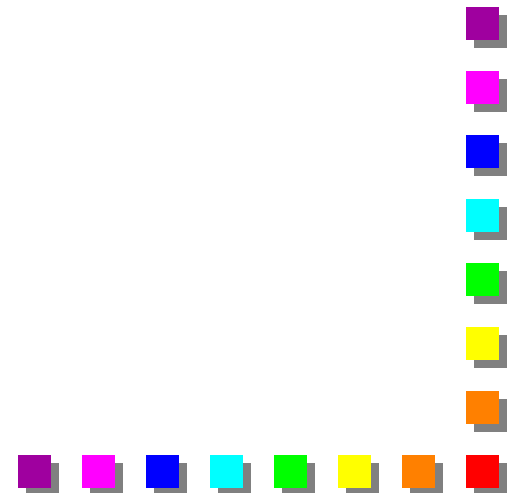
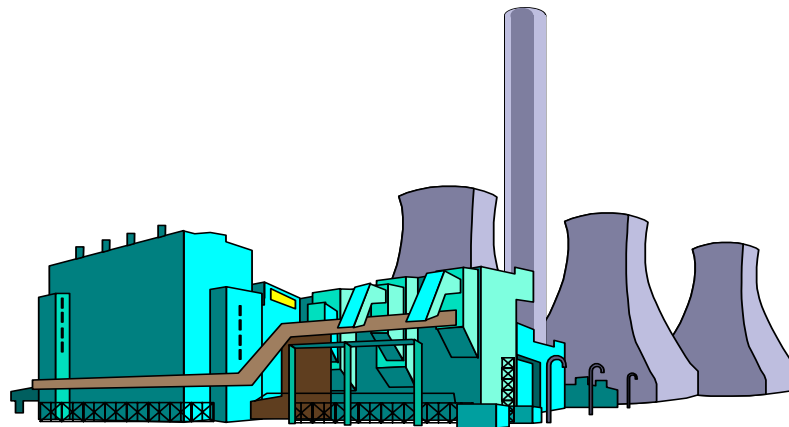


LAYERS OF PROTECTION ANALYSIS FOR HUMAN FACTORS (LOPA-HF)

Paul Baybutt, Primatech Inc.

ASSE Symposium on
Human Error In Occupational Safety,
March 13 – 14, 2003, Atlanta, Georgia



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

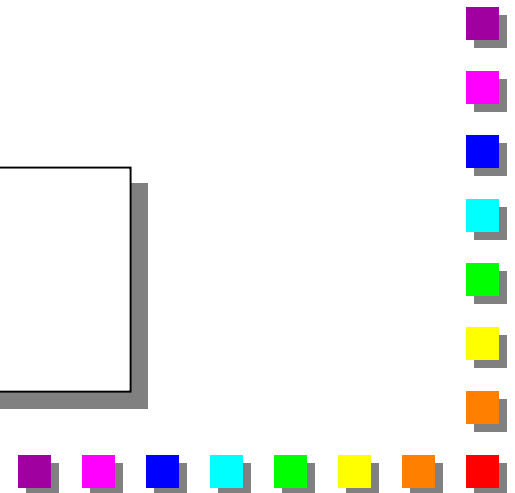


PATH FORWARD

- 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

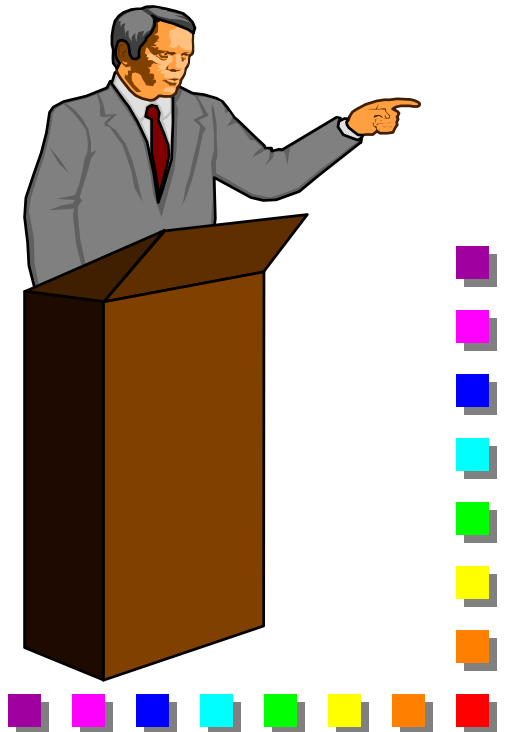
“To err is human; to forgive, infrequent.”

Franklin P. Adams



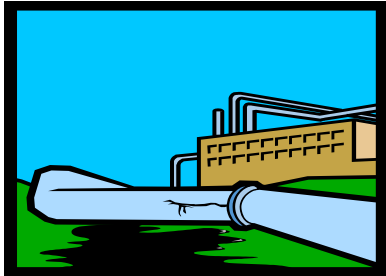
OVERVIEW

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



PROCESS ACCIDENTS

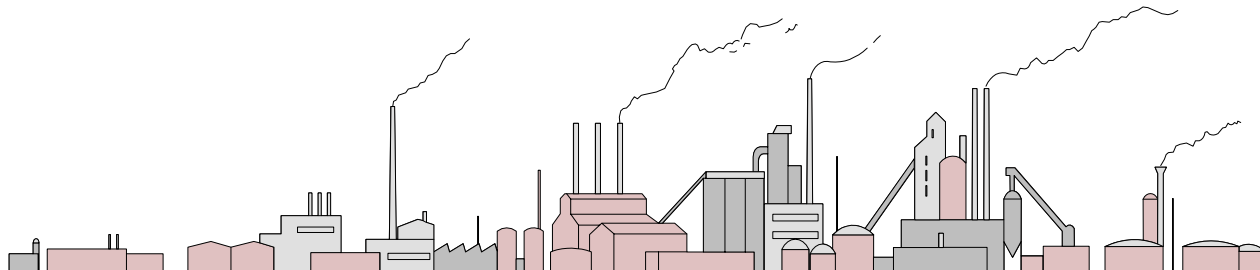
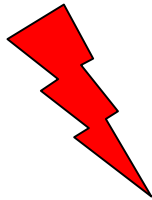
Equipment
Failures



Human
Failures



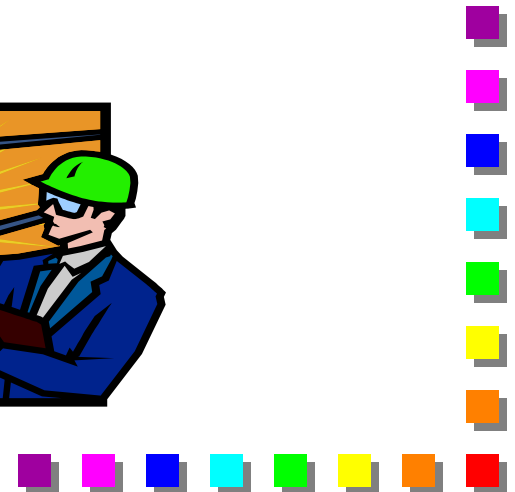
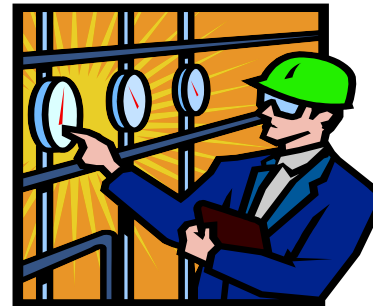
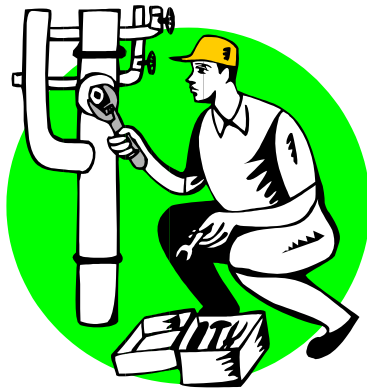
External
Events



