An Exploration of How and Why a Well-Executed LOPA Improves HAZOP Results

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LOPA Can Improve HAZOP Results

LINKEDIN:

A university student requested input to a master's thesis with the question, *How does a LOPA improve the results of the HAZOP*?

The most common response: **'It doesn't!**

Much of the feedback ranged from *unquestionable certainty* to *overt condescension*….Ouch!!

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So, what was all that about?

This simple query seemed to hit a global nerve…perhaps a tacit challenge to a 'universally held truth'?

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That feedback was a problem.....

…….it was not consistent with my own experience with LOPAs for different clients, projects and project phases, and industry sectors, e.g., offshore and midstream.

In my experience…the LOPA team identified safety-critical errors in *every* HAZOP.

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So how was that achieved?

…To answer that question, the workshop will:

1. Discuss typical HAZOP errors revealed by a well-executed LOPA.
2. Present the suggested activities that should occur in a *well-executed* LOPA. Responses to the '*why and how' questions are discussed.*

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3. Review several project examples ‘to see how this process plays out’
4. Review the suggested roles for the functional safety specialist and suggested capabilities needed to achieve the described results
5. Conclude with *a suggested number that quantifies* the HAZOP error reduction possible if the proposed process is used.

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So let's get started!

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Typical HAZOP errors identified by a *well-executed* LOPA:

- Scenario is not valid
- Incorrect scenario or hazard description. This may change the risk ranking (frequency or consequence)
- Listed safeguards are ineffective/will not work
- Missing safeguards
- Missed opportunity to apply a simpler or inherently safe solution

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Admittedly the primary purpose of the LOPA is not to find and fix errors in the HAZOP.

However.....

….the LOPA process asks different questions and provides a *different perspective* and toolset for examining HAZOP scenarios and recommendations.

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No surprise…this new information *can and should shed new light on the* HAZOP analysis and results.

…….Stated that way, it seems ***likely*** that a well-executed LOPA ***will find*** errors in the HAZOP.

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Sidebar - W*hat is the value of finding a single error in a HAZOP?*

Posit 1: **The potential consequence of every *material* error in a HAZOP study is a failure to *correctly* identify and mitigate a significant safety risk or operability problem**.

Example errors, an incorrect hazard assessment, description or risk ranking.

Posit – to propose as an explanation: suggestion (Merriam Webster)

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A question for the group:

Thoughts on this statement?

Agree or disagree?

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So what does this mean……

"a well-executed LOPA?"

A bit wonky but here it is:

"The right tasks are correctly performed at the right time by competent individuals and by doing so, achieved the desired result'

- The right tasks?
- The right time?
- Competent individuals?
- Desired result?

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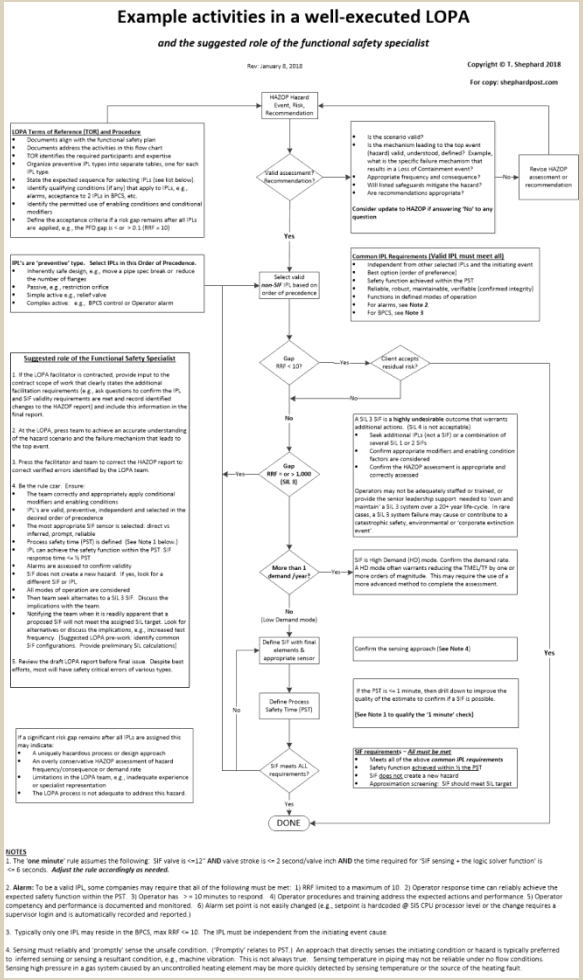
This flow chart suggests answers to the first 3 questions. Finding and fixing HAZOP errors (types) is one result.

