4th CCPS Middle East Process Safety Conference

How Do We Prevent Losing Sight in Risk Assessments

AcuTech
PROCESS RISK MANAGEMENT

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Colin D Armstrong | Principal Engineer

- Leads AcuTech's QRA and FSS practice
- Completed numerous FSS and QRA projects in oil, gas, LNG, and specialty chemical industries worldwide
- Experienced in all aspects of consequence modeling, frequency assessment, scenario analysis and identification (FTA, FMEA, event tree, LOPA, etc.)
- Instructor of QRA and Consequence Modeling for operating companies and students at University of Maryland
- Investigator and expert witness in response to incidents and OSHA citations

Brad Fuller | Manager of Risk Assessment Services

- 25+ years of engineering, consulting, and project management experience
- Accomplished in PSM, security, and risk management focusing on the energy, petroleum LNG, chemical, and transportation sectors
- Skilled in all aspects of qualitative and quantitative risk assessment
- Experienced PHA (HAZOP/LOPA) facilitator, leading projects at US and international facilities and operations
- Author of CCPS *Guidelines for Chemical Transportation Safety, Security and Risk Management*

Assessments Are The Basis For How We Identify, Understand and Manage Risk

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- Provide a survey of potential hazards
- Advise our selection of mitigation measures
- Prioritize efforts, expenses, and capital projects
- Use various methods to assess risks from different viewpoints/perspectives
  - PHA – Qualitative scenario-based review, deviation focus, revaluates safeguards to mitigate hazards (Risk Matrix)
  - QRA – Quantitative use of equipment accidental release data, consequence models, and impact probabilities to compare against risk tolerance criteria (individual/ societal risk)
  - RBI – Mechanical integrity focused to determine inspection frequency
  - Others – May focus on projects, specific equipment or controls, variety of techniques (FTA, FMEA, Bow-Tie, Event Tree, etc.)

The Problem

- Every year companies invest capital and the time of their internal resources to conduct risk assessments.
  - **Purpose** is to comply with process safety regulations, Recognized And Generally Accepted Good Engineering Practices (RAGAGEPs), company and industry guidelines, and other specialized studies.
  - **Goal** is to protect the safety and health of their personnel and communities, minimize impacts to the environment, ensure continuity of operations, and secure future sustainability.

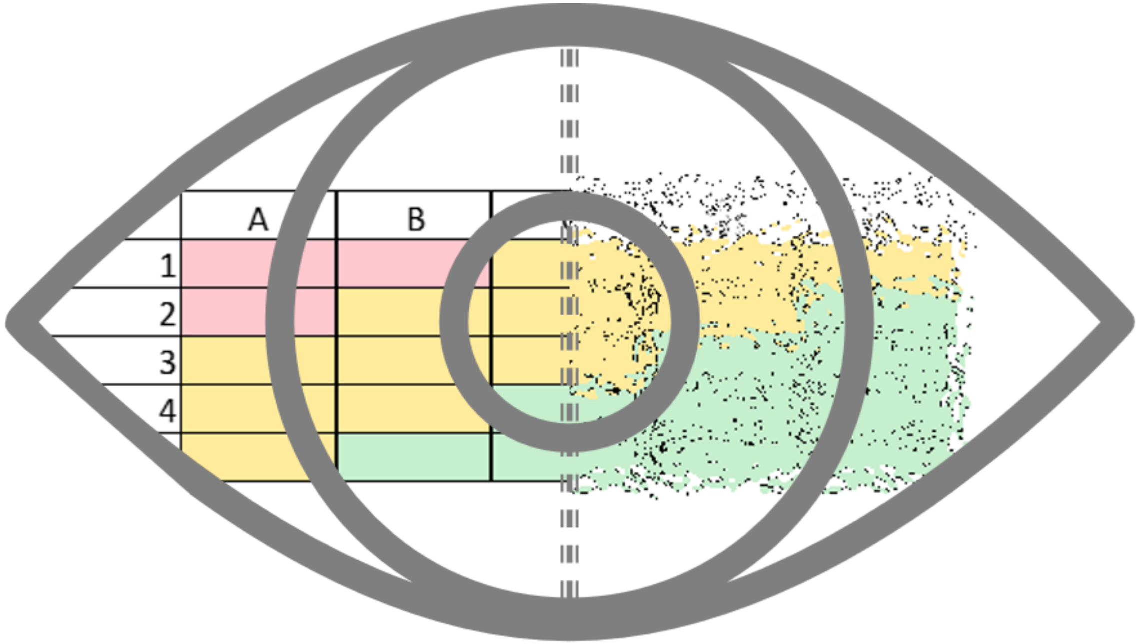
- While there is a clear business case for investment in process safety, all too often, even when significant hazards/ risks are uncovered:
  - **There is a hesitancy to make or accept recommendations**
  - **Lack of support and follow through to drive identified recommendations to completion**
  - **Ultimately would improve safety and continually manage operational risks**

Have You Seen These Issues?

- Issues
  - Hesitancy to highlight potential hazards/ risk, and to propose/ document recommendations to management.
  - Open Recommendations with no clear action plan.
  - Assessment reports that are shelved, filed away, and collecting dust.

- Too often, there is a disconnect between completing the studies and completing the actions required to mitigate identified risks

- Over the years AcuTech has seen that
  - Some organizations are successful in moving from study, to results, to actions, to implementation
  - Others lose sight before they can reach implementation



Case Study

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- Based on AcuTech's global consulting practice a case study with lessons learned is presented
  - Real-world examples of the obstacles and pitfalls will be assessed to determine why good studies fail.

- Includes comparison of both qualitative (e.g., Process Hazard Analysis (PHA)) and quantitative risk assessment (QRA) projects.

- Focusing on why
  - Some studies are successful – **Leading To Action**
  - Others flounder – **Never Gaining Traction**

- While all companies have good intentions when they start the risk assessment process, some can lose sight when the process moves from study completion to action and follow-up .