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

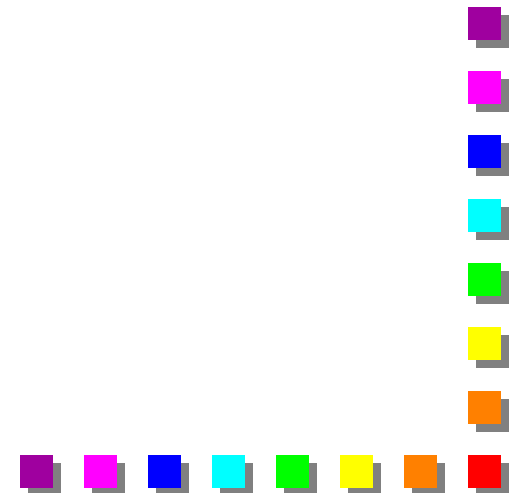
May 26, 1992 – September 30, 2002

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) <i>Human factors</i>	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

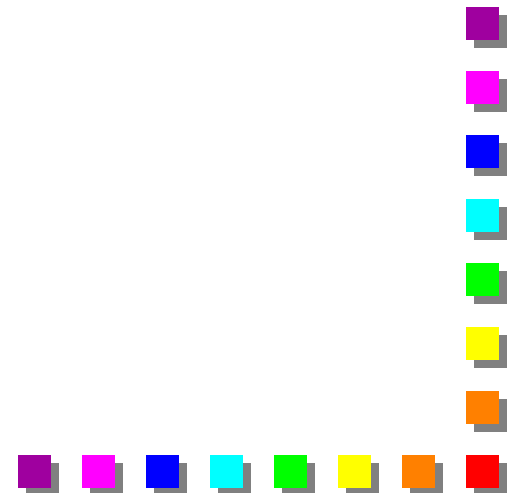
HUMAN FAILURES

- 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



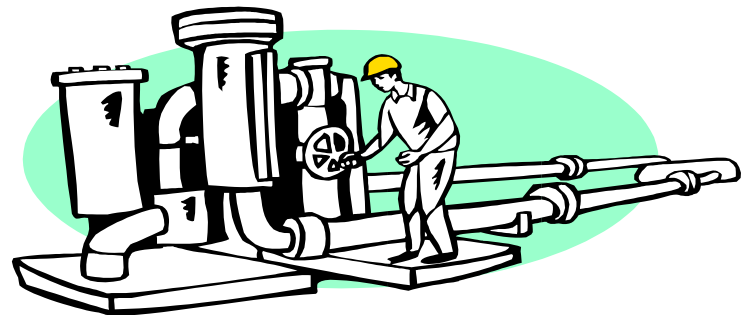
HUMAN FACTORS

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

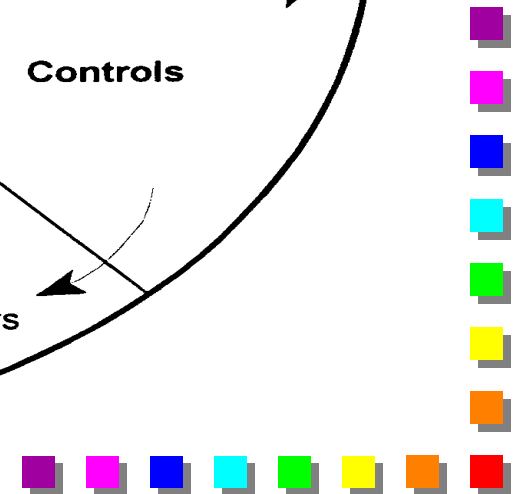
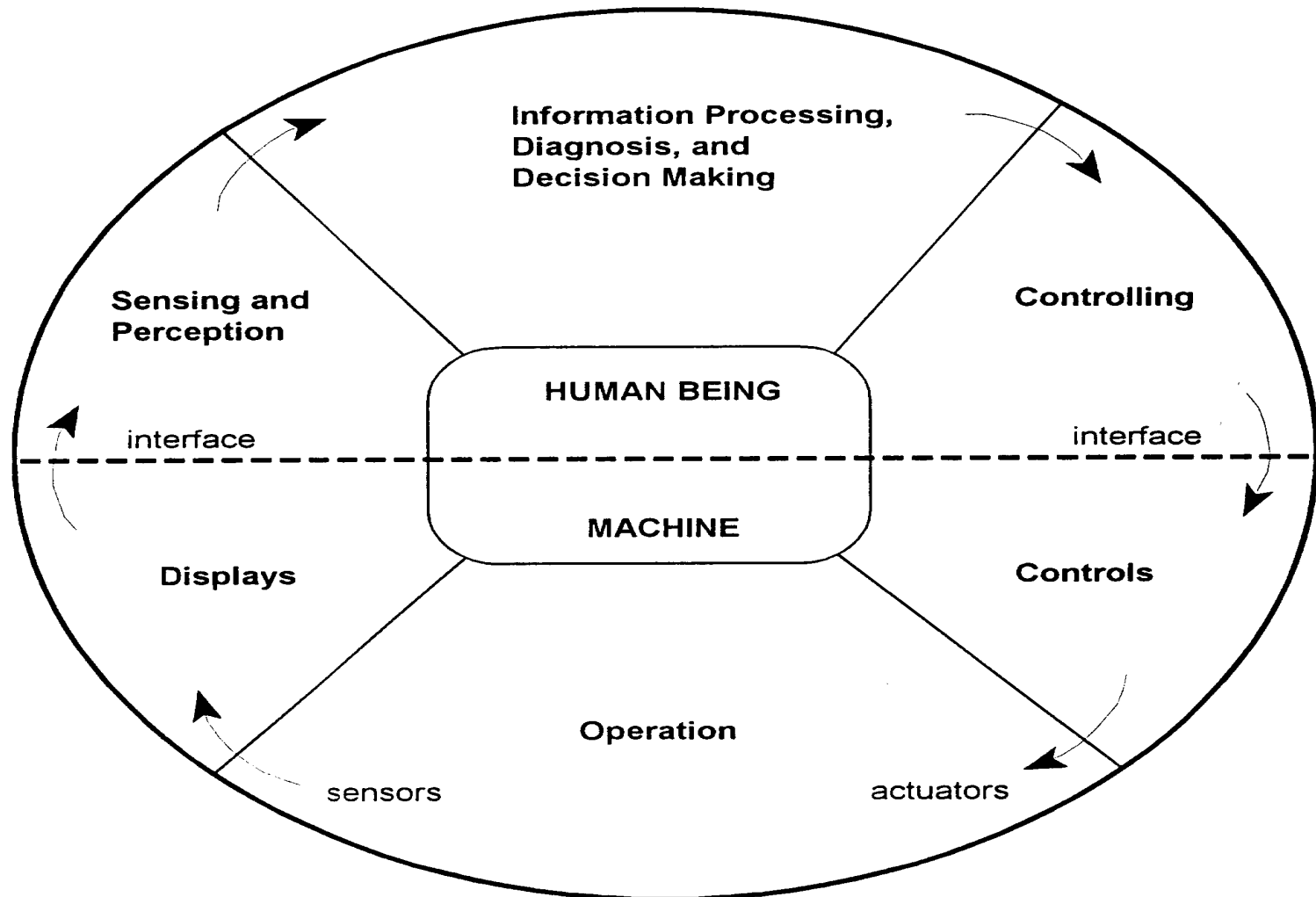


