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MIDDLE EAST
PROCESS SAFETY
CONFERENCE

Four major gaps preventing most companies worldwide from achieving excellent process safety performance

William G. Bridges

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William Bridges

Process Improvement Institute - President

STUDIES

BS & MS Chemical Engineering

Functional safety professional

Process safety expert

Co-invented LOPA

Human factors expert

EXPERIENCE

39 years

13 years in plant, 2 as Operator

+250 Unit PHAs

+8000 PHAs managed

+2000 LOPAs

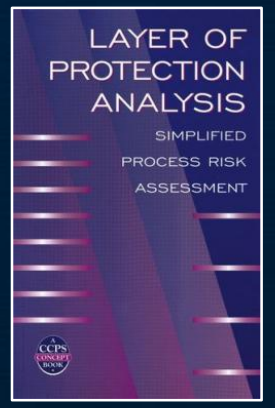
+1000 SIL Verification/Assessments

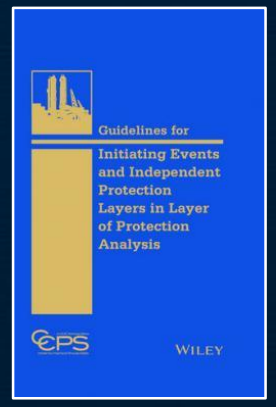
+3500 trained PHA/LOPA leaders

+3000 folks trained in GCC area

PUBLICATIONS

Main author





5 CCPS Guidelines book contributing author

+50 Papers presented

PROCEDURES

Accurate and clear operating and maintenance work instructions

NEAR MISSES

Getting Near Misses reported and investigated

PHA

Of all modes of operation (including startup, shutdown, and online maintenance) and all damage mechanism

HUMAN FACTORS

Addressing human factors missing from most management systems

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90% Of accidents have at least one root cause related to procedures

MAIN DEFFICIENCIES

CONTENT ACCURACY

FORMAT

PROCEDURES

DRAFT: Have USER write the first draft of instructions (engineers shoudl not write operating procedures)

↓

VALIDATION: Have another USER walk-down the first draft in the field. Make a revised draft.

↓

VERIFICATION: Have a technical expert (e.g., engineer) walk-down the revised draft in the field.

↓

PRESENTATION: Follow rules for page format and writing of steps. Issue final draft.

↓

RISK REVIEW: Before using the final procedure analyze risk of ***Performing a Step Wrong and Skipping a Step****

** This is necessary even if the procedure is perfect because humans do not follow procedures perfectly*

+95%
ACCURACY of CONTENT

+80%
FORMAT RULES

HUMAN ERROR
2-10x

PROCEDURES

PROCEDURE

Unloading Monomer from Tanker to Storage

STEPS	DETAILS
1. Wear standard PPE, plus rubber gloves and full-face organic respirator.	Standard PPE includes hard hat, safety glasses with side shields, and steel-toe shoes.
2. Weigh in the tanker.	Record weight on GROSS line of form.
3. Check bill of lading.	... to verify correct type of material is in tanker.
4. Sign in tanker driver.	Driver must sign in as a visitor and be escorted at all times.
5. Take Certificate of Analysis to QC.	***CAUTION: To avoid contamination, DO NOT unload until you receive approval from QC.***
6. Spot tanker.	A) Direct driver to location. B) Verify brake is set. C) Chock the wheels on at least one side between the two rear axles. D) Ground the tanker (attach grounding strap to an unpainted metal surface).
7. Have the storage area operator make sure the storage tank can hold contents of tanker.	***WARNING:*** *Failure to perform this step can result in an overflow and spill of hazardous Monomer.* Perform **Tank Gauging Procedure (SOP-01-804)** or check the storage tank load cell readout. Storage tank operating limits are stenciled on the control panel.
8. Place 5-psig nitrogen pad on tanker.	A) Connect from local 5-psig nitrogen drop to aft bottom nitrogen connection on tanker. B) Open nitrogen supply valve. C) Then open valve at tanker.
9. Connect Monomer unloading hoses.	A) Verify hoses and gaskets are in good condition. (Hoses are normally stored on hose rack at unloading spot.) B) Connect from tanker to air pump. (Use aft bottom connection on tanker. Remove cap.) C) Connect from air pump to storage tank. (Connect to storage tank line labeled "from TW.")

