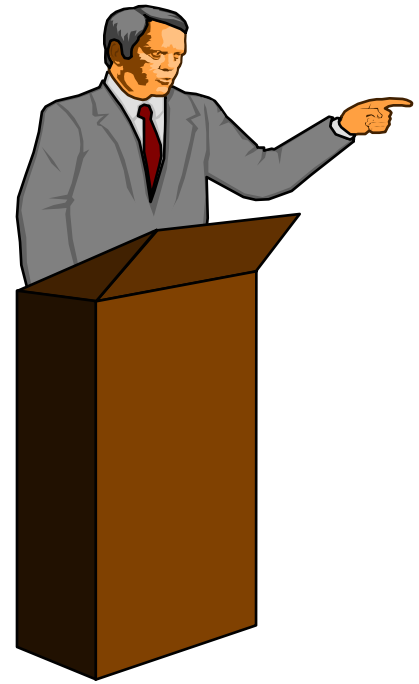
- Many companies covered by PSM/RMP
- Process hazard analysis (PHA) required
- "The PHA shall address human factors"
- Present approaches only pay lip service
- Find a better way to mount HF on this horse
  - LOPA-HF

"To err is human; to forgive, infrequent."

Franklin P. Adams

OVERVIEW

- Causes of process accidents
- Human factors in PHA
- Human factors models
- LOPA-HF
- Example

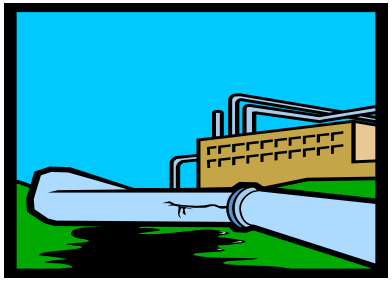


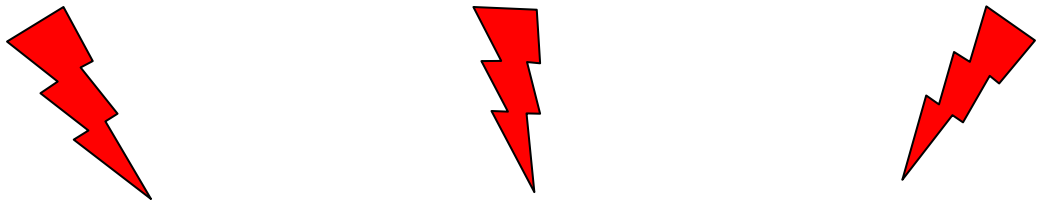
PROCESS ACCIDENTS

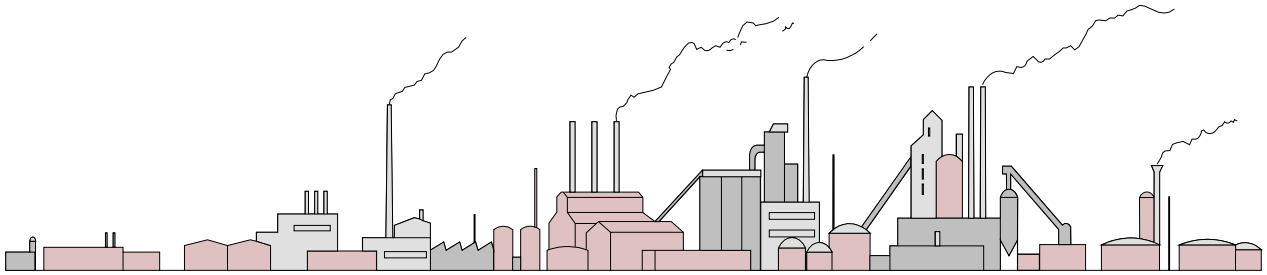
Equipment Failures

Human Failures

External Events



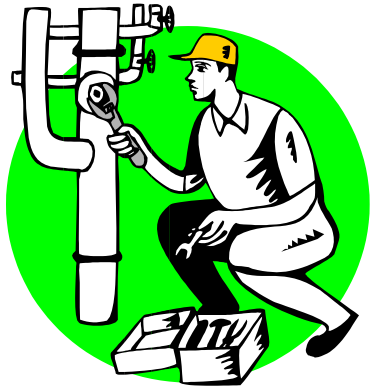


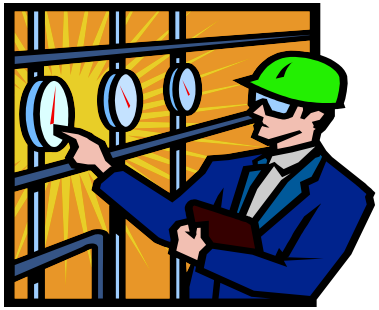


Generally believed that 50 – 90% of all accidents are caused by human failures

HUMAN FACTORS IN PHA

- Account for human failure as a cause of hazard scenarios
  - "Human errors"
- Consider factors that impact human performance
  - "Human Factors"





OSHA PHA CITATIONS

May 26, 1992 – September 30, 2002

code of federal regulations

(e)(1) Initial PHA	680
(e)(2) Methodology	32
(e)(3) PHA shall address (general)	60
(e)(3)(i) Hazards of process	77
(e)(3)(ii) Previous incidents	36
(e)(3)(iii) E&A controls	**72**
(e)(3)(iv) Consequences of failure of E&A controls	**57**
(e)(3)(v) Facility siting	**95**
(e)(3)(vi) Human factors	***80***
(e)(3)(vii) Qualitative evaluation	**33**
(e)(4) Qualified team	**41**
(e)(5) System to address findings	**238**
(e)(6) Revalidate PHA	**39**
(e)(7) Retain for life of process	**19**
Total	1559

HUMAN FAILURES

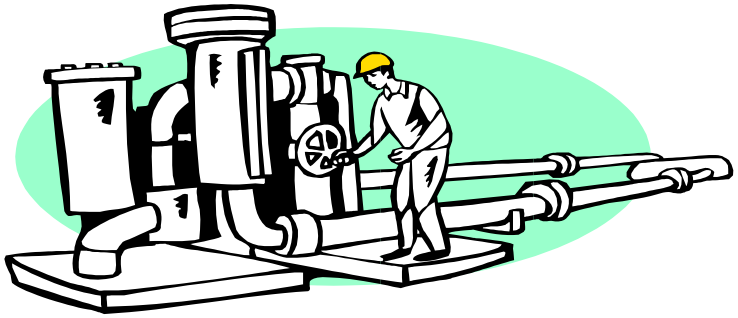
- Acts of omission (something not done)
  - E.g. failure to execute a step in a procedure
- Acts of commission (something done incorrectly)
  - E.g. mechanic closes block valves in both the main line and the bypass