EXAMPLES OF HUMAN FACTORS FOR PROCESSES

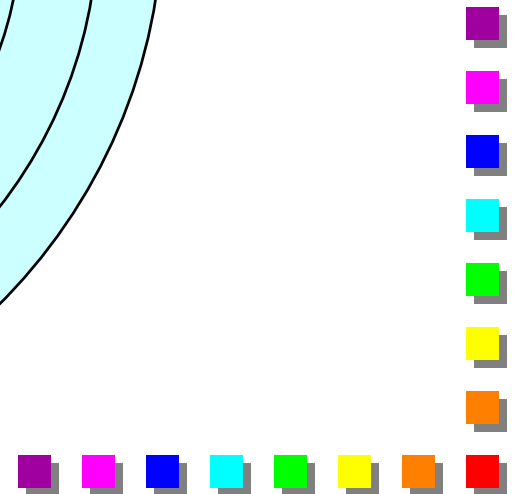
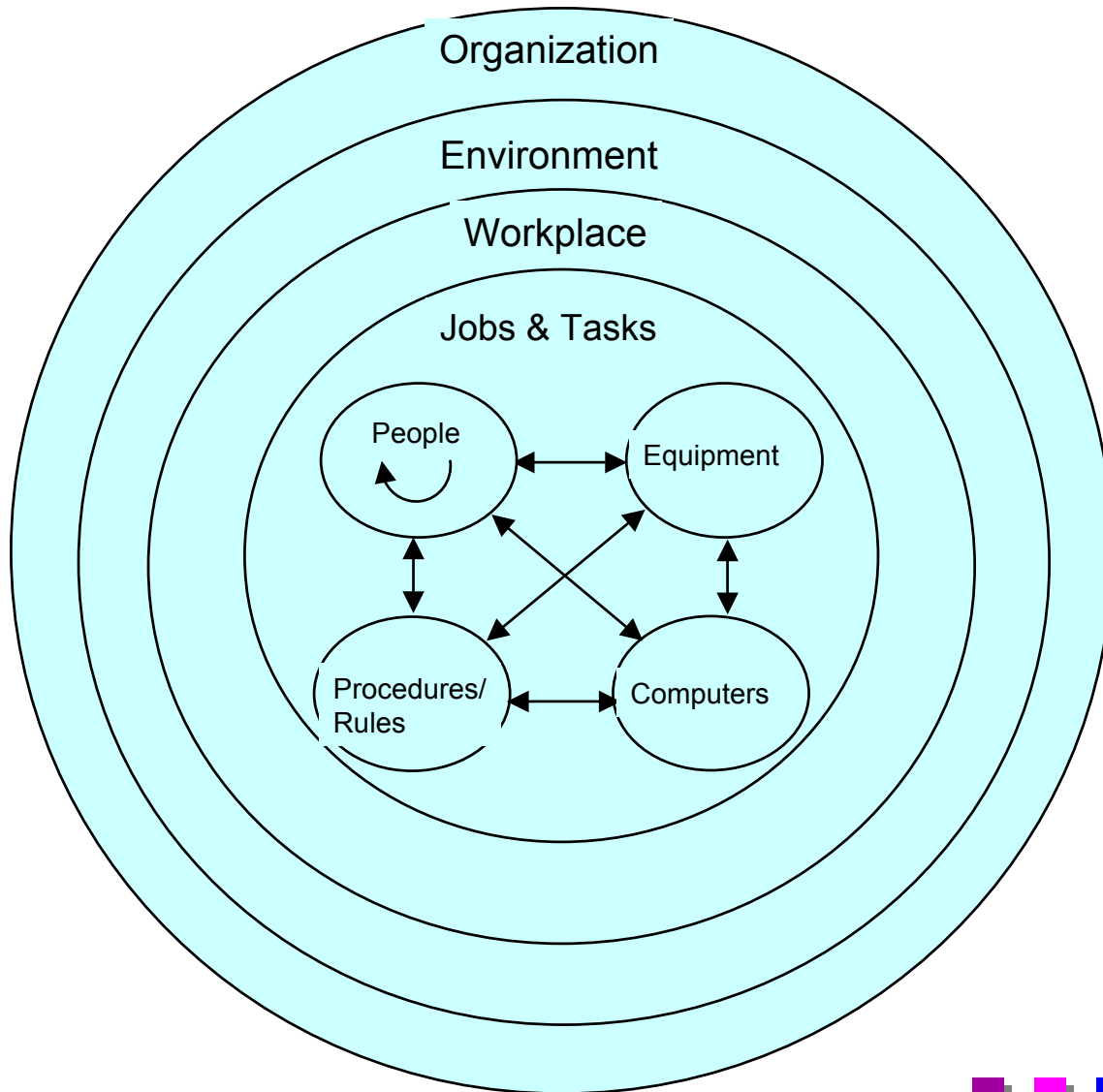
- Operator/process and operator/equipment interface
- Number of tasks operators must perform and their frequency
- Extended or unusual work schedules and shift rotations
- Clarity and simplicity of control displays
- Automatic instrumentation versus manual procedures
- Operator feedback
- Clarity of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



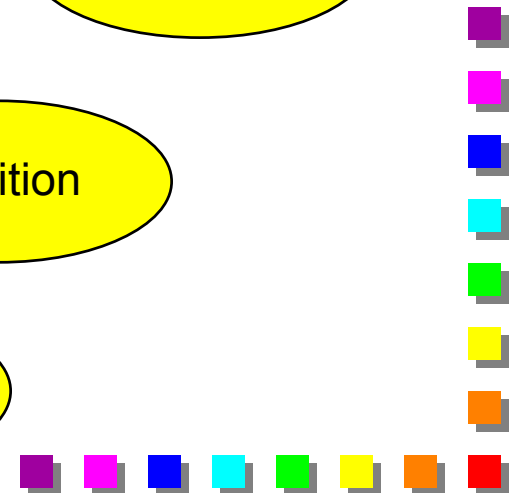
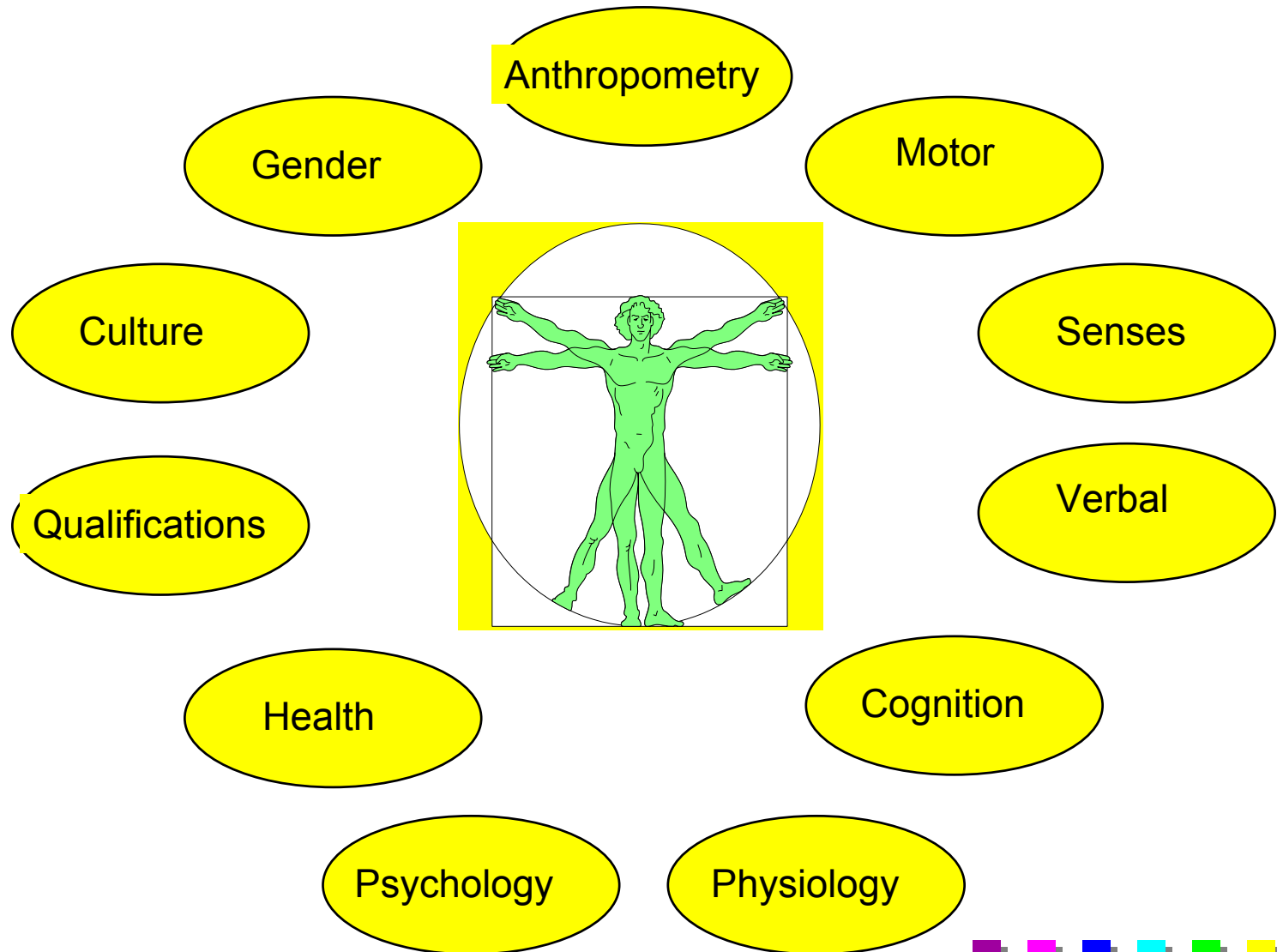
CLASSICAL HUMAN-MACHINE MODEL