Comparison PHA to QRA

PHA

- Evaluates risk from a process hazard/ scenario-based viewpoint
  - Causes (based on deviations from normal operation)
  - Consequence (e.g., people, environment, assets)
  - Safeguards
  - Scenario risk ranking
- Recommendations are qualitative (Risk Matrix)
- Typical Hazard and Operability (HAZOP) can be expanded to include Layer of Protection Analysis (LOPA), which is a more semi-quantitative approach

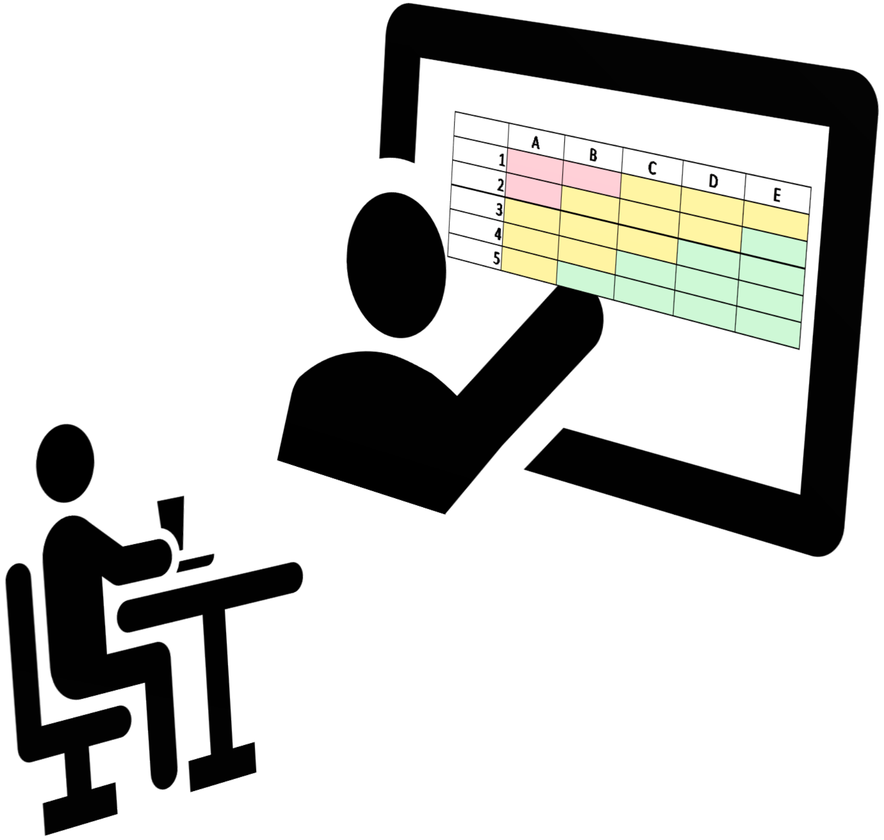
QRA

- Evaluates risk/ hazards/ impacts using quantitative methods and tools
  - Release scenarios
  - Release frequencies
  - Consequence modeling (e.g., toxic, fire, explosion)
  - Impact probabilities based on location (e.g., personnel location indoors vs. outdoors)
  - Accounting of detection/ isolation (mitigation/ safeguards)
- Results Comparison to Risk Tolerance Criteria

Process Hazard Analysis

- Pro's
  - PHA process (What-If, HAZOP) is well understood and has been applied throughout industry
  - Team-based study includes multi-disciplines/ experts
  - Defines detailed hazard scenarios, potential consequences and safeguards, to define risk level
  - Use of Risk Matrix to determine gaps, and need for recommendations
  - Studies commonly expanded to include Layer of Protection Analysis (LOPA) and identification/ need for Independent Protection Layers (IPLs), as well as Safety Instrumented System (SIS) requirements

- Con's
  - Team-based study heavily reliant on the participation/ experience of the team
  - Subject to team's bias
  - Recommendations associated with low-risk scenarios may not be considered, documented, or rejected
  - Defined LOPA process required for successful and consistent application



LOPA Overview

Protection layer diagram

Source:
Factory Mutual Research

Expanding PHA To Include LOPA

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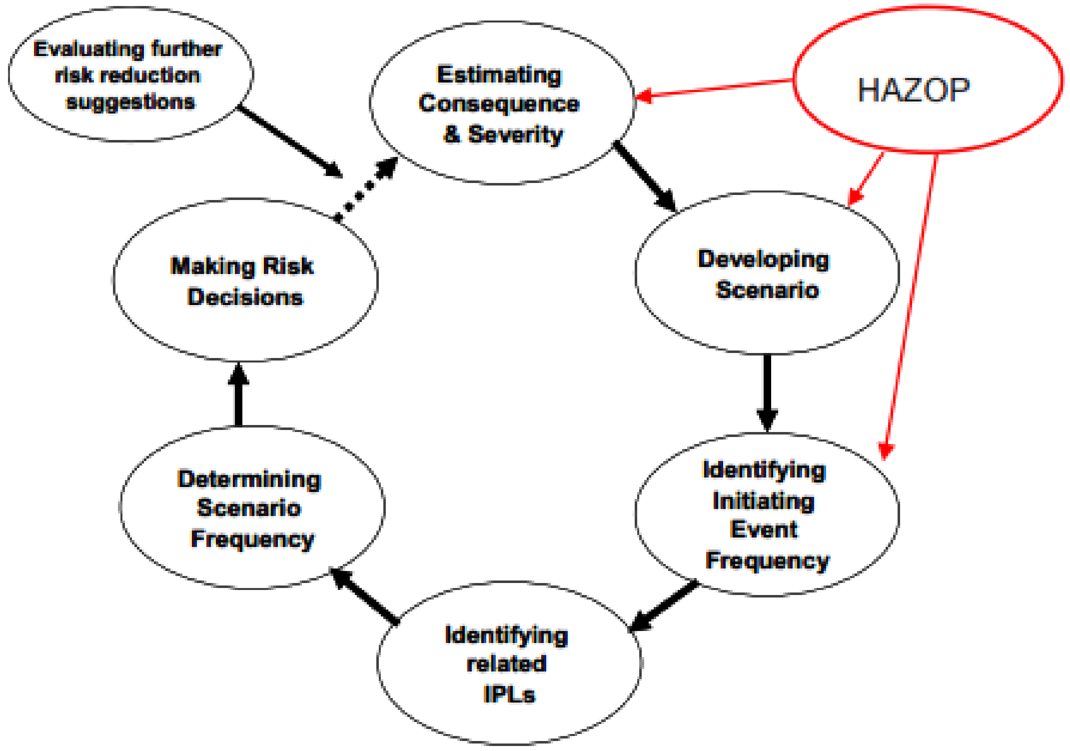
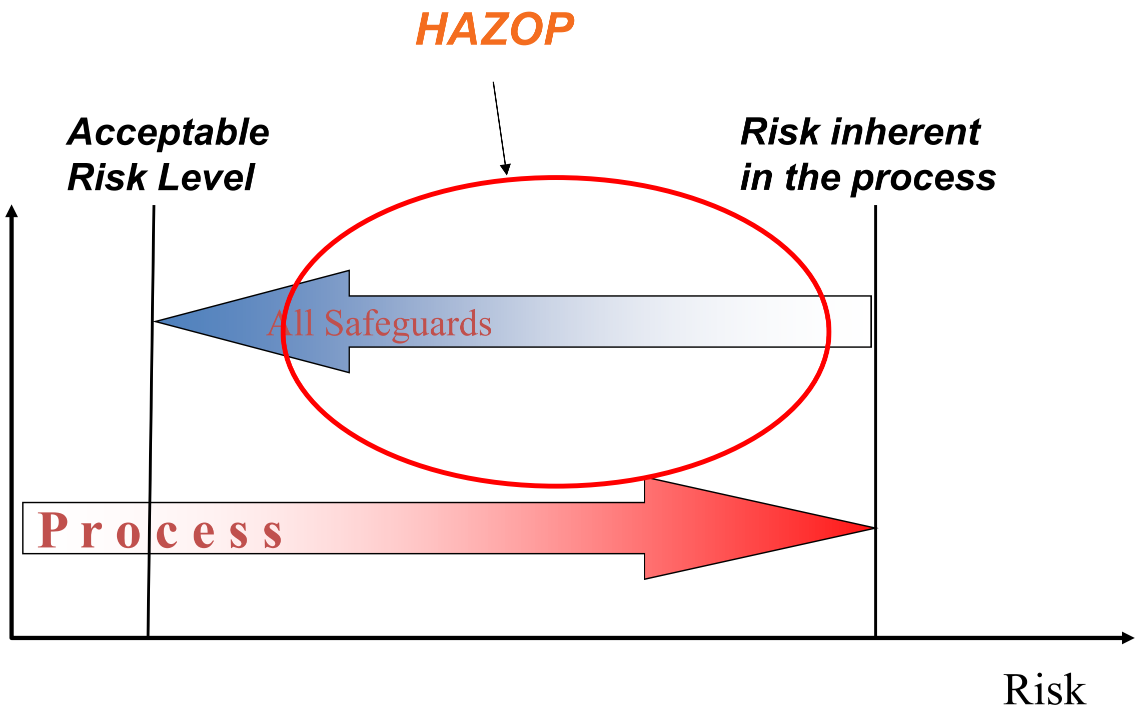
- LOPA is a simplified form of risk assessment.
- LOPA typically uses order of magnitude categories to approximate the risk of a scenario for
  - Initiating event frequency
  - Consequence severity
  - Likelihood of failure of independent protection layers (IPLs)
- Target Mitigated Event Level (TMEL) Frequency
  - Based on Scenario Consequence
- Result can be used to support SIS