TROUBLE SHOOTING GUIDE

Trouble-Shooting Guide

Alarm or Indicator:	**PAL 4446 – Low Pressure Alarm for Suction of Organic Feed Pump 40-PM-18.445**

Action Limit:	5 kPa		
Consequence:	Possible pump seal failure, releasing or spraying organic waste into the berm.		
Process Area:	FB&D Incinerator; Liquid Organic Liquid Feed	**Oper. Mode:**	Normal
Drawing #s:	D-400-PI-013		

IMMEDIATE ACTION (by system or by operator)

- DCS should shut down the organic feed pump (40-PM-18.445).
- From the DCS display, MAKE SURE the organic feed pump is shutdown.
- HAVE the field operator check for leaks near the organic feed pump.
- IF there is a large leak/release, THEN use the ESD switch to shutdown the unit and then follow/complete the shutdown and isolation procedure, OPS-ESD-117.
- IF there is a minor leak or no leak, THEN:
  - COMPLETE the rest of the trouble-shooting,
  - and DECIDE how to contain the leak for now,

DECIDE IF ALARM is REAL

- From the DCS, CHECK the pressure and feed tank level trends. IF the trends indicate the alarm if valid, THEN continue with finding the cause or fixing or bypassing the problem.

FINDING and FIXING the CAUSE

- CHECK valves upstream of the organic feed pump to see if any are closed too far, including checking ESD valves.
- CHECK, by feel with hand, if the heat tracing is on; IF Not, then TURN ON or open heat trace valves
- MAKE SURE nitrogen to the pump seal is at the normal operating pressure.
- CHECK if the line if plugged or frozen (skill)

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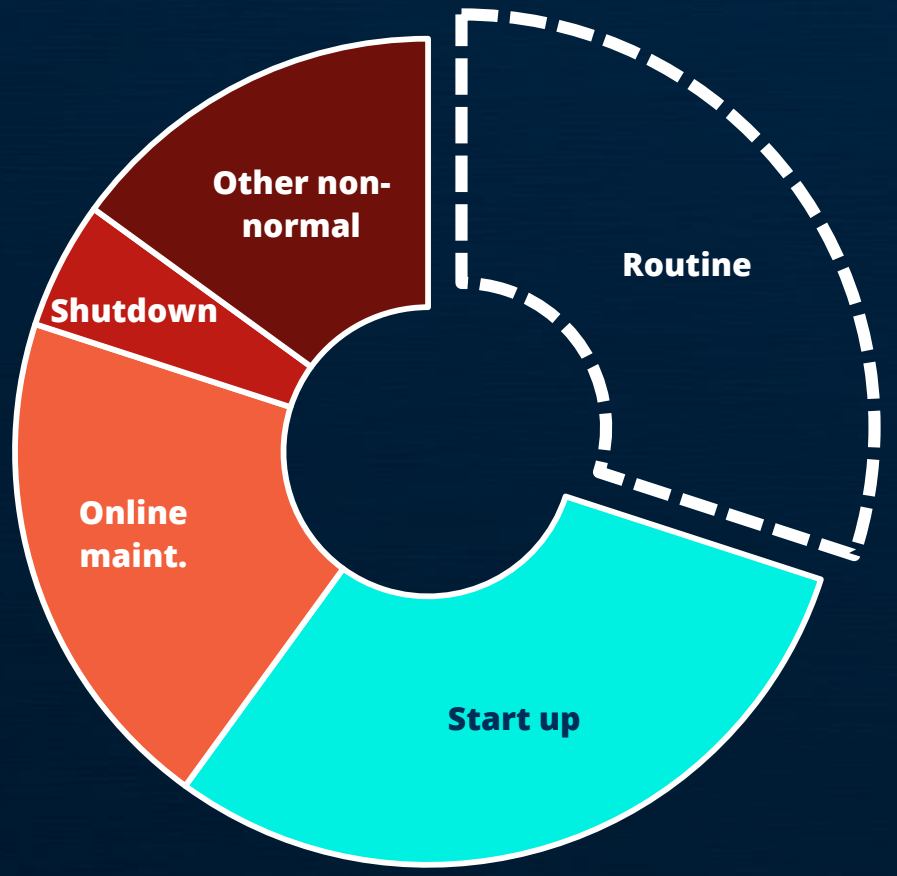
MODES OF OPERATION

(STEP-BY-STEP)

DAMAGE MECHANISMS

PREVIOUS INCIDENTS



ACCIDENTS DISTRIBUTION

+80% of Process Safety Accidents occur during startup, shutdown, and online maintenance

+80% of companies do not **DO NOT properly analyze** hazards during non-routine modes