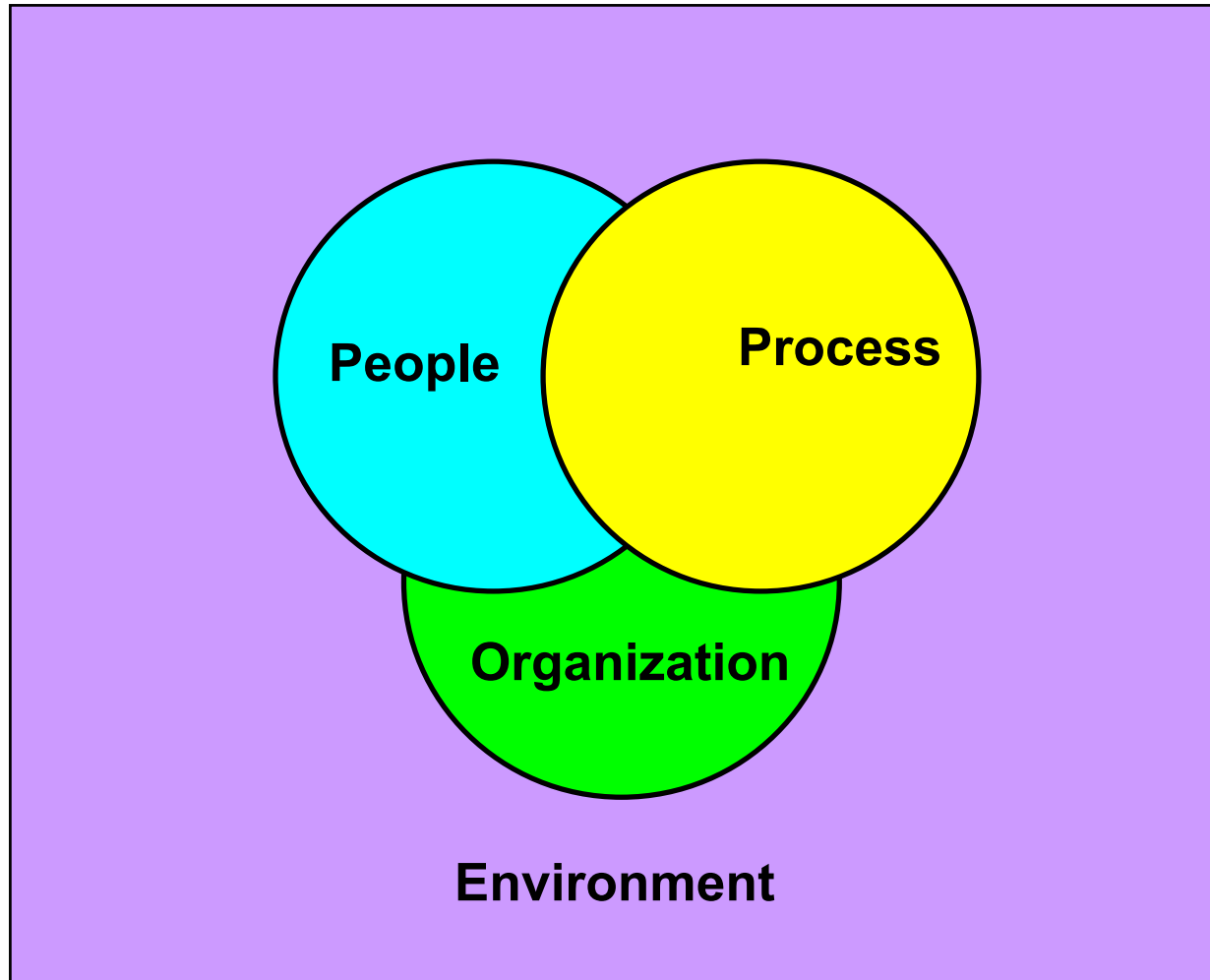
WHAT IS A FACILITY?



WHAT IS A HUMAN?



IMPROVED HUMAN FACTORS MODEL



PERSON-PROCESS MATRIX MODEL

PROCESS ATTRIBUTES

Equipment
Procedures
Environment
People
Etc.