HUMAN FACTORS

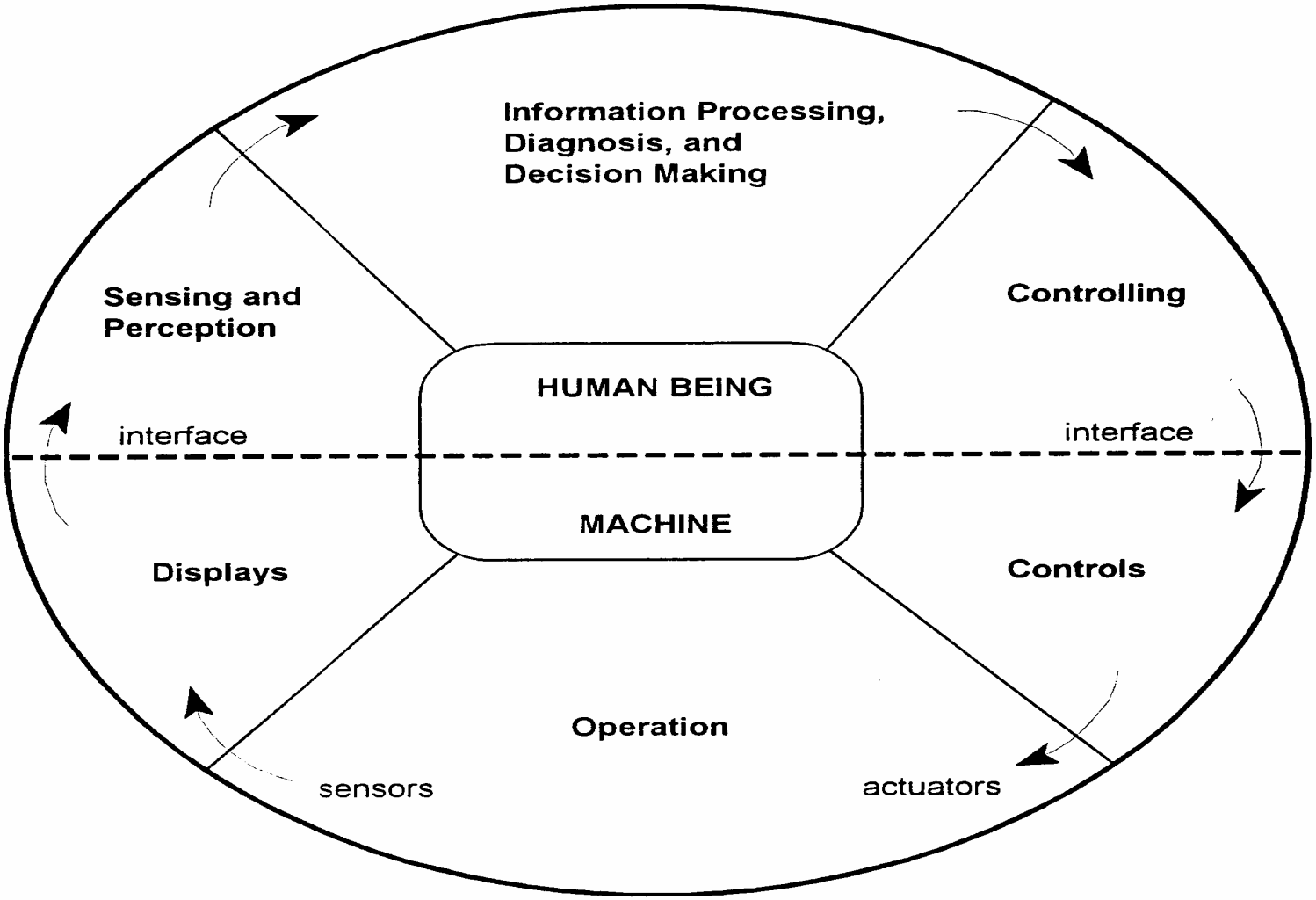
- Don’t confuse human factors in PSM/PHA with OSHA’s ergonomic standard

EXAMPLES OF HUMAN FACTORS FOR PROCESSES

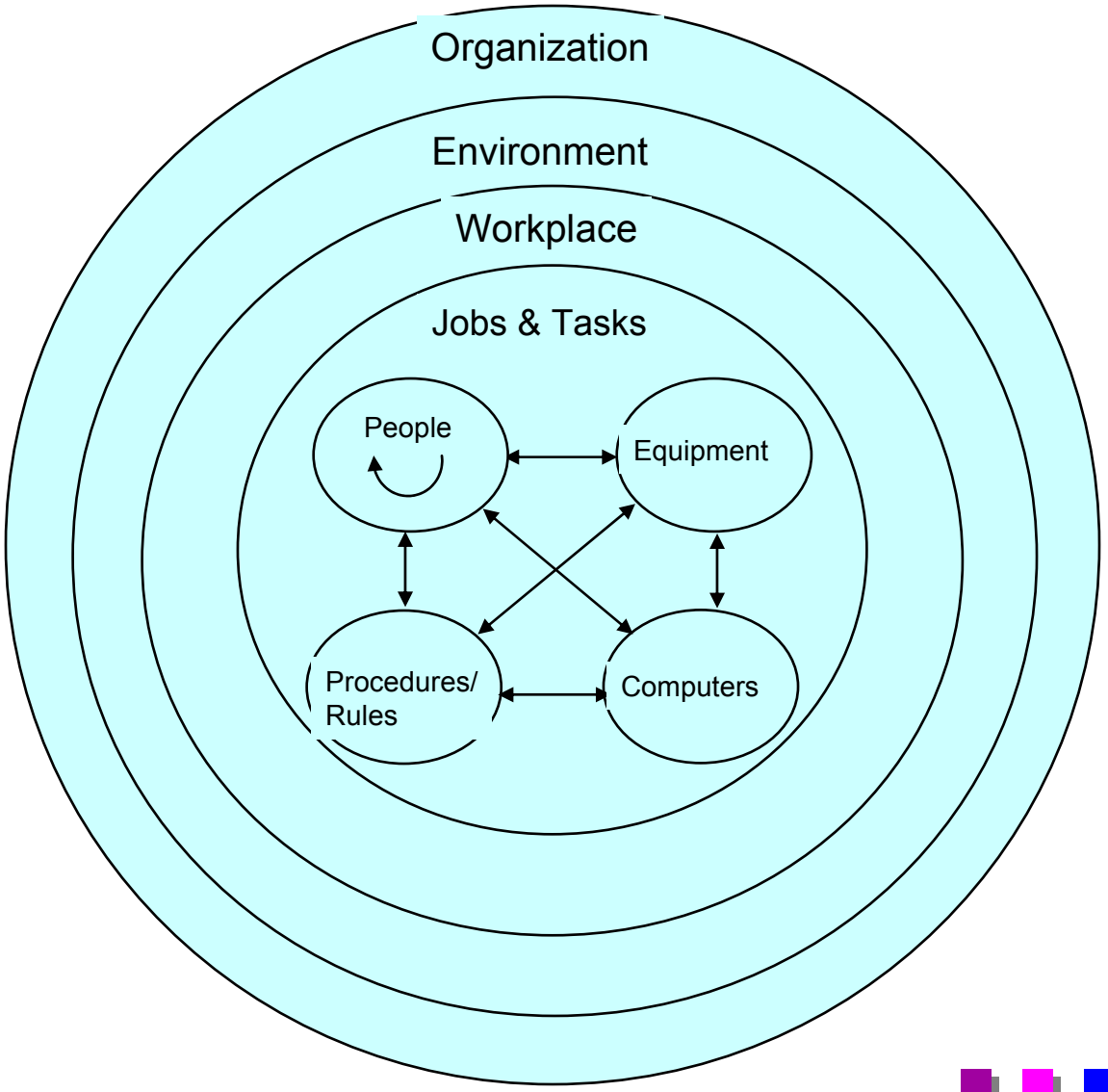
- Operator/process and operator/equipment interface
- Number of tasks operators must perform and their frequency
- Extended or unusual work schedules and shift rotations
- Clarity and simplicity of control displays
- Automatic instrumentation versus manual procedures
- Operator feedback
- Clarity of signs and codes
- Etc.