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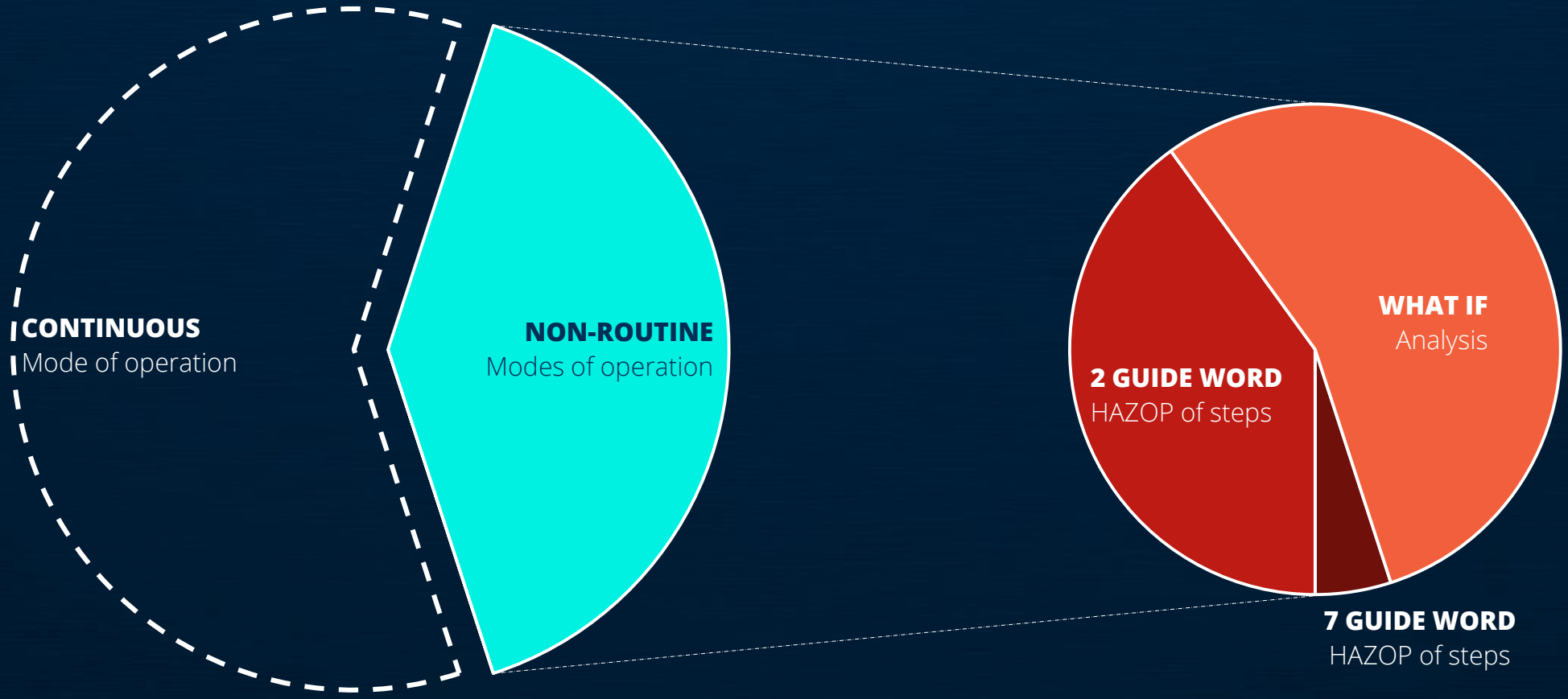

PHA TIME

METHODOLOGY

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70% PHAs do not cover Damage Mechanisms in each node*

*PHAs audited by PII

Example A – Referencing Generic Tables for Typical Causes and Typical Safeguards

Dev#	*Deviation*	*Causes*	*Consequences*	*Existing Safeguards*	*Recommendations*
9.10	Loss of containment	Accelerate corrosion External fire High pressure (linked from 9.7) Typical causes of loss of containment (see Table A.1)	Release to atmosphere leading to potential injury of workers and/or community	Pressure Relief Valve's 231A, B, C on Reactor and no valves in line to reactor Most lines / connections are welded construction; only a few flanges Drills conducted each year on evacuation, rescue and isolation Emergency Response personnel are trained at SABIC FTC Generic safeguards protecting against or mitigating process material releases (see Table A.2)	Safety 7. Consider changing the ITPM schedule for managing most PSVs whose inspections are too infrequent based on industry standards and best practice. For instance, the current inspection frequency for PSV-8220 on the Ammonia Receiver (I-2005G) is 9 years, whereas, consensus codes typically recommend testing/inspection every 1-4 years for PSVs in highly toxic services.