X	X	X		
X	X	X	X	
X	-	-		

Skills

Senses

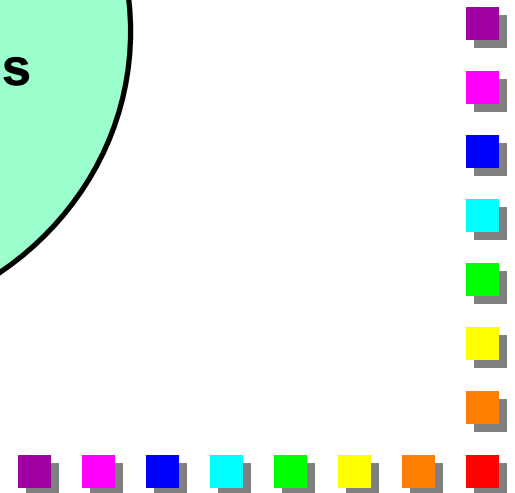
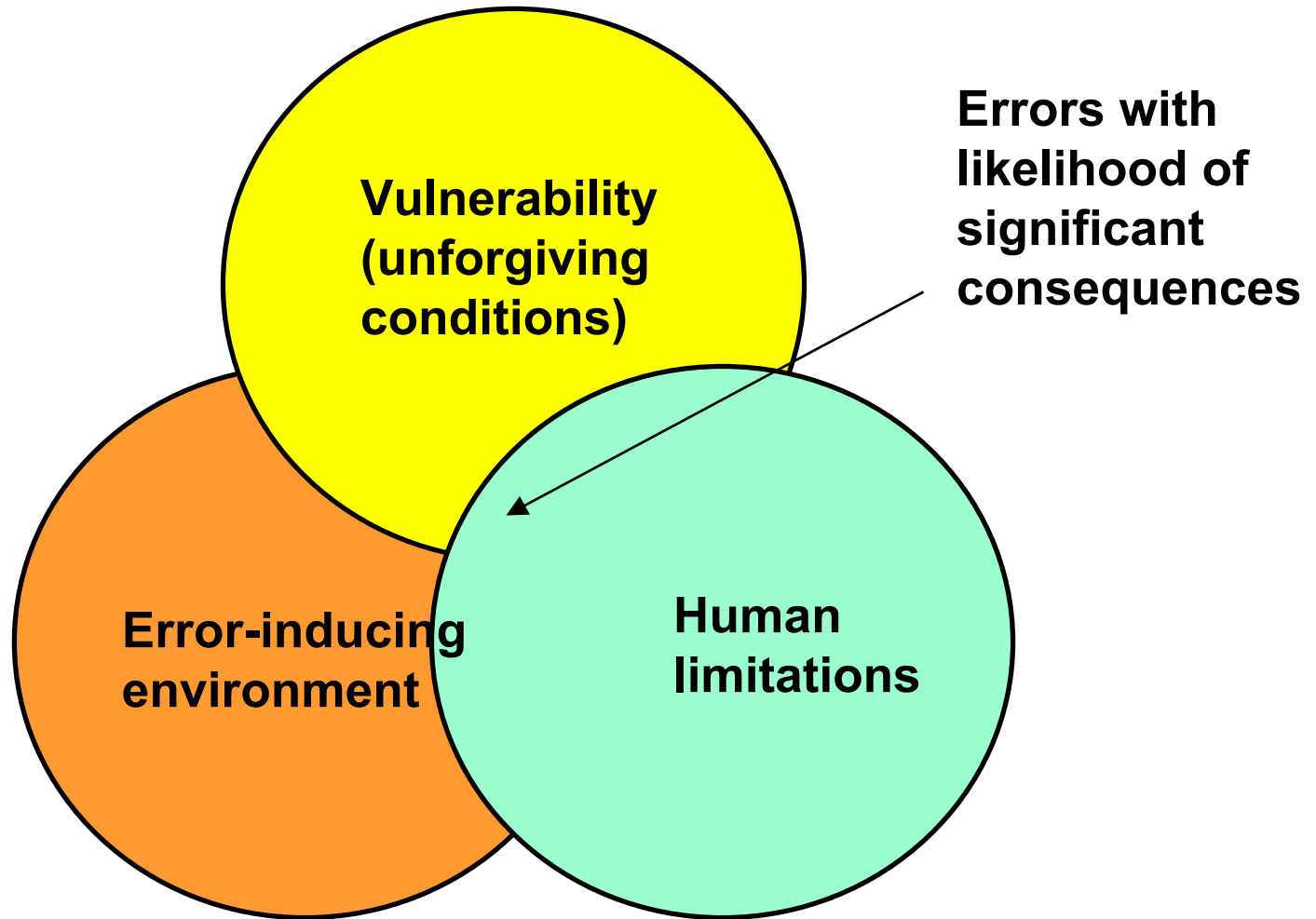
Strength

Etc.

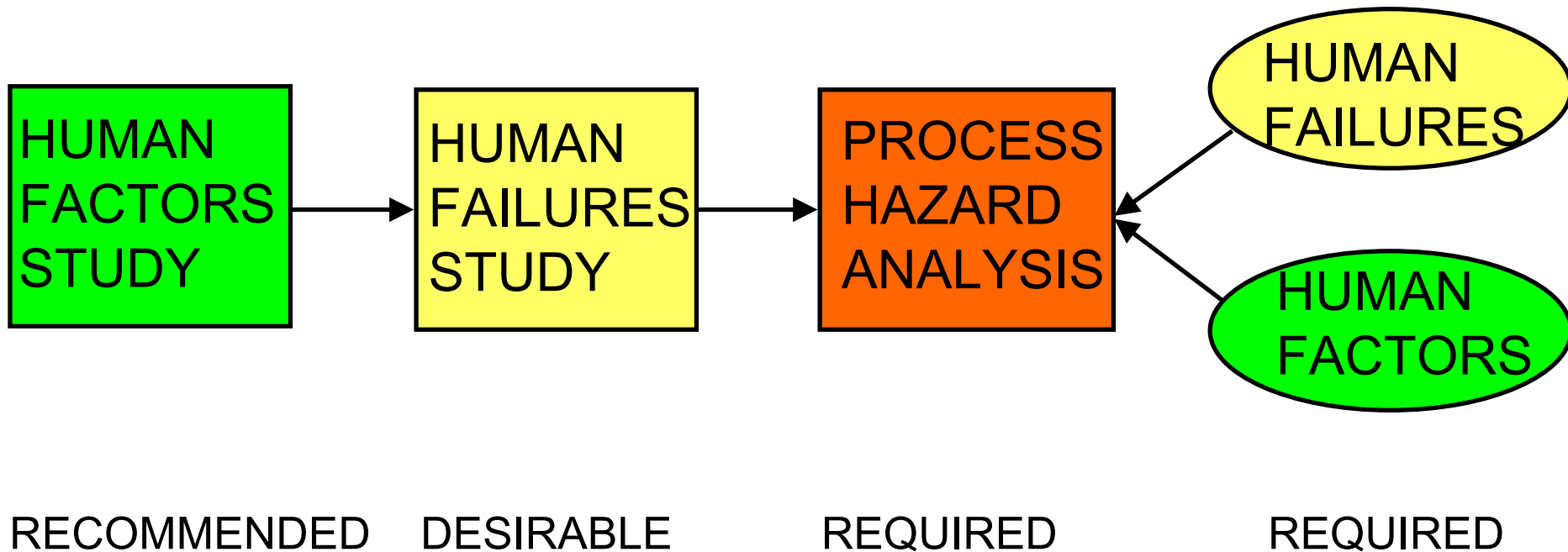
HUMAN

ATTRIBUTES

SYSTEMS VIEW OF HUMAN ERROR



TREATMENT OF HUMAN FACTORS IN PROCESS SAFETY



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.)