We will look at several of these elements to examine why and how errors are 'found'.

Note: This approach was used for LOPAs performed after completion of the HAZOP, i.e., separate study workshops.



Flowchart posted online: shephardpost.com

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HAZOP Hazard Event, Risk, Recommendation

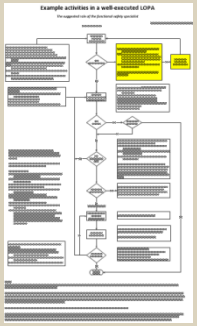
Valid assessment? Recommendation?

- Valid scenario?
- Appropriate frequency and consequence?
- Is the mechanism leading to the top event (hazard) valid, understood, defined? Example, what is the failure mechanism that specifically leads to a Loss of Containment?
- Will listed safeguards mitigate the hazard?
- Are recommendations appropriate?

Consider update to HAZOP if answering 'No' to any question

No

Revise HAZOP assessment or recommendation



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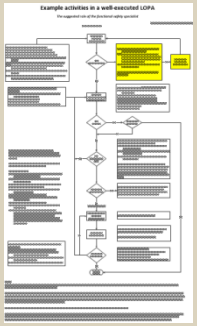
Consistent experience: every HAZOP had one or more errors in these areas, e.g., invalid scenarios, incorrect hazard description / understanding, etc.

How and Why: The LOPA team tends to discuss the hazard description in greater depth. New questions, asked and answered, provided a new understanding. LOPA participants (those attending the HAZOP) change their view.



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Selecting an IPL *requires* an accurate understanding of the hazard event, scenarios and how the hazard is mitigated.

- Can we explain the *mechanism* that causes a 'Loss of Containment' event? (Drill down.)
  - A catastrophic pipe or vessel failure? Flange leak?
- How are humans exposed and for what duration?

IPL – Independent Layer of Protection

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A HAZARD scenario, found to be incorrect in the LOPA, may trigger a revisit (possibly changes) to the selected hazard frequency or consequence values. Errors in either can affect the *Tolerable Frequency* used in the LOPA..that can translate to:

- Too many or too few IPLs
- An inappropriately high or low SIL target resulting in a safety and cost impact
- Unnecessarily complex designs, i.e., higher life-cycle costs, difficult to maintain.

SIL – Safety Integrity Level
IPL – Independent Protection Layer

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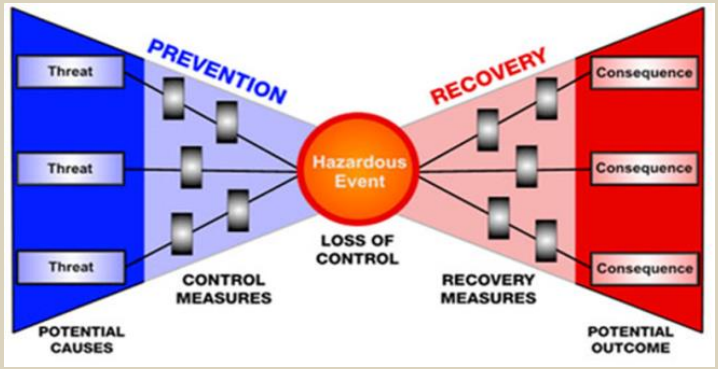
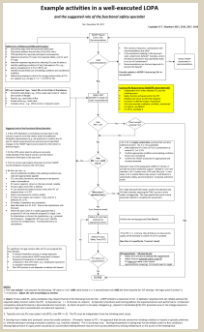
A HAZOP lists the 'available' safeguards and may make *recommendations* to consider additional safeguards if needed.



If viewed as a bow-tie diagram, assessments do not necessarily distinguish between preventive (left side) and mitigation (right side) safeguards.



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Safeguard preference and 'validity' (IPL view) is often not a HAZOP consideration.

IPL's are 'preventive' type. Select IPLs in this Order of Precedence.

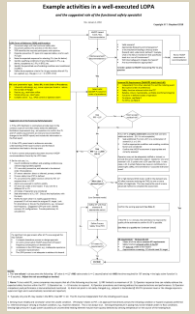
- Inherently safe design, e.g., move a pipe spec break or reduce the number of flanges
- Passive, e.g., restriction orifice
- Simple active e.g., relief valve
- Complex active: e.g., BPCS control or Operator alarm

→ Select valid ***non-SIF*** IPL based on order of precedence

Common IPL Requirements (Valid IPL must meet all)

- Independent from other selected IPLs and the initiating event
- Best option (order of preference)
- Safety function achieved within the PST
- Reliable, robust, maintainable, verifiable (confirmed integrity)
- Functions in defined modes of operation
- For alarms, see **Note 2**
- For BPCS, see **Note 3**

Viewed from this perspective, the LOPA team does a deeper analysis to determine and select safeguards (IPLs) that are *preferred* and meet all IPL requirements.