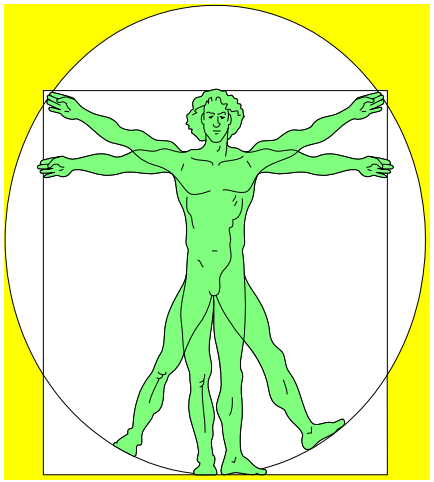
CLASSICAL HUMAN-MACHINE MODEL



WHAT IS A FACILITY?



WHAT IS A HUMAN?



Anthropometry

Gender

Motor

Culture

Senses

Qualifications

Verbal

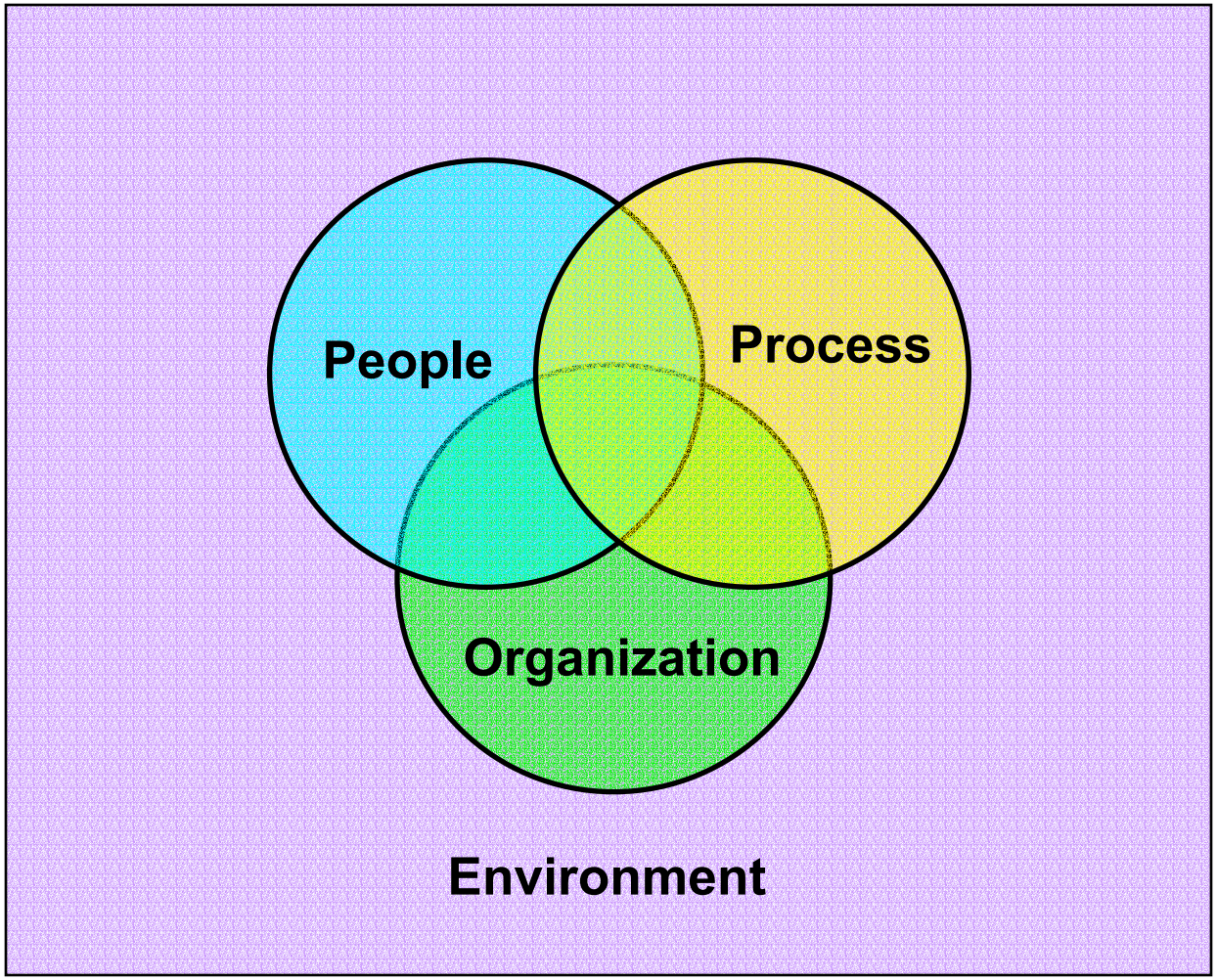
Health

Cognition

Psychology

Physiology

IMPROVED HUMAN FACTORS MODEL



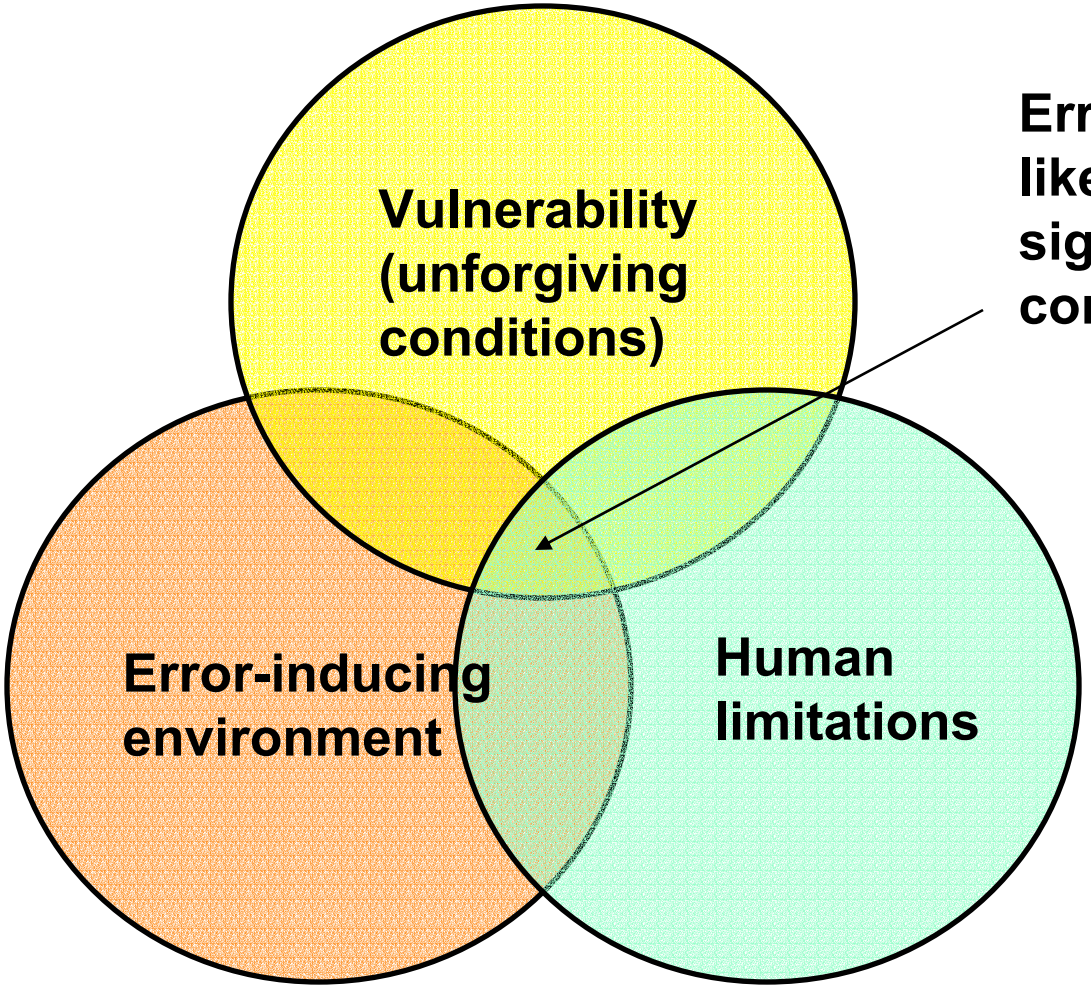
PERSON-PROCESS MATRIX MODEL

PROCESS ATTRIBUTES

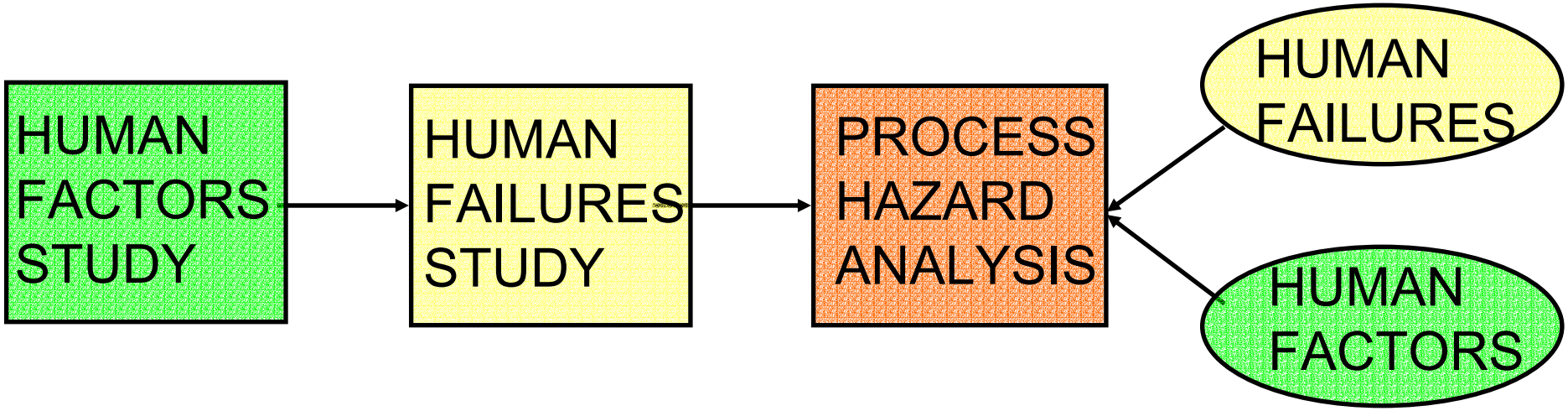
HUMAN ATTRIBUTES

	Equipment	Procedures	Environment	People	Etc.
Skills	X	X	X		
Senses	X	X	X	X	
Strength	X	-	-		
Etc.					

SYSTEMS VIEW OF HUMAN ERROR



TREATMENT OF HUMAN FACTORS IN PROCESS SAFETY



RECOMMENDED DESIRABLE REQUIRED REQUIRED

APPROACHES FOR TREATMENT OF HUMAN FAILURES IN PHA

- Simple brainstorming
- Checklists
- Structured brainstorming

"There are many ways of going forward, but only one way of standing still."