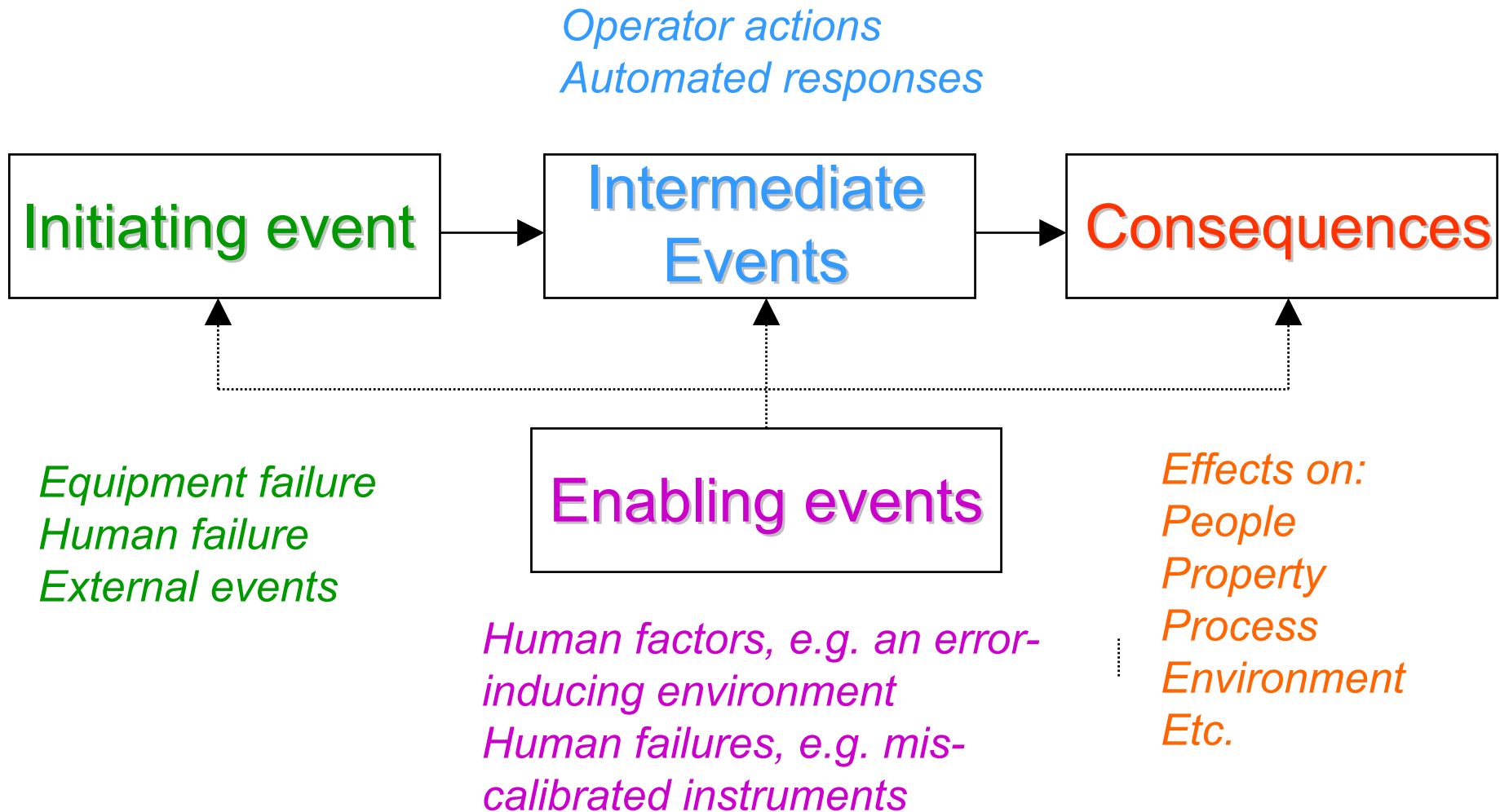
- Human factors are addressed by determining their impact on each individual element of a hazard scenario