PST – Process Safety Time

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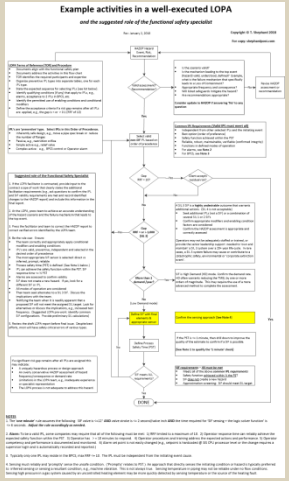
Define SIF with final elements & appropriate sensor

Confirm the sensing approach (**See Note 4**)

Note 4

Sensing must reliably and ‘promptly’ sense the unsafe condition. (‘Promptly’ relates to PST.)

An approach that directly senses the initiating condition or hazard is typically preferred to inferred sensing or sensing a resultant condition, e.g., machine vibration. This is not always true…..



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The HAZOP recommendation closure process may fail to address the question '*Does the proposed solution introduce a new operational problem or hazard*?'.

……..*and yes, this is true for some solutions*. When it occurs, the proposed *unsafe* safeguard must be scrapped and a new safeguard (IPL) identified.

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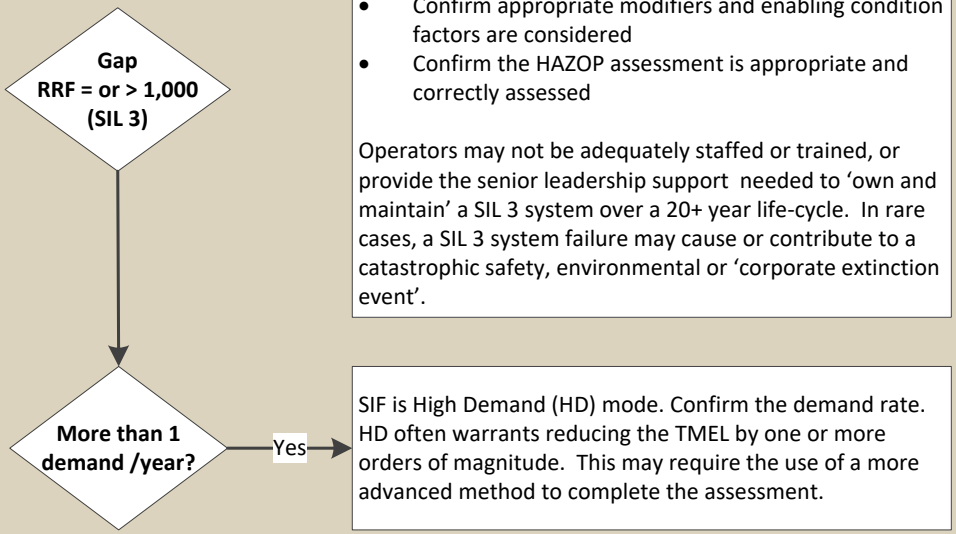
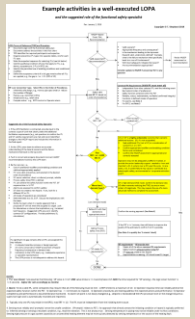
A HAZOP does not address the required reliability of a proposed safeguard, e.g., one of the safeguards (SIS function) may be a SIL 3 SIF.

Process conditions place frequent demands on a safety function, e.g., TF changes from 10^{-4} to 10^{-5}.



If known, the HAZOP team may spend additional time to confirm the scenario and assessments are correct or consider changes in the process.



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Before moving on to case studies….

Any thoughts or comments on what's been discussed so far?