Franklin D. Roosevelt

APPROACHES FOR TREATMENT OF HUMAN FACTORS IN A PHA

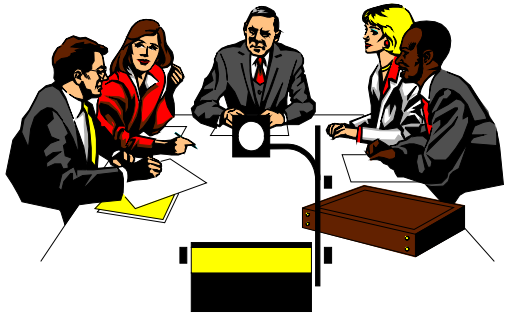
- Checklists
- LOPA-HF

“The only real mistake is the one from which we learn nothing.”

John Powell

HUMAN FACTORS CHECKLISTS

- Disadvantages
  - Lengthy checklists are cumbersome to use and quickly become repetitive and tiresome
  - If the checklists are kept simple, human factors may be missed
  - Do not provide much structure or guidance
  - Produces only a simplistic analysis



LOPA-HF

- Uses the framework of Layers of Protection Analysis (LOPA)
  - Simplified risk assessment method
  - Provides scenario risk estimate
    - objective, rational and reproducible
  - Compares it with risk tolerance criteria to decide if existing safeguards are adequate
  - Studies high risk scenarios from PHA
  - Can be viewed as an extension of PHA