“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

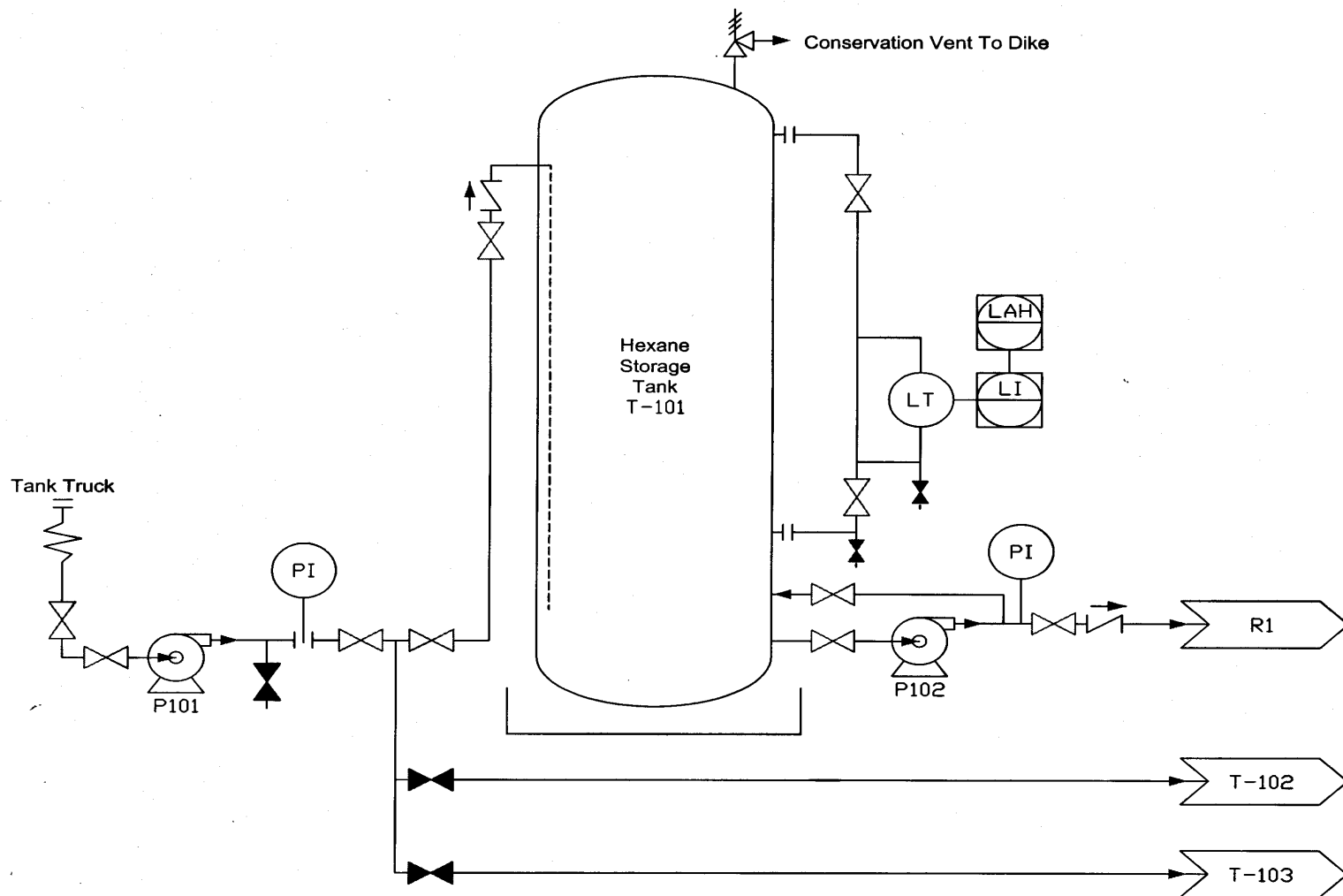


ISSUES LISTS

- 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

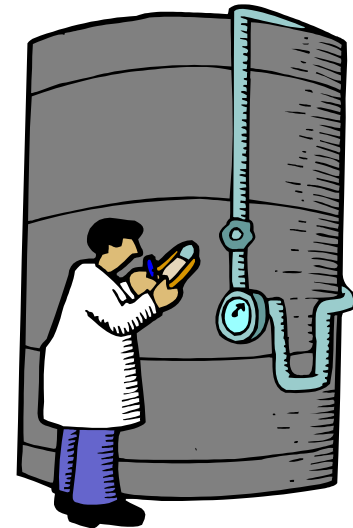


EXAMPLE OF LOPA-HF APPLIED TO HEXANE UNLOADING



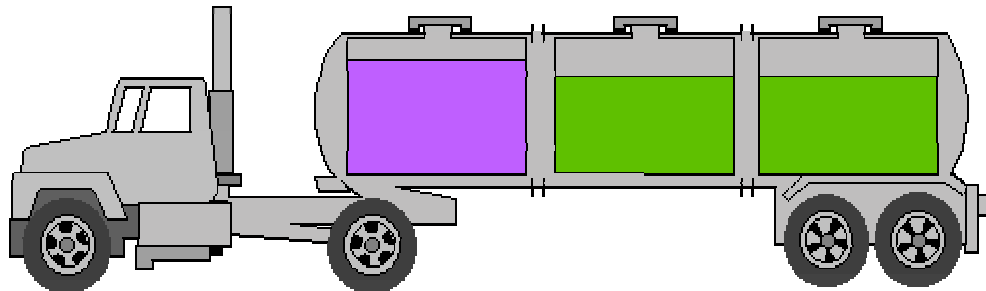
EXAMPLE – KEY POINTS

- 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

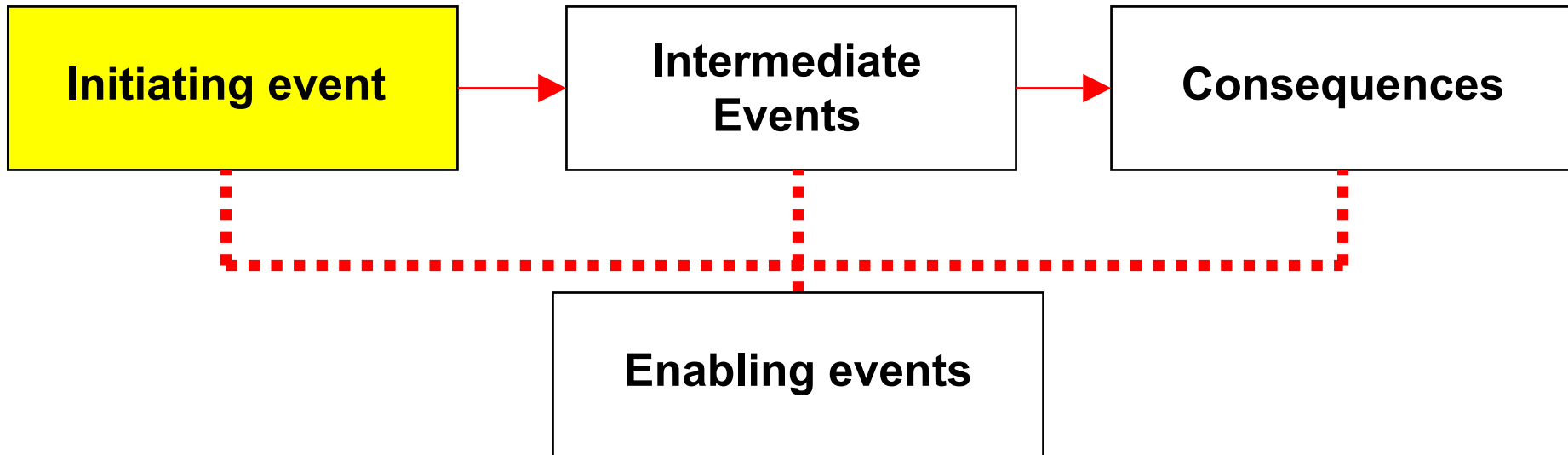


EXAMPLE (CONTD.)

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

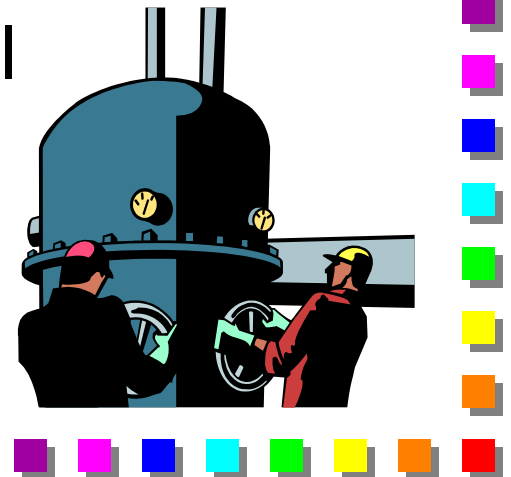


ELEMENTS OF A HAZARD SCENARIO



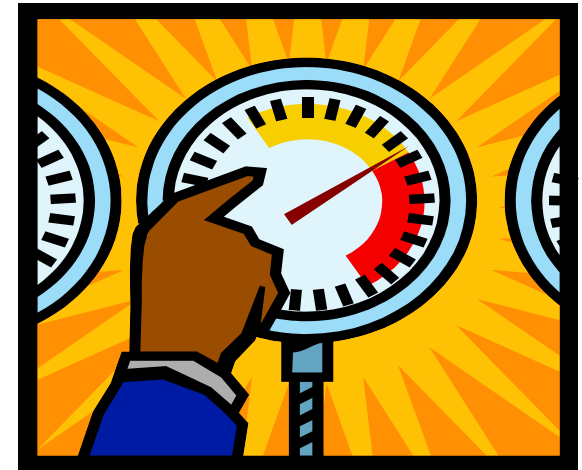
INITIATING EVENT

- “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.

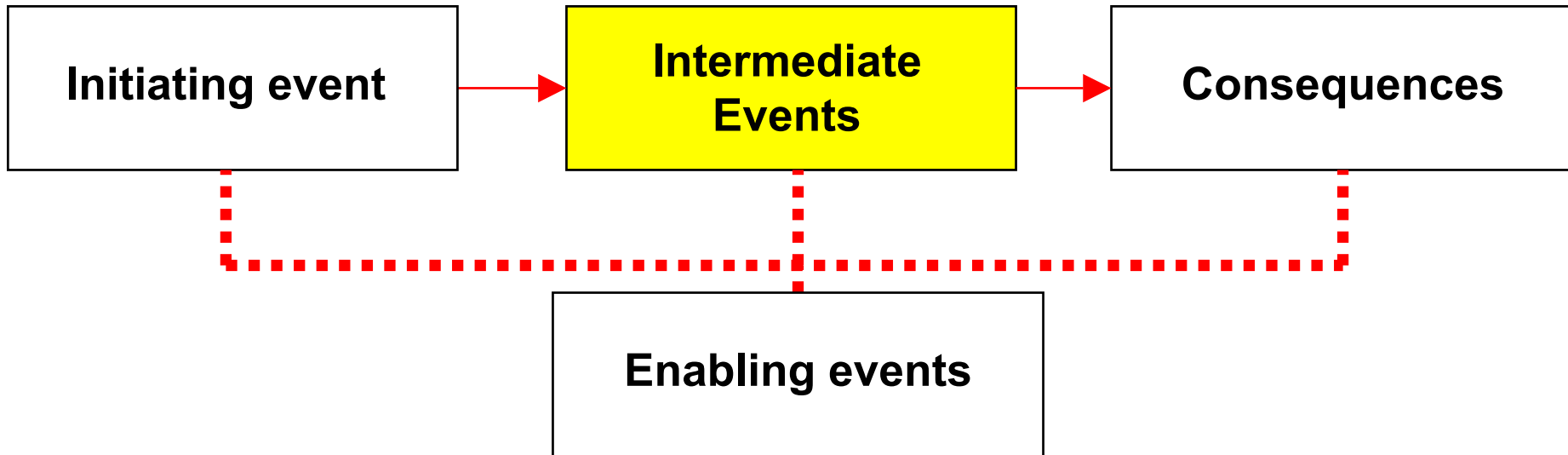
Protective Measures:

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
------------------	-----

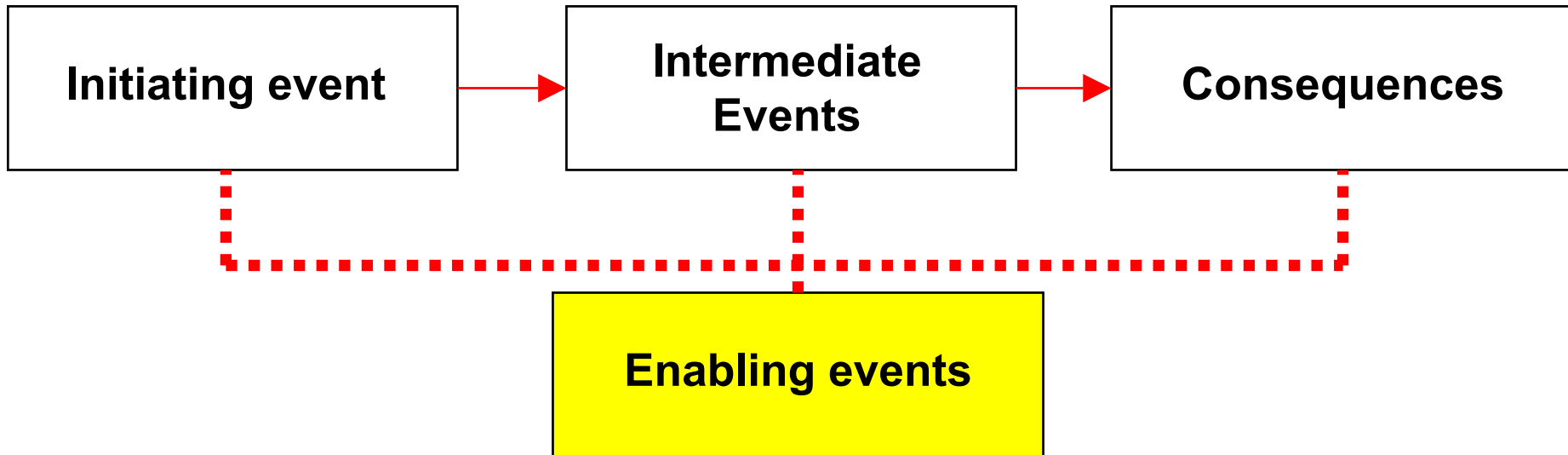
IPL2: Operator response to alarms

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.