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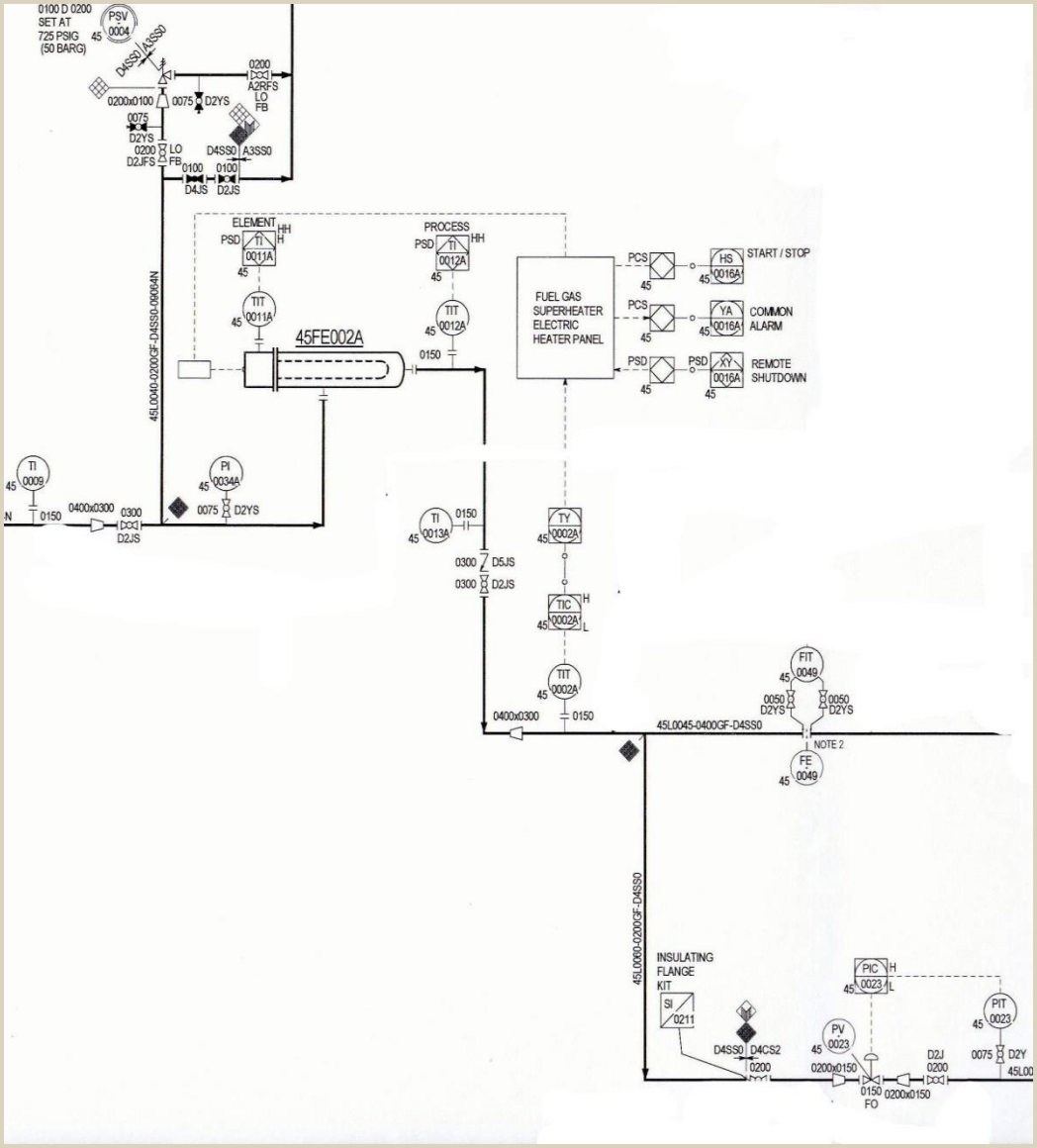
Example 1: Incorrect hazard scenario

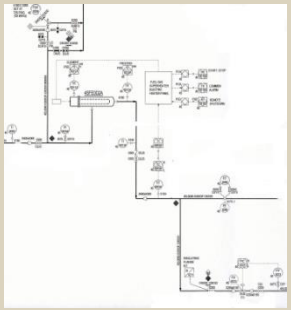
Initiating Event (IE): Blocked flow to/from electric heater.

Hazard Description: Continued heating increases line pressure. Potential line overpressure and rupture. A loss of containment (LOC) event. Personnel hazard.

Recommendation: Add downstream line PAHH to trip the heater (SIS).



A LOPA Can Improve HAZOP Results



LOPA Team Analysis :

- Pipe rupture is not plausible.
- A flange leak resulting from local heating is plausible.
- Flange temperature increases much faster than line pressure.

Revised solution: Delete PAHH. Select IPLs:

- Temperature controller (local panel)
- TAHH (flange) heater trip (SIS – SIL 2)

ALARP: If feasible, add a heater controller setpoint (SP) clamp to block a potentially excessive SP from a faulty BPCS TIC.

ALARP – As Low As Reasonably Practicable

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Example 2 – Invalid Scenario

Hazard description: Potential loss of nitrogen supply used for flare purge. Potential ingress of air into the flare and flare header. Potential explosion.