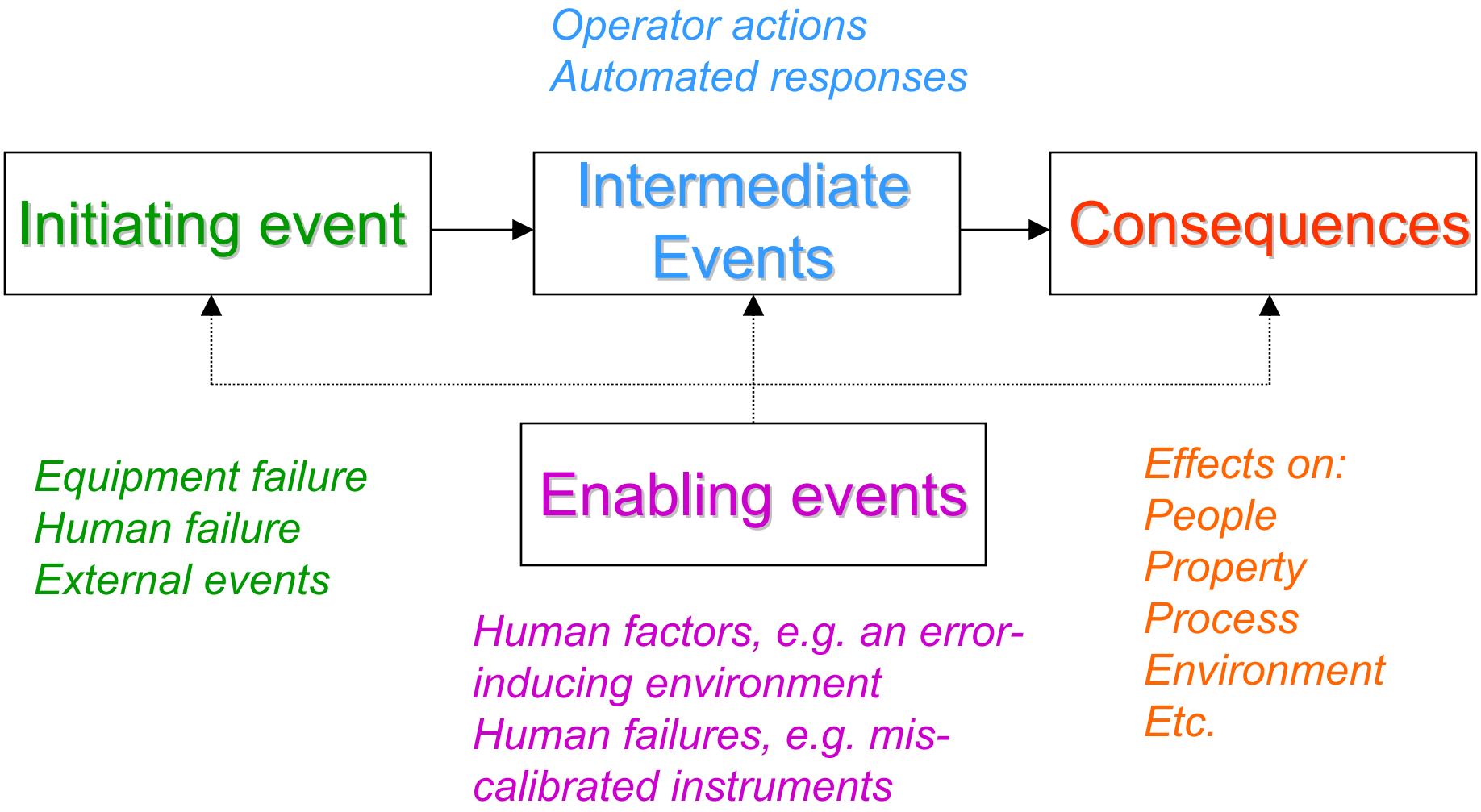
LOPA-HF (CONTD.)

- Human factors are addressed by determining their impact on each individual element of a hazard scenario

"To the man who only has a hammer in the toolkit, every problem looks like a nail."

Abraham Maslow

CONSTITUENT ELEMENTS OF A HAZARD SCENARIO



LOPA-HF (CONTD.)

- Dominant human factors that influence each part of the hazard scenario are identified
  - using simple Issues Lists
- Information is recorded in a worksheet

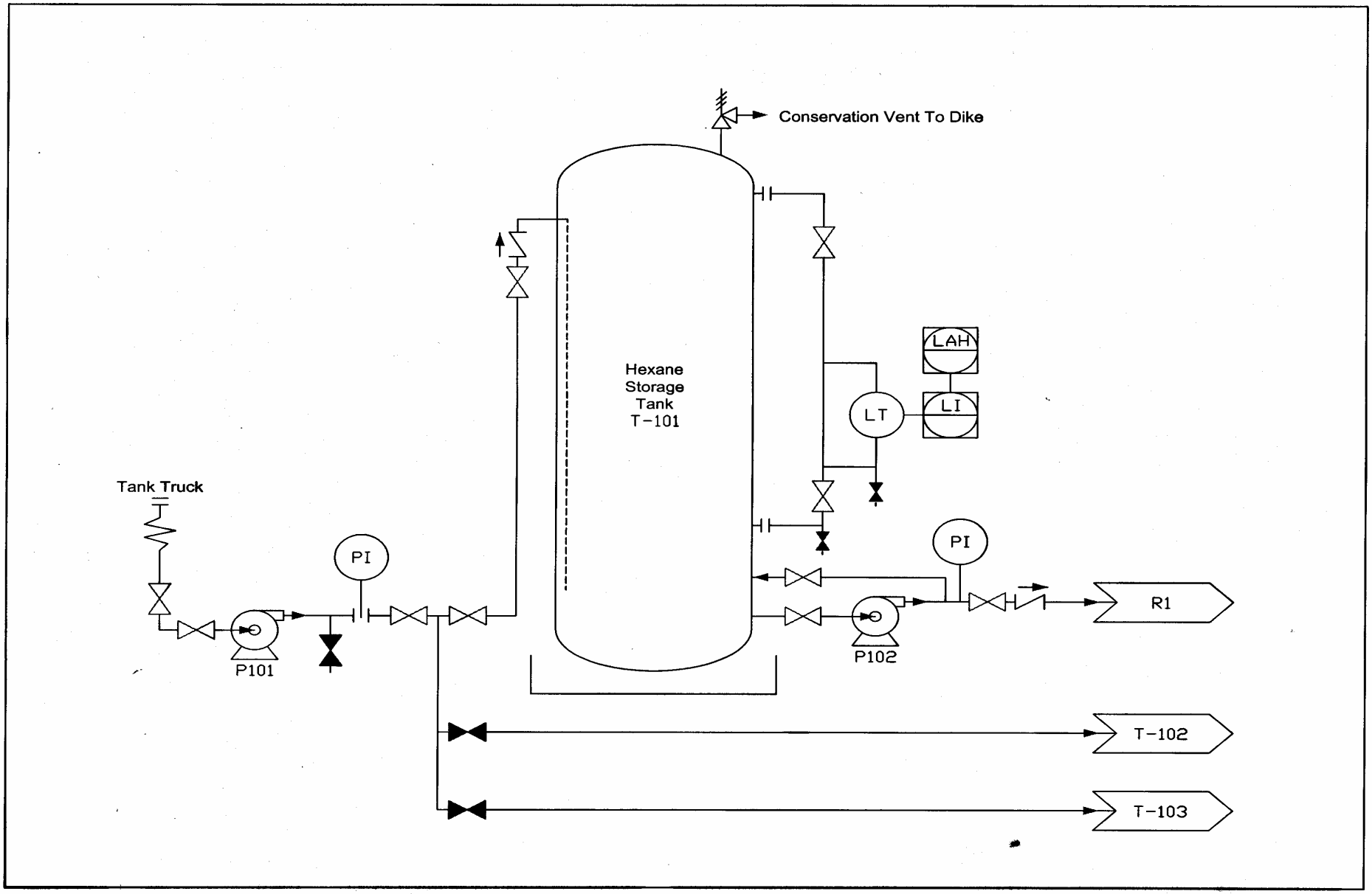
“The mind is not a vessel to be filled but a fire to be kindled.”