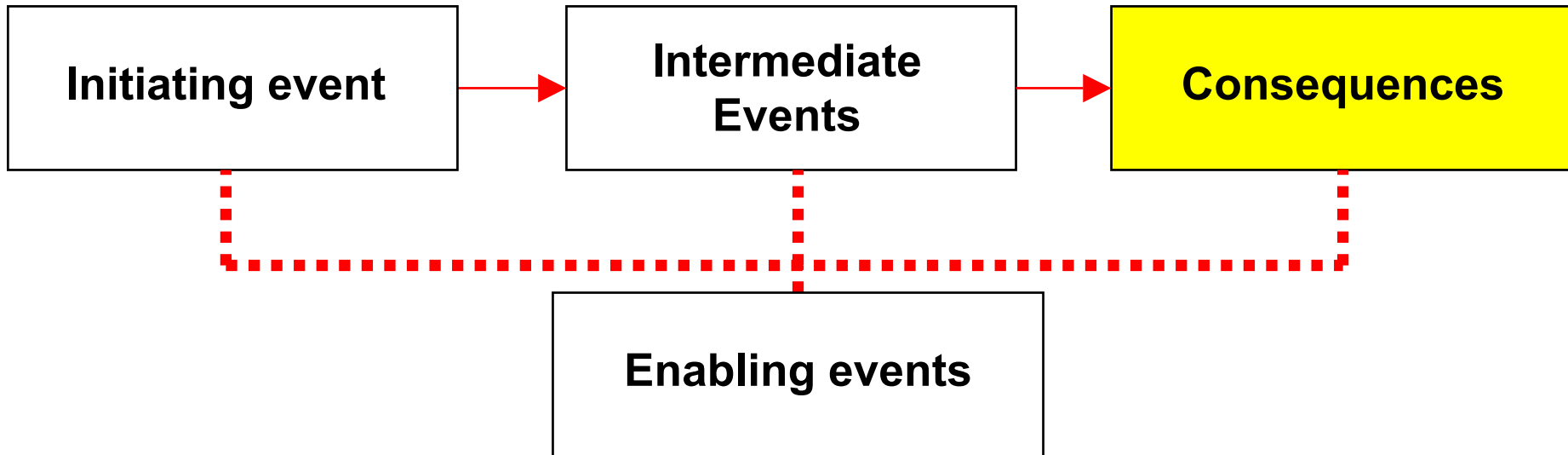
Protective Measures:

None.

Recommendations:

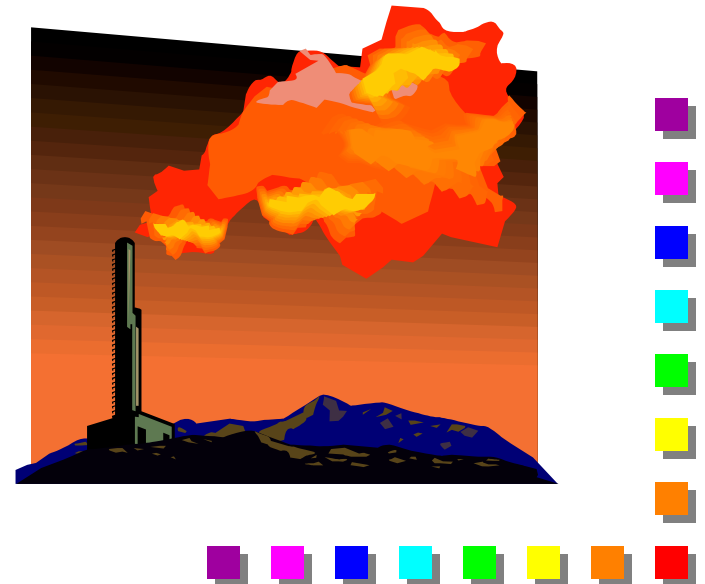
Revise the process optimization procedure to confirm operation of the alarm after completion of adjustments.

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

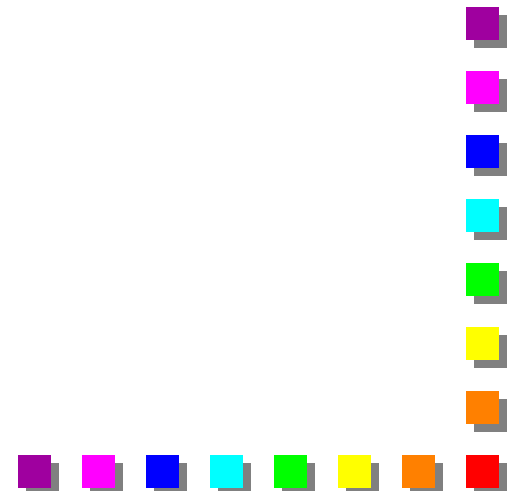
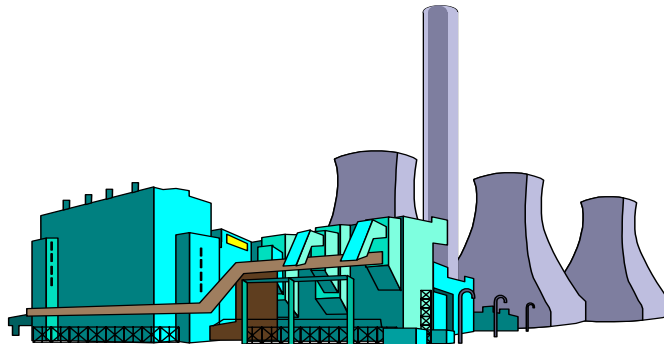
- Credits assigned for each type of human factors improvement
 - ▶ According to its effectiveness
- When aggregated, each 10 credits of improvements contributes an order of magnitude reduction in the scenario likelihood
- Target risk level can be met by accumulating sufficient credits
 - ▶ Analysts decide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

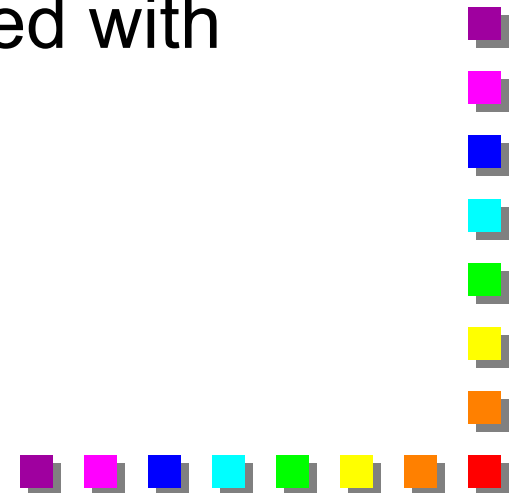
CONCLUSIONS – ADVANTAGES OF LOPA-HF

- 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