Example B – Specific Listing of Causes and Safeguards

1.9	Loss of containment	Corrosion/erosion External fire and/or flame impingement Gasket, packing, or seal failure Improper maintenance Material defect Operator failing to close or inadvertently opening a valve to the atmosphere (e.g., a valve at a hose connection) Railcar inadvertently derailed Valve leaking to the atmosphere High pressure (linked from 1.5) Acid corrosion caused by high concentration of water (linked from 1.8) High ambient temperature External impact (such as from a mini-engine or another railcar)	Catastrophic release of chlorine from a ruptured railcar Steady release of chlorine from a ruptured connection Steady release of chlorine from a leaky connection High pressure caused by thermal expansion of liquid chlorine if railcar is also over-full	Chlorine repair kit Derailer and warning flag to prevent impact by a mini-engine or another railcar Limited vehicular access to area Maintenance/operator response as required, including isolation if needed Operator periodically monitoring the railcar valves while unloading Personal protective equipment in the area Plugs installed in all chlorine valves to the atmosphere when the valves are not in use Relief valve on each railcar for mitigating releases caused by overpressure Supplier maintenance of railcars (per strictly enforced US DOT requirements) Video monitoring of the unloading area Concrete crossties on rail spur Dike preventing any combustibles spilled nearby from reaching the unloading rack area Concrete railroad ties in chlorine unloading area to prevent fires near railcar	10. Consider installing a chlorine detection system in the unloading and vaporizing area to help detect chlorine releases (especially at likely release points) 11. Verify that periodic maintenance and inspections are being performed in accordance with Chlorine Institute recommendations 12. Review the drainage system for the unloading are, and identify the areas that may be affected by a large chlorine release 13. Consider prohibiting the use of heavy equipment (e.g., cranes) in the unloading and vaporizing area unless special precautions to prevent equipment damage are enacted 33. Consider providing a high pressure alarm for each vaporizer 40. Consider providing a water deluge system in the unloading area to help mitigate chlorine releases from the railcar

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Actual Causal Factor

II Recommendation (If implemented)

No.: 1 | **Description:** Transfer line from Pentane Storage tank to Reactor R-1

SOP: SOP-100-001, SOP-100-002, **P&ID:** CUL-101-001

Item	Deviation	Causes	Consequences	Safeguards	Action Items
1.10	Loss of containment	1. II Causal Factor - Humna error - Drain valve was left open after maintenance on storage tank and piping	1. Incident # 2015-08-20-33 1000 lbs of pentane released resulted in small fire	1. II Recommendation Implemented - added valve configuration list to "Start-up after maintenance turnaround" procedure and signoffs before continuing to startup procedure	

Detailed result of the incident

Recommendations (If neccesary)

Documenting Previous Incidents within PHA tables

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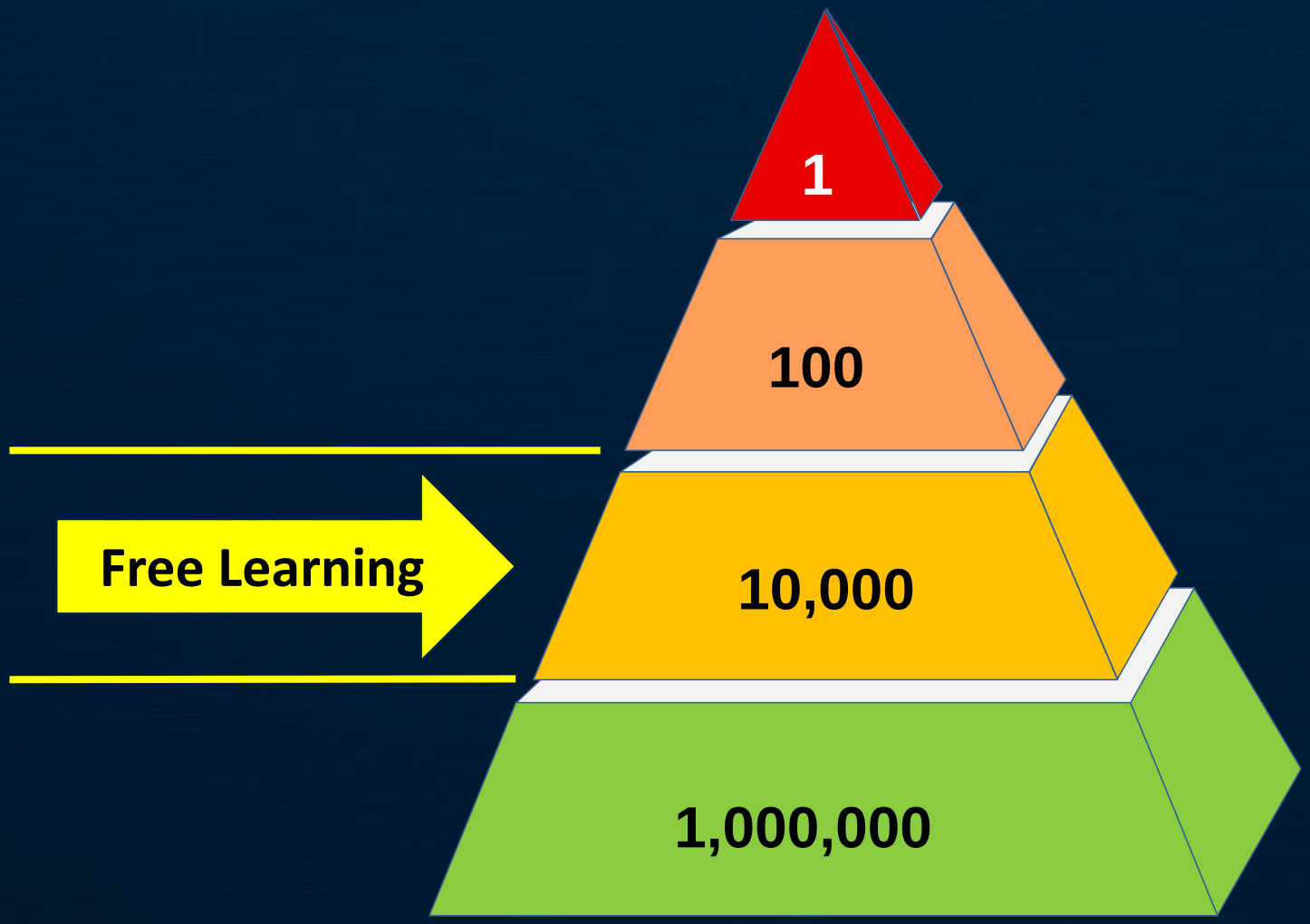