Plutarch

ISSUES LISTS

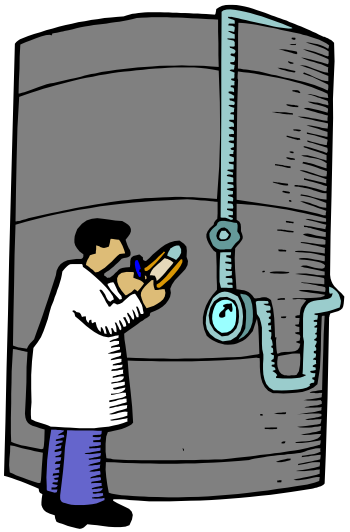
- Each represents part of the body of knowledge on human factors
- Prepared in advance
- Tailored for each situation
  - short
- Provide structure, guidance and completeness
- Allow analysts to focus quickly on the principal human factors issues
  - without the need to wade through a PHA human factors checklist

EXAMPLE OF LOPA-HF APPLIED TO HEXANE UNLOADING



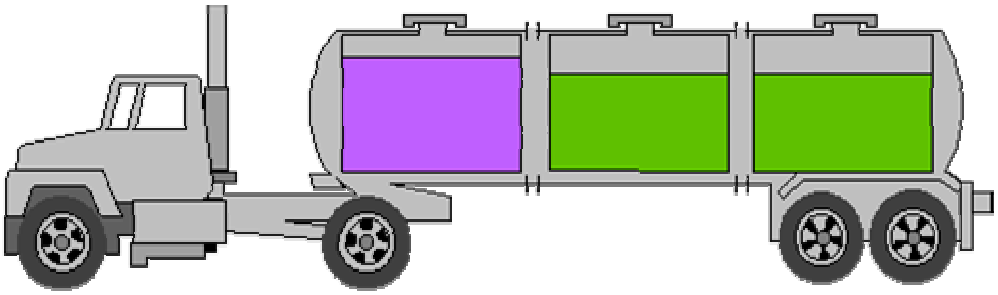
EXAMPLE – KEY POINTS

- Unload hexane from a tank truck into a storage tank using a pump
- Tank surrounded by a dike
  - Equipped with a level indicator and a high level alarm that annunciates in the control room



EXAMPLE – KEY POINTS (CONTD.)

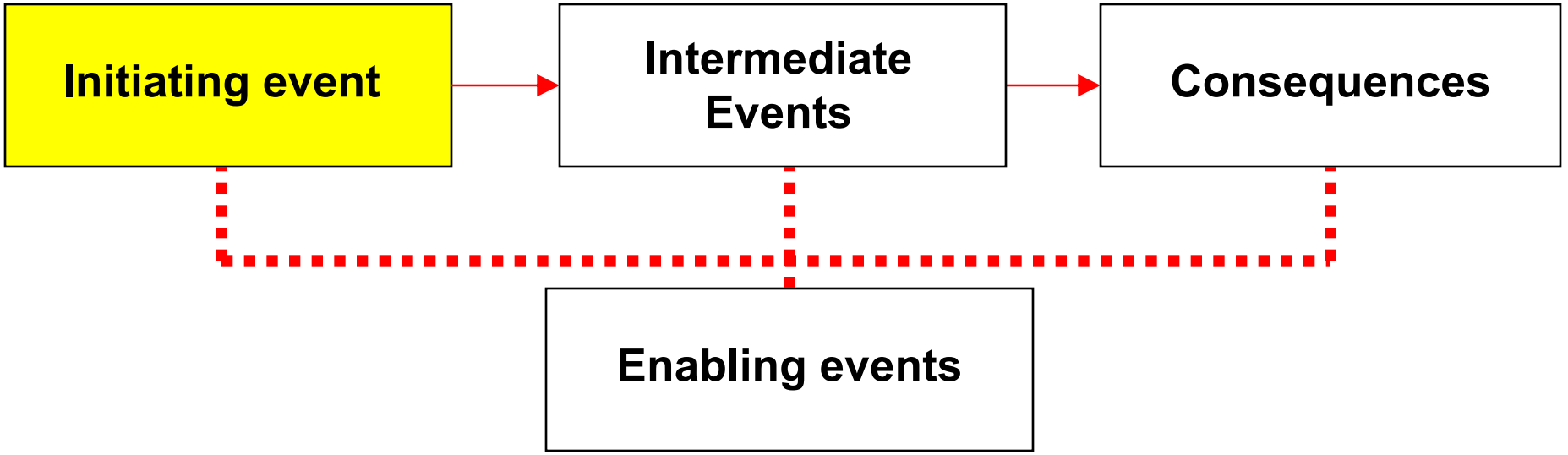
- Two operators involved in the unloading operation
  - Field operator initiates the transfer with the truck driver
  - Control room operator monitors and operates various process functions from a computer console
- Truck driver required to supervise the transfer



EXAMPLE (CONTD.)

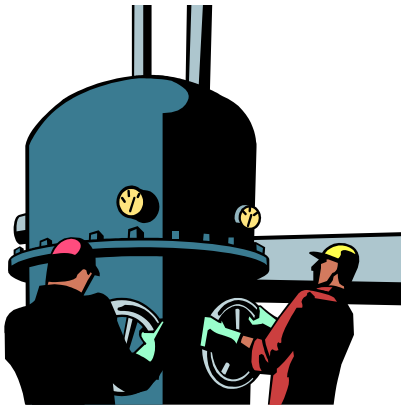
- Scenario considered:
  - Overfilling the hexane storage tank with the spill not contained by the dike

ELEMENTS OF A HAZARD SCENARIO

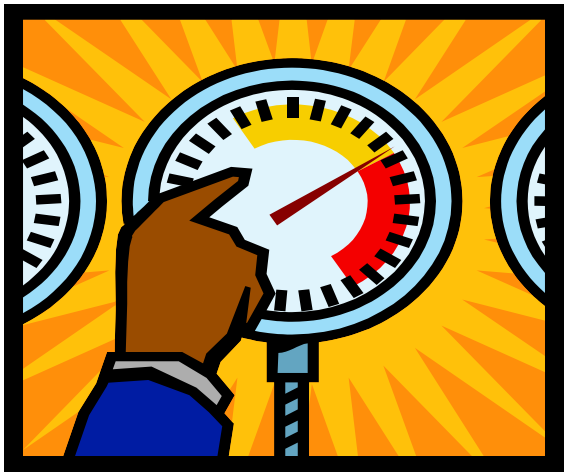


INITIATING EVENT

- “Delivery of hexane when there is insufficient room in the storage tank due to a failure in the inventory control system”
- Issues Lists used to identify
  - dominant human factors contributors to the failure rate
  - existing protective measures
  - recommendations for additional protective measures