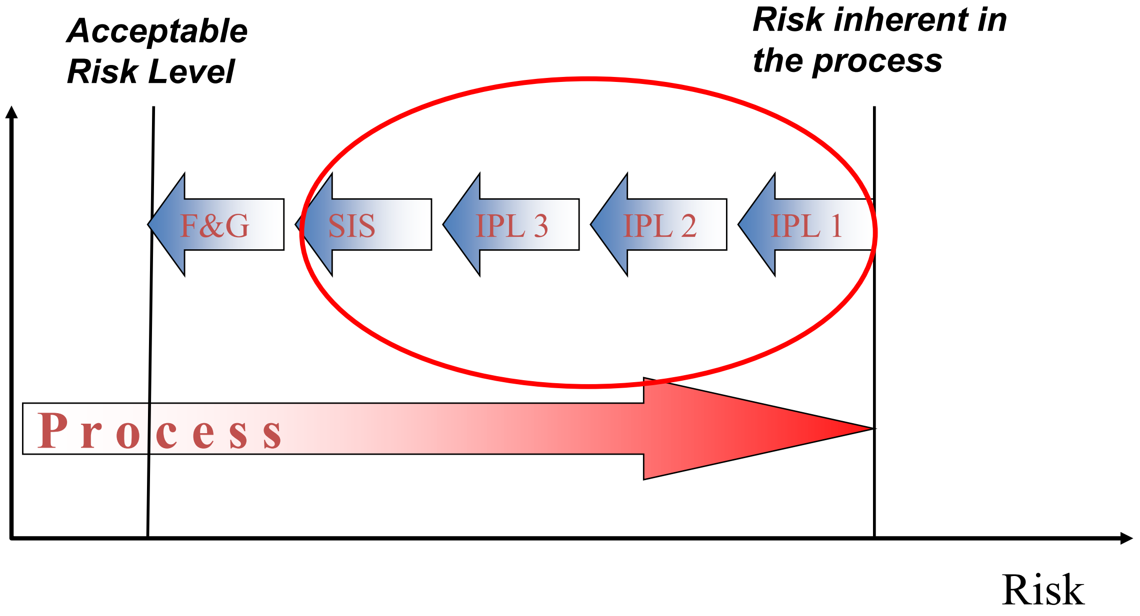


Comparison HAZOP to LOPA

HAZOP is Concerned with Overall Risk



LOPA Evaluates IPLs



Quantitative Risk Assessment

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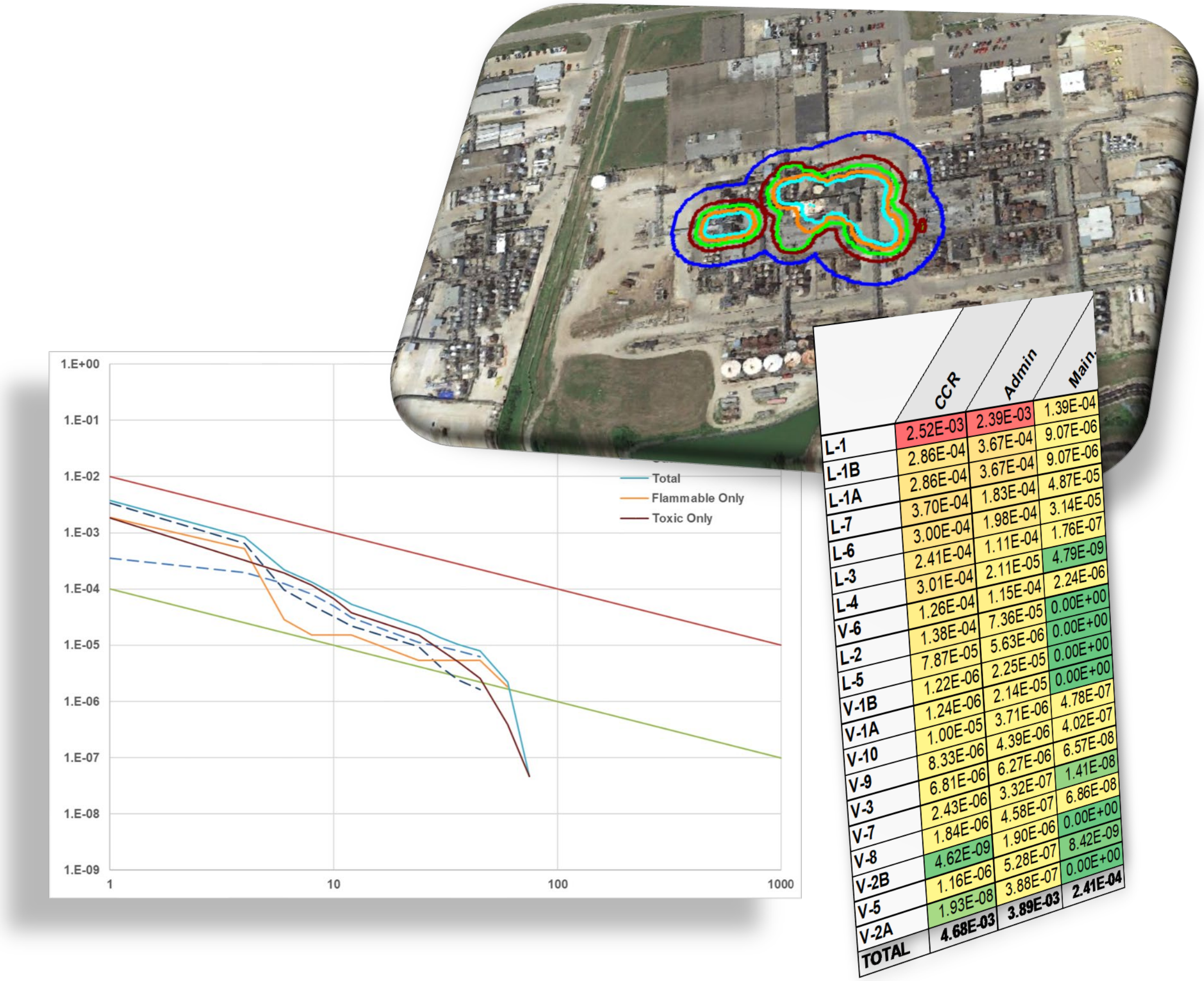
- Pro's
  - More accurate consequence results (e.g., modeling of toxic, fire and explosions)
  - Results based on consequence and/or risk level
  - Risk Results (individual, societal, location specific, building specific, worker/ public specific)
  - Results compared to Risk Criteria

- Con's
  - Time consuming
  - Cost
  - Methods and results not as commonly understood
  - Lack of company risk criteria
  - Results are aggregate and not linked to a single scenario
  - Difficult to translate results to actionable plan



	CCR	Admin	Main.
L-1	2.52E-03	2.39E-03	1.39E-04
L-1B	2.86E-04	3.67E-04	9.07E-06
L-1A	2.86E-04	3.67E-04	9.07E-06
L-7	3.70E-04	1.83E-04	4.87E-05
L-6	3.00E-04	1.98E-04	3.14E-05
L-3	2.41E-04	1.11E-04	1.76E-07
L-4	3.01E-04	2.11E-05	4.79E-09
V-6	1.26E-04	1.15E-04	2.24E-06
L-2	1.38E-04	7.36E-05	0.00E+00
L-5	7.87E-05	5.63E-06	0.00E+00
V-1B	1.22E-06	2.25E-05	0.00E+00