Major Accident (catastrophe)

Minor Accidents

Near Misses

Errors (*which include unsafe acts and unsafe conditions*)

NEAR MISSES

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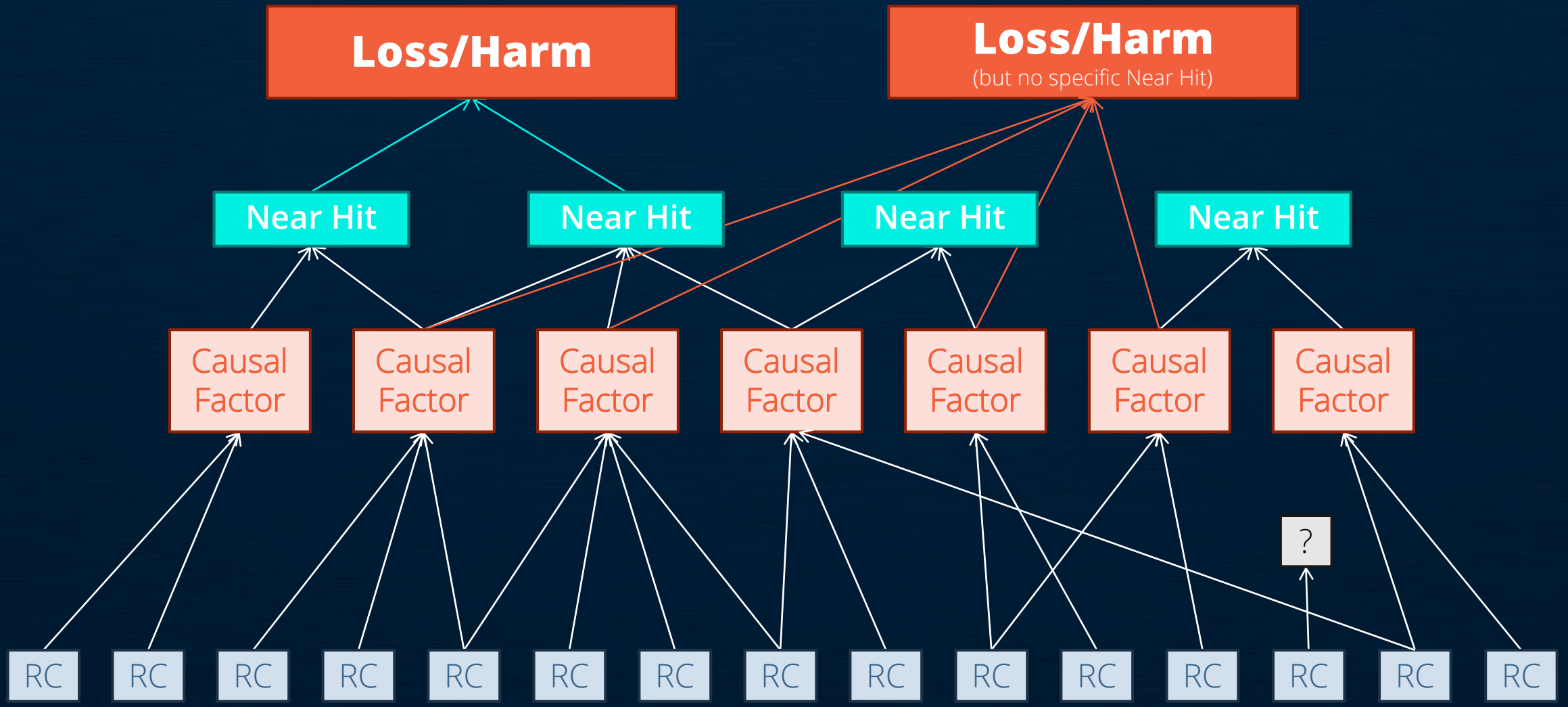
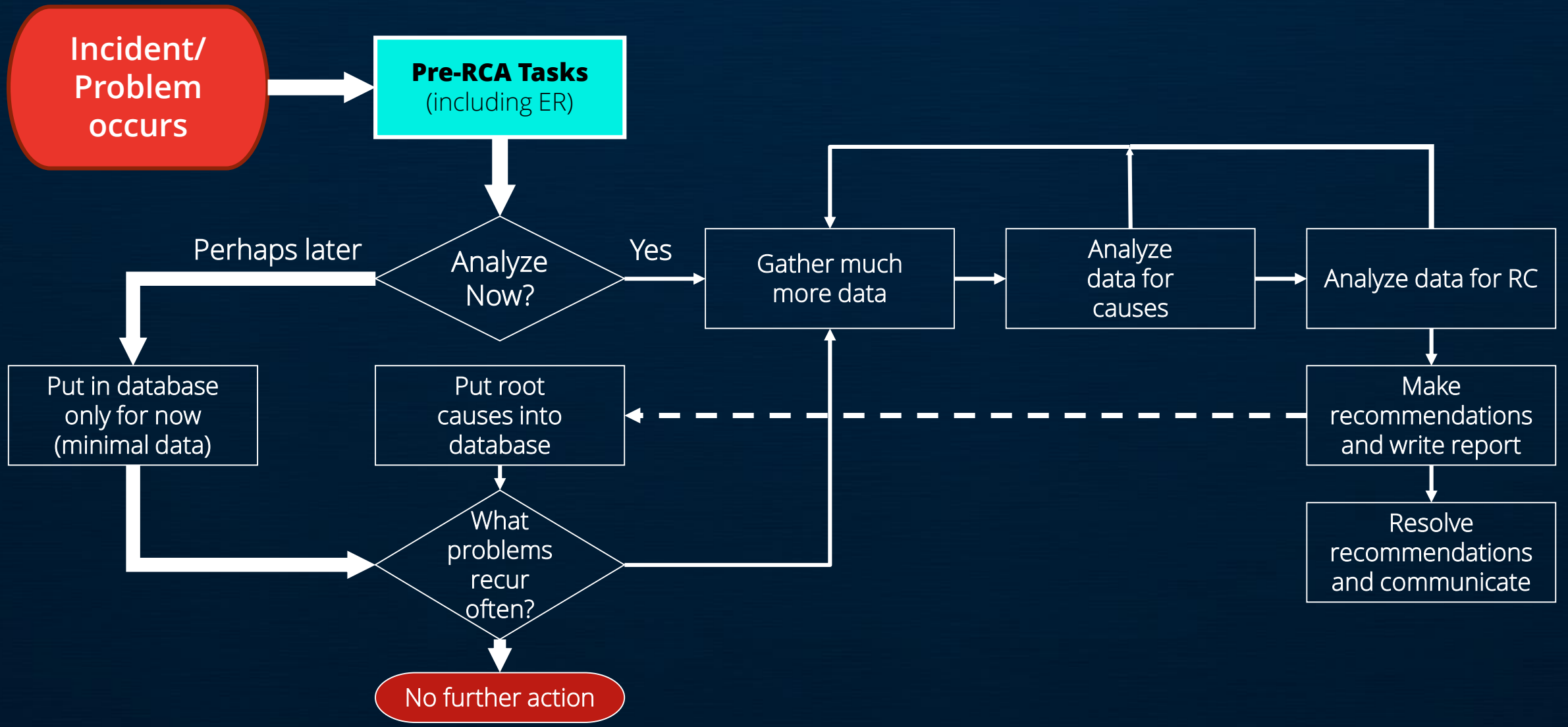