I.E.: Failure or loss of the nitrogen generation system. Loss of N2 purge from this system.

HAZOP Safeguards: Backup N2 from bottles

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Example 2 - LOPA Assessment

Scenario review: A lengthy discussion attempting to understand the hazard scenario and operating modes. How are the N2 bottles used? When is the N2 skid down and the flare/header contains flammables?

Outcome: Essential information was missing.

LOPA Recommendation: Confirm the use of the N2 bottles, operating procedures and shutdown scenarios.

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Example 2 – LOPA Results

LOPA recommendation response: Operations advised the scenario is not plausible given the revised operating procedures and current design.

HAZOP: The HAZOP report was updated (corrected) with new information.

LOPA : The LOPA report was updated with the recommendation response. The scenario was marked as invalid.

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Example 3- Safeguard missed in HAZOP

Background: Hypochlorite Generator Skid

- Generates sodium hypochlorite from seawater (biocide).
- The conversion occurs in the electrolyzer
- A byproduct, hydrogen (H2), is released in a degassing tank. Dual fans purge the tank to prevent H2 accumulation and a potentially explosive mixture.

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Example 3- HAZOP Result

Hazard: Potential H2 buildup in degassing tank. Potential vessel explosion.

I.E.: Loss of forced air ventilation (various causes)

Safeguards: Non-conductive degassing tank. Dual purge fans.

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Example 3 - LOPA Results

Scenario review: Lengthy discussion to clarify the hazard scenario and modes, how the package works. 'It's a standard vendor package.' Consulted experts to fully understand the inner workings and operating sequences. *Several revelations.*

New details on hazard: The lower explosive limit is reached in 30 seconds on fan loss. H2 release continues for 5 minutes after power removed from electrolyzer.

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Example 3 - LOPA Results

LOPA recommendation:

Add a new SIF (SIS) that is independent from the vendor package. A new flow sensor monitors the degasser exhaust flow. FALL independently trips the electrolyzer.

SIS – Safety Instrumented System

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Suggested role of the Functional Safety Specialist

1. If the LOPA facilitator is contracted, provide input to the contract scope of work that clearly states the additional facilitation requirements (e.g., ask questions to confirm the IPL and SIF validity requirements are met and record identified changes to the HAZOP report) and include this information in the final report.

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Suggested role of the Functional Safety Specialist

2. Encourage the LOPA team to seek and achieve an accurate understanding of the hazard scenario and the failure mechanism that leads to the top event.
3. Press and confirm the HAZOP report is updated to correct the findings identified by the LOPA team.
4. During the LOPA, be the rule czar. See list.

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Suggested role of the Functional Safety Specialist

5. Review the draft LOPA report before issue. Despite the facilitator's best efforts, the report typically has 1 or more significant errors, e.g., copy/paste errors, missing information, etc.

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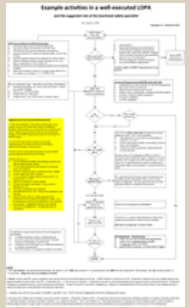
Suggested capabilities of the Functional Safety Specialist

Managing all suggested activities is a very challenging task. It requires:

- A broad and deep FS experience and expertise, e.g., correct application of rules, SIL calculations, control systems architecture, instrumentation, etc.
- Interpersonal skills that gains team trust, and does not bog down the process.
- Self-confidence, the courage to speak up



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To close out, a few final posit statements to consider…..

Posit 2 – **A well-executed LOPA *will likely* find safety significant errors in *every* HAZOP.**

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Posit 3 – **A well-executed LOPA should find an average of 5% errors in a HAZOP. ***

This number *seems* reasonable. The actual value may be higher or lower. *It certainly seems like a safety-important value that warrants a concerted effort to validate.*

* Percent = the number of assessed scenarios having at least 1 safety-significant error / total # of assessed scenarios * 100. **Assumptions:** small to mid-size project. Simple processes that generate25-50 scenarios to assess in a LOPA.

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Thoughts on these final *posit* statements?

Agree or disagree?

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This concludes the workshop.

Thank You!

Author Bio – Tom Shephard CAP, PMP

- 37 years working for several operating companies (petroleum, O&G) and engineering companies
- A passionate seeker of best practice tools & methods
- Technical safety department management
- From 2004, functional safety lead on many projects
- Automation project management and technical lead
- Projects in refining, offshore, O&G, midstream, pipeline
- A lifetime of hands-on SIS work. All project phases and activities. Specification, design, implementation, startup

Retired : wood. *(Previously Wood Group Mustang)*