V-1A	1.24E-06	2.14E-05	0.00E+00
V-10	1.00E-05	3.71E-06	4.78E-07
V-9	8.33E-06	4.39E-06	4.02E-07
V-3	6.81E-06	6.27E-06	6.57E-08
V-7	2.43E-06	3.32E-07	1.41E-08
V-8	1.84E-06	4.58E-07	6.86E-08
V-2B	4.62E-09	1.90E-06	0.00E+00
V-5	1.16E-06	5.28E-07	8.42E-09
V-2A	1.93E-08	3.88E-07	0.00E+00
TOTAL	4.68E-03	3.89E-03	2.41E-04

QRA Complexity As Compared To PHA

- Risk Analysis
  - Consequence Modeling
    - Release Scenarios
      - Hole Size Ranges
      - Event Tree Analysis
        - Detection and Isolation
    - Hazard Identification (HAZID)
      - Process Conditions
      - Process Inventories
    - Location and Climate
      - Weather Data
        - Wind Speed and Stability
        - Ambient Conditions
      - Process Locations
      - Terrain
  - Vulnerability Definitions
    - Building Design Data
    - PI Diagrams
  - Frequency Analysis
    - Release Frequencies
      - Parts Count
      - PHA/LOPA/FTA
    - Climate Statistics
      - Wind Rose
      - Historical Climate Data
    - Ignition

Information Flow Between Studies

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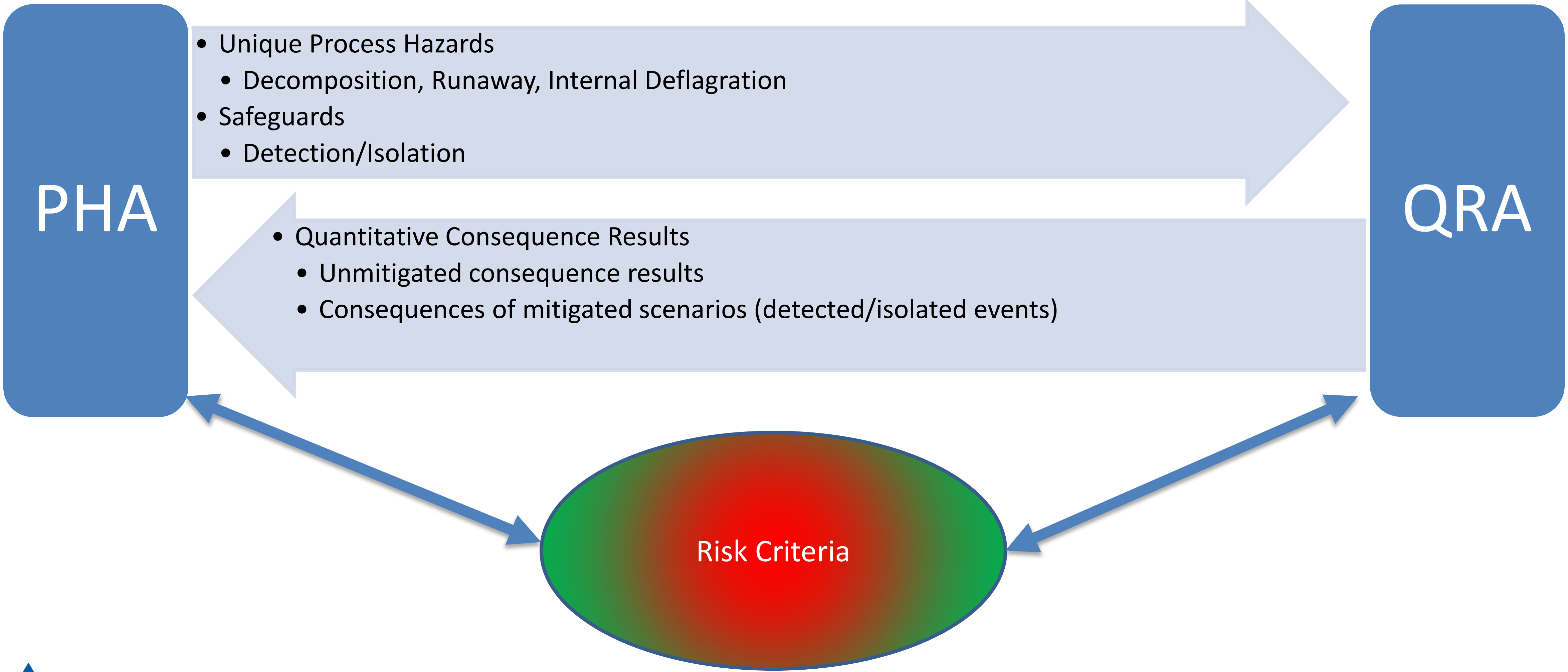