15-20 = NEAR MISS INVESTIGATION / ACCIDENT

+90% Chance of finding problems and correcting them

NEAR MISSES


Incident/ Problem occurs
Pre-RCA Tasks (including ER)
Analyze Now?
Perhaps later
Yes
Put in database only for now (minimal data)
Put root causes into database
What problems recur often?
No further action
Gather much more data
Analyze data for causes
Analyze data for RC
Make recommendations and write report
Resolve recommendations and communicate

NEAR MISSES

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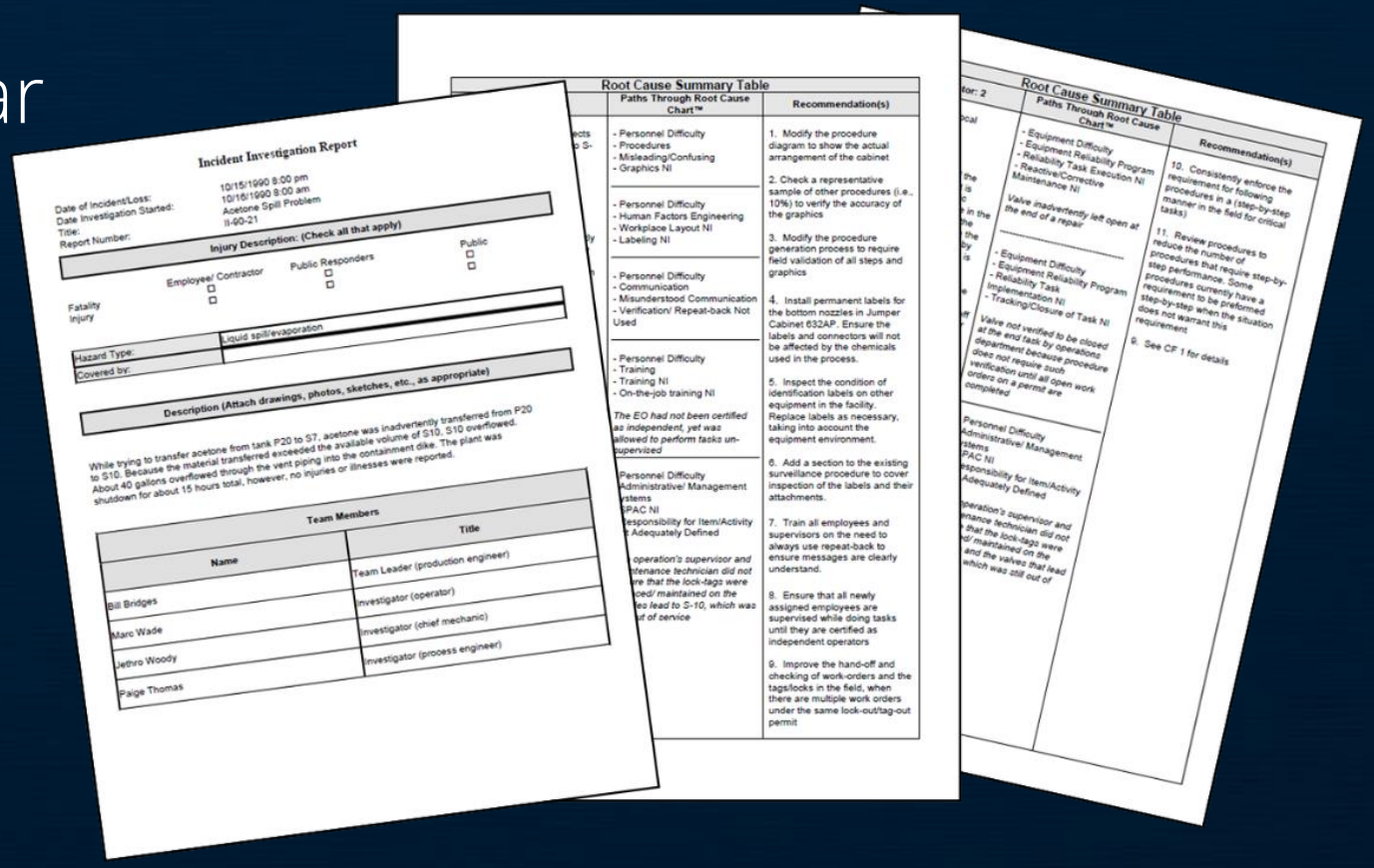
USE a Full Root Cause Approach for near miss investigations, but....

... only produce a **MINIMUM REPORT**



Incident Investigation Report

Date of Incident/Loss: 10/15/1990 8:00 pm
Date Investigation Started: 10/16/1990 8:00 am
Title: Acetone Spill Problem
Report Number: II-90-21

Injury Description: (Check all that apply)

	Employee/ Contractor	Public Responders	Public
Fatality	☐	☐	☐
Injury	☐	☐	☐

Hazard Type:	Liquid spill/evaporation
Covered by:	

Description (Attach drawings, photos, sketches, etc., as appropriate)

While trying to transfer acetone from tank P20 to S7, acetone was inadvertently transferred from P20 to S10. Because the material transferred exceeded the available volume of S10, S10 overflowed. About 40 gallons overflowed through the vent piping into the containment dike. The plant was shutdown for about 15 hours total, however, no injuries or illnesses were reported.

Team Members

Name	Title
Bill Bridges	Team Leader (production engineer)
Marc Wade	Investigator (operator)
Jethro Woody	Investigator (chief mechanic)
Paige Thomas	Investigator (process engineer)