HUMAN FACTORS ISSUES LIST – INCORRECT ACTION BY PERSON



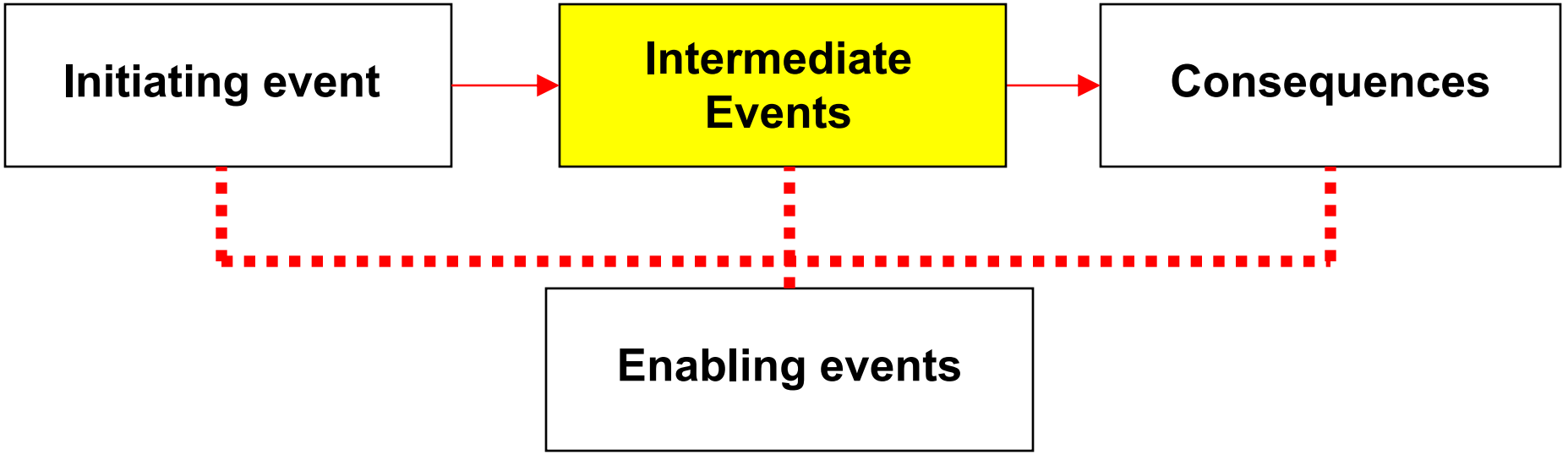
- Work overload/underload
- Insufficient training
- Inadequate skills
- Inadequate resources
- Inadequate procedures
- Inadequate labeling
- Equipment not easily operable
- Displays/controls not visible/heard
- Displays/controls confusing
- Displays/controls not accessible/usable
- Inadequate communications
- Environmental issues (temperature, humidity, light, noise, distractions)
- Error (wrong action, no specific reason)
- Mistake (wrong action, misunderstood)
- Other?

PROTECTIVE MEASURES ISSUES LIST – INCORRECT ACTION BY PERSON

- Training
- Procedures
- Equipment labeled
- Check
- Other?

LOPA - HF WORKSHEET	
Scenario Description: Overfilling the hexane storage tank with the spill not contained by the dike.	
Initiating event: Delivery of hexane when there is insufficient room in the storage tank due to a failure in the inventory control system.	
Human Factors:	Mistake in ordering due to work overload. Mistake in gaging the tank contents due to inadequate training.
Protective Measures:	Unloading procedures. Level indicator. High level alarm.
Recommendations:	Improve training of the operators and the truck driver. Consider installing a high level trip for the feed pump and an inlet shutdown valve to help prevent overfilling accidents.

ELEMENTS OF A HAZARD SCENARIO

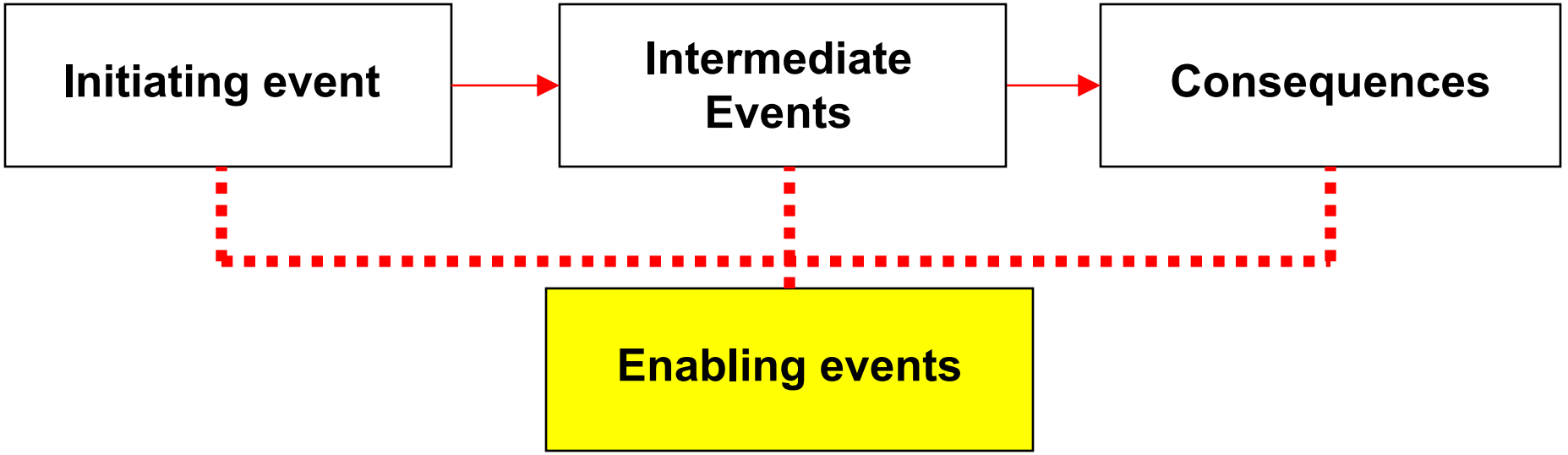


INTERMEDIATE EVENTS

- Include:
  - operator actions
  - automated responses of the process control and safety systems
- Many intermediate events are safeguards that can prevent, detect, or mitigate accidents

LOPA - HF WORKSHEET	
IPL1: Dike	
Human Factors:	None
Protective Measures:	N/A
Recommendations:	N/A
IPL2: Operator response to alarms	
Human Factors:	Inadequately designed computer control interface.
Protective Measures:	Level indicator (weak)
Recommendations:	Consider installing a high level trip for the feed pump and an inlet shutdown valve to help prevent overfilling accidents.