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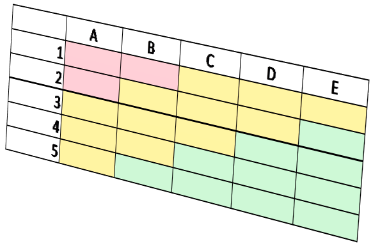
Need for Established Risk Criteria

- PHAs assess risk for each scenario that is considered in the study
- The team estimates the severity of each scenario
- The team estimates or calculates the frequency of each scenario
- Risk assessments are for individual scenarios
- LOPA additionally requires initiating event frequencies, IPL probabilities, and TMELs



- QRAs assess risk from all scenarios in the study
- The study models the consequence severity of each scenario (including potential impacts probabilities)
- The study calculates the frequency of each scenario
- The risk is aggregated/summed to determine the cumulative risk at specific locations, the overall site, or the surrounding community

Why Can Good Studies Fail?

- Process safety culture
- Lack of risk assessment guidelines
- Engagement/ buy-in to the risk assessment process
- Skepticism in the results/ lack of transparency
- Non-practical recommendations
- Non-regulatory recommendations
- Results are not clearly communicated
- Risk assessment goals not defined, next steps are not clear
- Large of recommendations to be resolved
- Cost to implement recommendations
- Imperfect management systems

Stakeholder Engagement - Issues

- Stakeholders may not be
  - knowledgeable in the study scope, methods, or objectives
  - aware of requirements

- When stakeholders are not engaged in the risk assessment process
  - Results may be dismissed, “They made a mistake”, “ ‘They used the wrong information”
  - The scope and limitations of the study are not understood
  - The inputs or assumptions are questioned
    - “This wouldn’t happen here”
    - “This isn’t how we operate”

Stakeholder Engagement - Solutions

- Stakeholders should be involved in risk assessments from the beginning of the study
  - Stakeholders are not necessarily the engineers associated with the scope of the study, but the decision-makers
  - Stakeholders could change based on the results

- Involve stakeholders at the start and thoroughly present the risk assessment plan, including potential outcomes
  - Don’t be shy, especially if the study could require major actions.

- Present the results to stakeholders following completion
  - Don’t just toss a report over the fence

- Involve stakeholders in the recommendation process if possible
  - For QRAs or Facility Siting Studies, provide results, and hold a meeting to review them and develop the recommendations together

Traits of Successful Companies

- Process safety culture
  - Leadership of an organization has the primary responsibility for identifying the need for, fostering, and sustaining the process safety culture.
  - Top-down commitment to day-to-day safety, support of the risk assessment process, communication of hazard/risks, and visible continuous improvement.
  - Everyone in the organization has a role in process safety culture.

- Risk assessment guidelines
  - Key for successful and consistent assessments.
  - Defined risk assessment processes for PHA, LOPA, QRA, etc.
  - Defined required participants (e.g., operations, engineering, instrumentation & controls, maintenance, EHS, etc.).
  - Defined Risk Criteria (Risk Matrix and Quantitative Risk Criteria).
  - Ensures engagement/ buy-in to the risk assessment process.
  - Reduces skepticism in the results/ lack of transparency .

Traits of Successful Companies

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- Identifying and developing recommendations
  - Recommendations need to follow company risk assessment guidelines
    - When are recommendations required (e.g., high hazard, high risk, LOPA gap, exceed risk criteria)?
    - When are recommendations at the discretion of the team?
    - When are recommendations not required (e.g., low hazard, low risk, operability issue only)?
    - What type of recommendations will management not accept (e.g., focus on safety and environment, or other non-regulatory impacts to assets, reputation, operability to be identified)?
    - Recommendations should identify issues and engineered solutions should be a follow-on activity to avoid non-practical recommendations.

- Risk results review
  - To ensure results and recommendations are clearly communicated.
  - Team should review recommendations for clarity before completion of the study.
  - Recommendations with management should be with the full risk assessment team.

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Traits of Successful Companies

- Risk assessment goals need to be defined
  - What if a high risk is identified (immediately notify management, is a temporary mitigation measure required, etc.)?
  - Defined recommendation owner(s).
  - If recommendation requires SIS can that be implemented or a long-term solution?
  - If recommendation requires relocation/ retrofit of an occupied building is more analysis required or the risk drivers, can be existing building be modified, what is the suitable new location, how will the risk to building occupants be communicated and managed until the final changes are implemented?

- Resolution of recommendations
  - Processes are needed to ensure success.
  - Prioritization system based (e.g., risk level, ease of implementation, regulatory requirement, etc.).
  - Defined recommendation review, approval, and implementation timeline.
  - Reoccurring management review meeting to review status of open risk recommendations, including cost, other risk-management solutions, or risk acceptance.