Root Cause Summary Table

	Paths Through Root Cause Chart™	Recommendation(s)
	- Personnel Difficulty - Procedures - Misleading/Confusing - Graphics NI	1. Modify the procedure diagram to show the actual arrangement of the cabinet 2. Check a representative sample of other procedures (i.e., 10%) to verify the accuracy of the graphics 3. Modify the procedure generation process to require field validation of all steps and graphics 4. Install permanent labels for the bottom nozzles in Jumper Cabinet 632AP. Ensure the labels and connectors will not be affected by the chemicals used in the process. 5. Inspect the condition of identification labels on other equipment in the facility. Replace labels as necessary, taking into account the equipment environment. 6. Add a section to the existing surveillance procedure to cover inspection of the labels and their attachments. 7. Train all employees and supervisors on the need to always use repeat-back to ensure messages are clearly understand. 8. Ensure that all newly assigned employees are supervised while doing tasks until they are certified as independent operators 9. Improve the hand-off and checking of work-orders and the tags/locks in the field, when there are multiple work orders under the same lock-out/tag-out permit
	- Personnel Difficulty - Human Factors Engineering - Workplace Layout NI - Labeling NI	
	- Personnel Difficulty - Communication - Misunderstood Communication - Verification/ Repeat-back Not Used	
	- Personnel Difficulty - Training - Training NI - On-the-job training NI	
	The EO had not been certified as independent, yet was allowed to perform tasks un-supervised	
	- Personnel Difficulty Administrative/ Management systems SPAC NI esponsibility for Item/Activity t Adequately Defined	
	operation's supervisor and tenance technician did not re that the lock-tags were ed/ maintained on the es lead to S-10, which was of service	

Root Cause Summary Table

	Paths Through Root Cause Chart™	Recommendation(s)
	- Equipment Difficulty - Equipment Reliability Program - Reliability Task Execution NI - Reactive/Corrective Maintenance NI *Valve inadvertently left open at the end of a repair*	10. Consistently enforce the requirement for following procedures in a (step-by-step manner in the field for critical tasks) 11. Review procedures to reduce the number of procedures that require step-by-step performance. Some procedures currently have a requirement to be preformed step-by-step when the situation does not warrant this requirement 9. See CF 1 for details
	- Equipment Difficulty - Equipment Reliability Program - Reliability Task Implementation NI - Tracking/Closure of Task NI *Valve not verified to be closed at the end task by operations department because procedure does not require such verification until all open work orders on a permit are completed*	
	Personnel Difficulty Administrative/ Management systems SPAC NI esponsibility for Item/Activity Adequately Defined operation's supervisor and enance technician did not that the lock-tags were d/ maintained on the and the valves that lead which was still out of	

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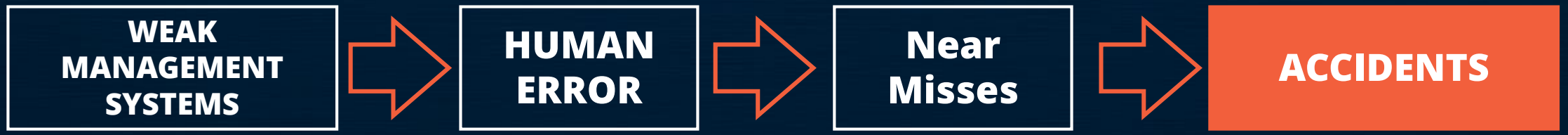
99% of accidental losses begin with a human error*

(except for natural disasters)

*supported by data from more than 1500 investigations

Root causes of accidents are **management system weaknesses**

(Center for Chemical Process Safety, American Institute for Chemical Engineers, "Guidelines for Investigating Chemical Process Incidents", 2003) – US OSHA agrees



HUMAN FACTORS CATEGORIES

Human factor category	Human factor issue/level	Multiplier for cognitive & diagnosis errors
Available time (Includes staffing issues) For responses only	Inadequate time	P(failure) = 100%
	Barely adequate time (~2/3 × nominal)	10
	Nominal time	1
	Extra time (Between 1 and 2 and > 20min)	0.1
	Expansive time (>2x nominal and > 20min)	0.01
Stress/Stressor (Includes staffing issues)	Extreme	5
	High	2
	Nominal	1
Complexity and task design	Highly complex	5
	Moderately complex	2
	Nominal	1
	Obvious diagnosis	0.1
Experience/ Training	Low	10
	Nominal	1
	High	0.5
Procedures 1	Not available	20
	Incomplete	10
	Available, but poor	5
	Nominal	0.5
	Diagnostic/Symptom oriented	1

Human factor category	Human factor issue/level	Multiplier for cognitive & diagnosis errors
Human-Machine interface (includes tools)	Missing/Misleading	20
	Poor	10
	Nominal	1
	Good	0.5
Fitness for duty 3	Unfit (High fatigue level, ilness, strong medication, not physically capable of job today)	20
	Degraded fitness	5
	Nominal	1
Work processes and supervision	Poor	2
	Nominal	1
	Good	0.8
Work environment	Extreme	5
	Good	1
Communication 2	No communication or system interference/damage	10
	No standard for verbal communication rules	5
	Well implemented and practiced standard	1

HUMAN FACTORS TYPICALLY MISSING FROM PROCESS SAFETY

1. **Best practices for content and format of OP procedures**
2. **Verbal Communication Standard** (repeat back, etc.)
3. **Fitness for duty** (fatigue management, etc.)
4. **Task design to match human** (includes work environment)
5. **Human-System Interface** (displays, labels, handheld prompts, etc.)
6. **Staffing considerations for error reduction**

Closing gaps and finding missing scenarios has

greater than 100:1 payback