ELEMENTS OF A HAZARD SCENARIO



ENABLING EVENTS/CONDITIONS

- Do not directly cause the hazard scenario
  - Make possible another event in the scenario

"I hear and I forget. I see and I remember. I do and I understand."

Confucius

ENABLING EVENTS/CONDITIONS (CONTD.)

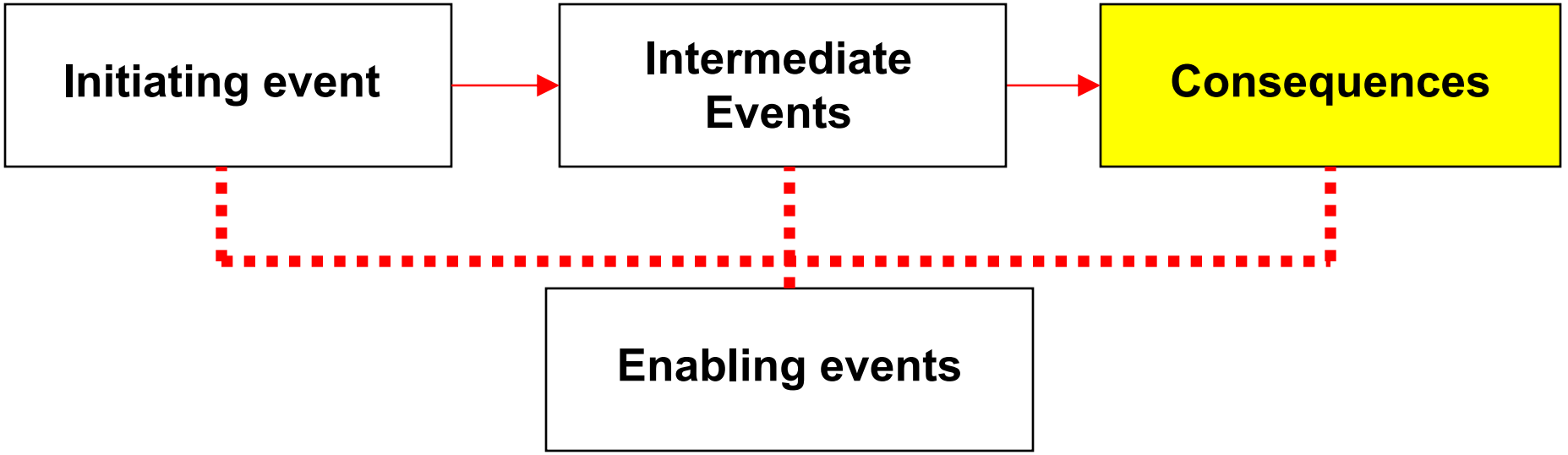
- Frequently influenced by human factors, e.g.
  - An error-inducing environment, e.g. work overload
  - Deliberate actions, e.g. disabled alarms
  - Human failures, e.g.
    - Mis-calibrated instruments
    - Incorrect maintenance that leaves the process in an undetected unsafe state

ENABLING EVENTS / CONDITIONS ISSUES LIST

- Installation of incorrect seals, gaskets, etc.
- Process left in incorrect state after turnaround, maintenance, sampling, or other operation
- Disabled alarms
- Overrides
- LOTO not effected
- Startup/shutdown/operating/emergency mode, etc.
- Other?

LOPA - HF WORKSHEET	
Enabling event/condition: High temperature alarm overridden	
Human Factors:	Alarm left inoperable after process adjustments owing to the lack of a check.
Protective Measures:	None.
Recommendations:	Revise the process optimization procedure to confirm operation of the alarm after completion of adjustments.

ELEMENTS OF A HAZARD SCENARIO



CONSEQUENCE

- Effect of the scenario on:
  - People (on-site or off-site)
  - Property (on-site or off-site)
  - Process (downtime, product quality, etc.)
  - Environment
  - Etc.

LOPA - HF WORKSHEET	
Consequence: Hexane release outside the dike that could result in fire and/or injury.	
Human Factors:	Lack of awareness of this hazard by the process personnel. Lack of a smoking prohibition outside the area of the tank farm where the spill could reach.
Protective Measures:	None.
Recommendations:	Address this hazard in the initial and refresher training for all affected personnel. Restrict smoking to designated locations.

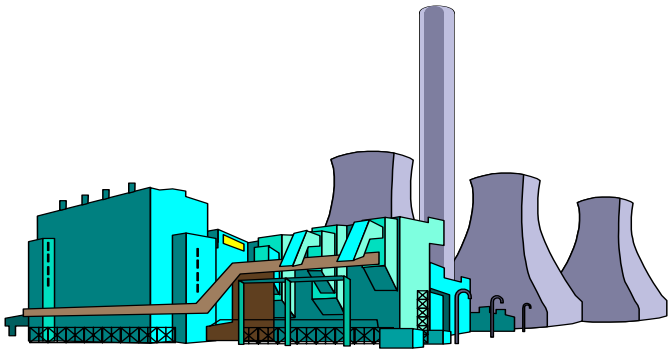
DECIDING ON CORRECTIVE ACTIONS - HF CREDITS

- Credits assigned for each type of human factors improvement
  - According to its effectiveness
- When aggregated, each 10 credits of improvements contributes an order of magnitude reduction in the scenario likelihood
- Target risk level can be met by accumulating sufficient credits
  - Analysts decide which of various possible combinations are preferred

SCENARIO ELEMENT	EVENT	RECOMMENDATIONS	CREDITS
Initiating event	Delivery of hexane when there is insufficient room in the storage tank due to a failure in the inventory control system.	Improve training of the operators and the truck driver. Consider installing a high level trip for the feed pump and an inlet shutdown valve to help prevent overfilling accidents.	2 4 + 4
IPL1	Dike	None	-
IPL2	Operator response to alarms	Consider installing a high level trip for the feed pump and an inlet shutdown valve to help prevent overfilling accidents.	4 + 4
Enabling condition	High temperature alarm overridden	Revise the process optimization procedure to confirm operation of the alarm after completion of adjustments.	3
Consequence	Hexane release outside the dike that could result in fire and/or injury.	Address this hazard in the initial and refresher training for all affected personnel.	2
		Restrict smoking to designated locations.	1

CONCLUSIONS – ADVANTAGES OF LOPA-HF

- Considers a wide range of human factors issues but in an organized and manageable way
  - using Issues Lists
- Focuses on the specific human factors issues that contribute to the risk
- Provides a structured analysis



CONCLUSIONS – ADVANTAGES OF LOPA-HF

- Builds on PHA
- Can be performed using qualitative methods
  - can be refined using quantitative analysis
- Easily used by people experienced with PHA or LOPA

CONTACT INFO

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www.primatech.com - papers on human factors

“There are no shortcuts to any place worth going.”

Anon