Risk Assessment Life Cycle

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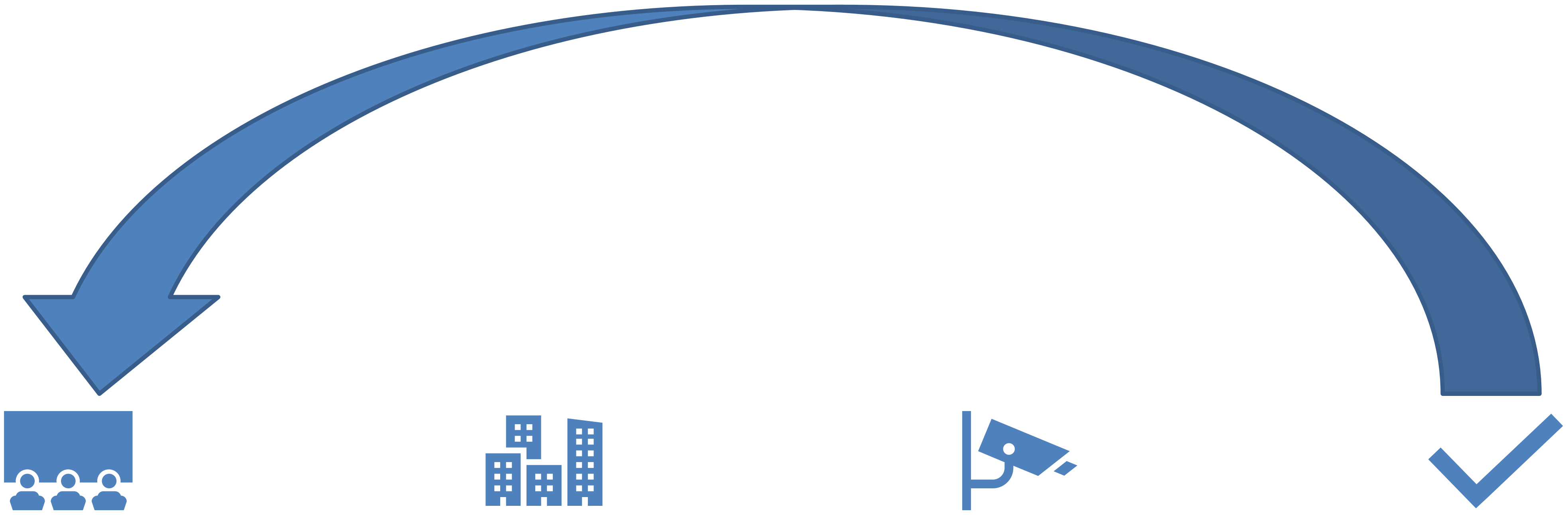

Perform Study

Take Action

Modify Buildings/Processes

Relocate Personnel

Monitor

Verify building occupancy

Maintain Safety Systems

Update

New Buildings

New Processes

Periodic Revalidation

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Questions?

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REMAINING SLIDES FOR CONSIDERATION FOR REMOVAL

Current Issues

- Lack of Engagement/Buy-In
  - Studies collect dust
- Skepticism
  - Stakeholders don’t believe the results
  - Assumptions and inputs are questioned
- Results are not clearly presented
- Non-Practical Recommendations
  - Mitigation options are overwhelming
- Actions never taken
  - Cost
  - Clarity

- A variety of methods can be employed to avoid these issues.

Keys to Success

- Stakeholder Engagement
- Transparent Methods
- Clear Results Communication
- Actionable Recommendations
- Informed follow-through

Transparent Methods - Issues

- Inputs or assumptions are questioned if not adequately documented or understood
- Study limitations may be considered deficiencies

Transparent Methods - Solutions

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- Present the methods at the start of the study
- Allow time for questions and encourage them
- Document methods, limitations, and assumptions clearly in the report
- Use publicly available methods, models, and inputs

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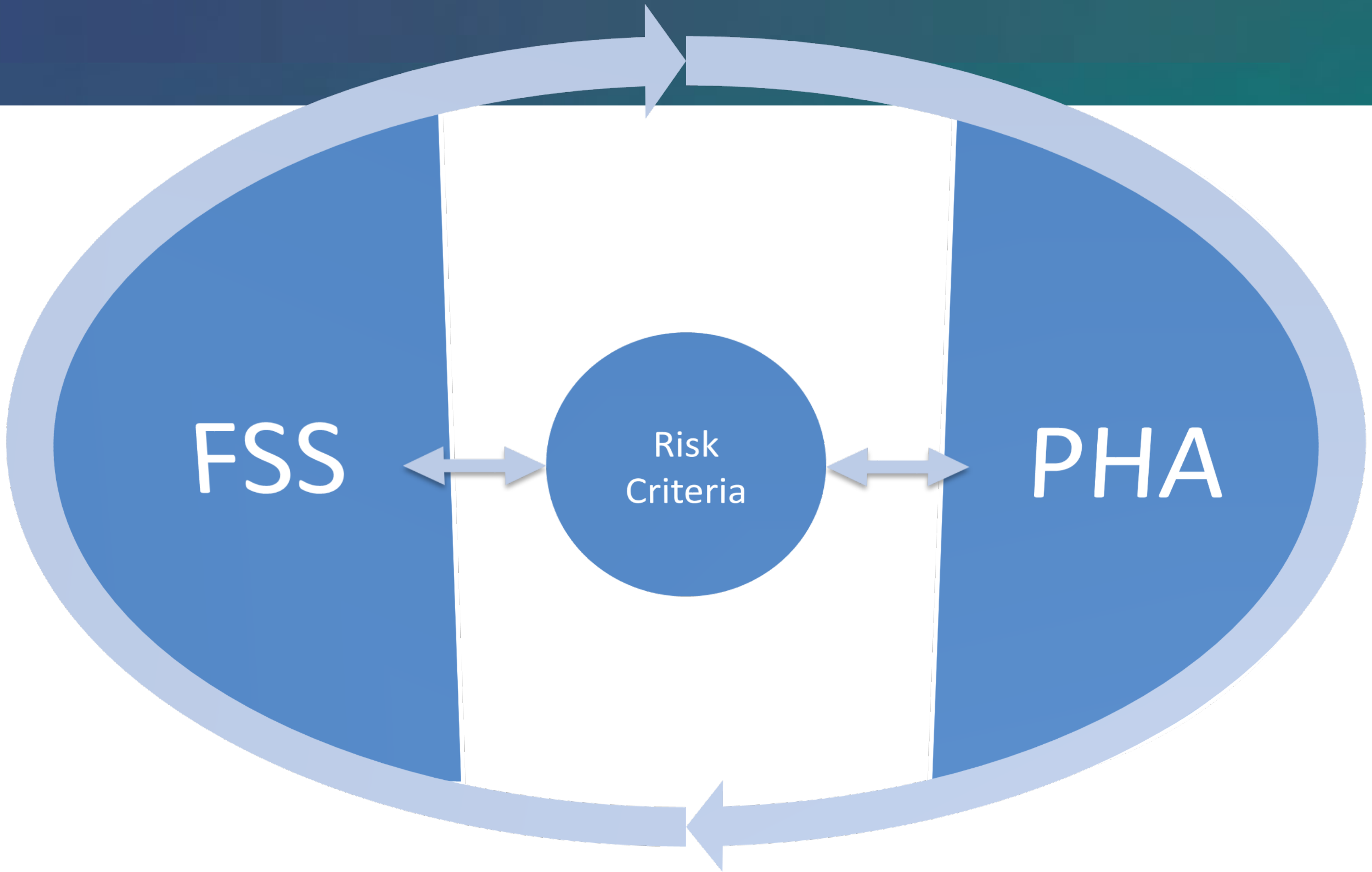
1. Advise our selection of mitigation measures
2. Identify risks (knowns/unknowns)
3. Prioritize risk mitigation efforts, expenses, and capital projects

1. Don’t identify measures clearly (confusing recs)
2. Don’t identify all risks, or focus on the wrong risks
3. Don’t provide data for prioritization
    1. Recommendations end up being prioritized based ease of implementation or cost

Agenda

- Elements of Process Hazard Analysis (PHA)
- Elements of Risk-Based Facility Siting Study (FSS)
- PHA/FSS Overlap
- How a PHA Feeds to FSS
- How a FSS Feeds to PHA
- Information Flow Between the Studies
- Aligning Studies through Risk Criteria
- Q&A

Let’s look first at what each one contains


FSS
Risk
Criteria
PHA

Elements of Hazard Analysis Studies

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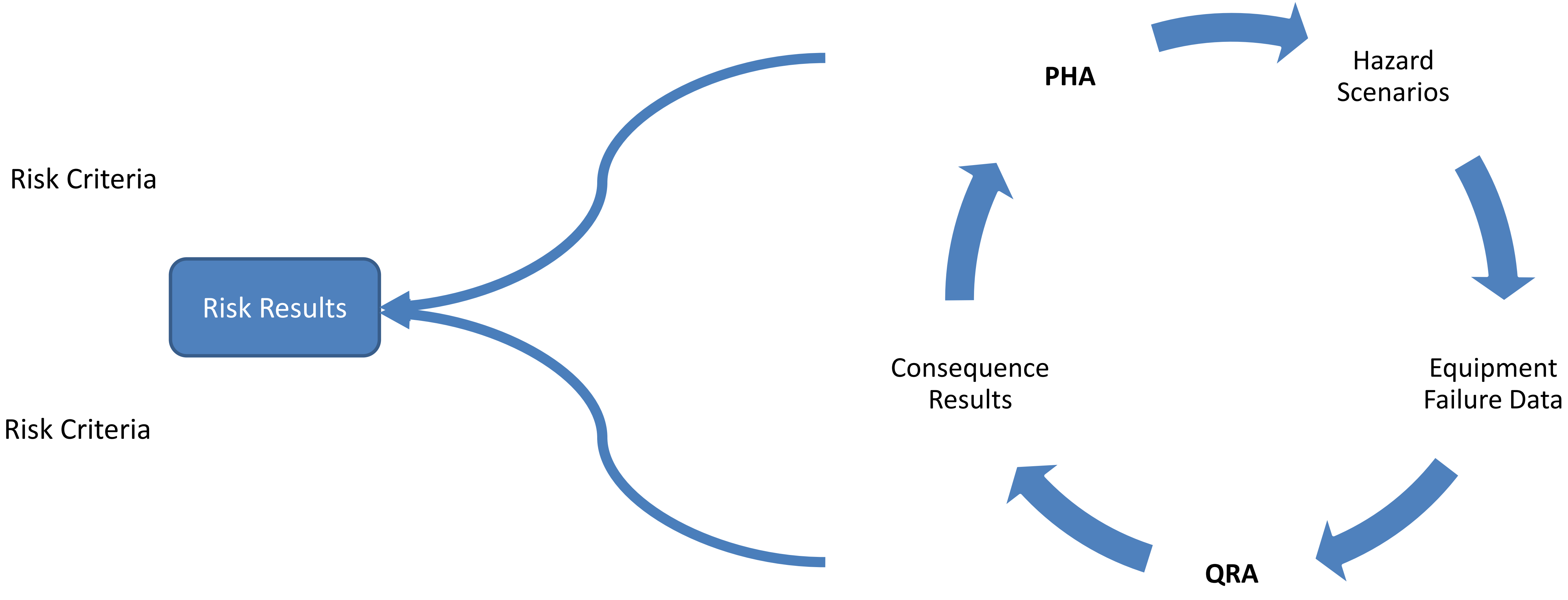
PHA

- Looks at risk from a process viewpoint
- Recommendations based on qualitative risk assessment – team 'gut feeling'

Facility Siting

- Looks at risk/hazards from a building viewpoint
- Recommendations based on quantitative risk assessment – what is the actual risk

Integrated Risk Assessment Life Cycle



How PHA Feeds to FSS

PHA

- Key PHA Elements
  - Cause
  - Consequence
  - Safeguards
  - Risk ranking

Unique Process Hazard Scenarios

Detection/ Isolation;
Secondary Containment;
Emergency Blowdown;
Ventilation;
Water Deluge

Aligning Scenarios

- Aligning the PHA scenarios with the siting study can improve the quality of the siting study
- The PHA should be considered during the siting study HAZID
- Generic release scenarios are generally included in a siting study but process-specific hazard scenarios from the PHA should also be considered.
- The siting study may provide a more complete and accurate risk assessment of the PHA scenario

Safeguard

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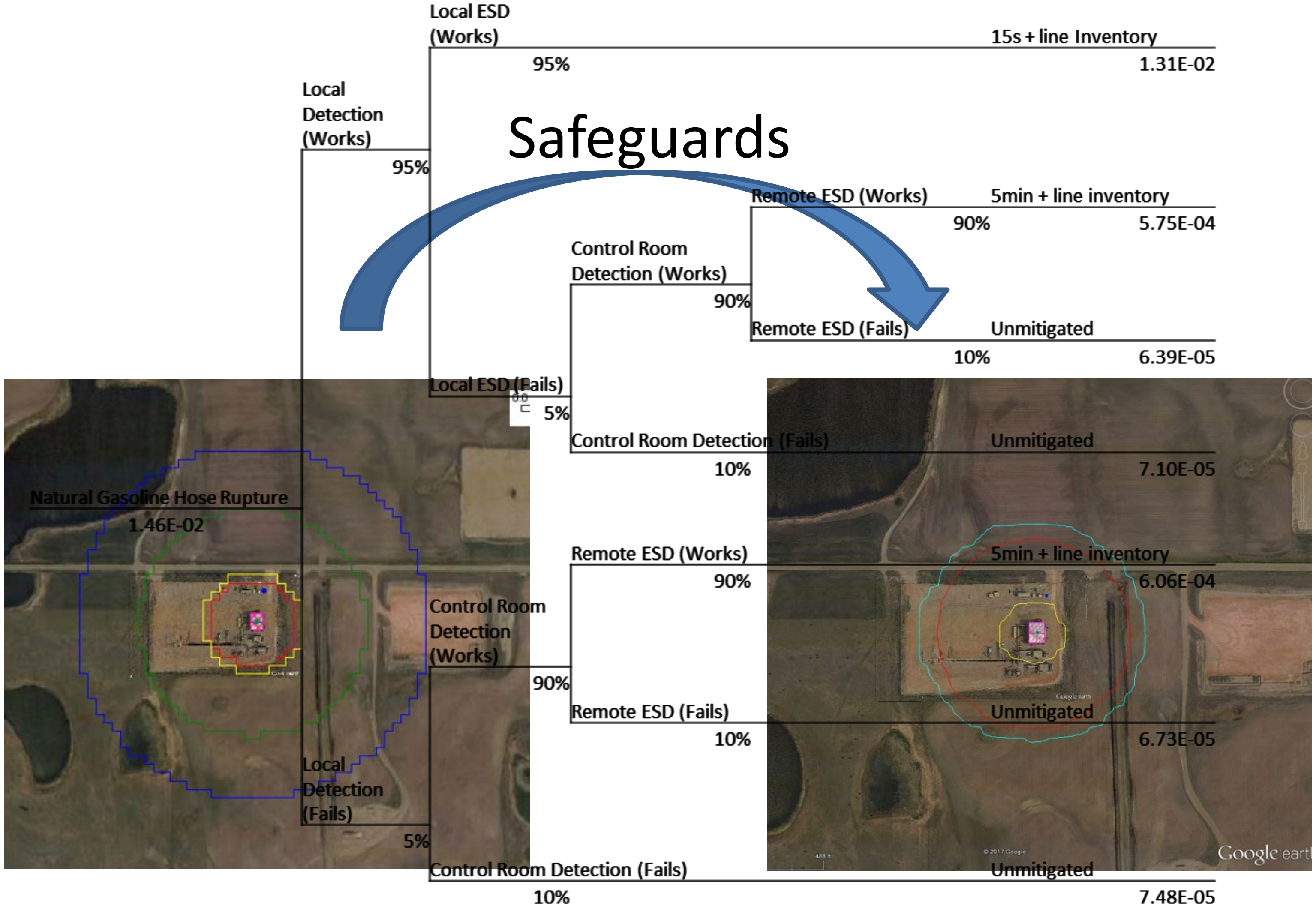
- **Safeguards**
  - PHA safeguards should be considered to define frequencies for scenario-based hazards in the FSS
  - FSS can assess the efficacy (consequence impacts) of certain safeguards (detection/isolation)
  - FSS may utilize event trees to consider the likelihood of mitigation options; may inform PHA safeguard listing



How FSS Feeds to PHA

Facility Siting

- Key FSS Elements
  - Consequence Modeling
    - Release Scenarios
    - Hazard Identification
    - Location/ Climate
  - Vulnerability Criteria
    - Building Design Information
  - Frequency Analysis
    - Likelihood of release, weather, ignition

Single Scenario Consequence

(consequence severity)

Single Scenario Risk

(severity/ likelihood of a single scenario)

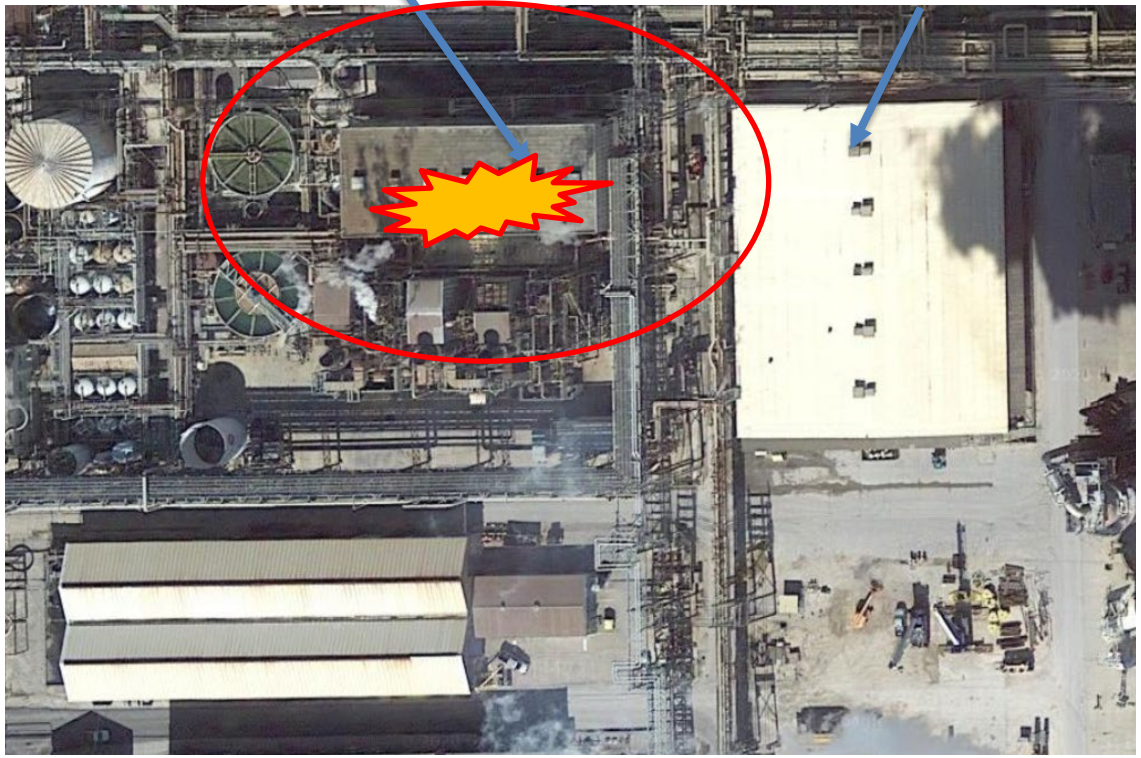
Individual Risk

(risk of all release scenarios on one person in a building)

Consequence

Compressor Building

Control Room



- Consequence
  - Consequence modeling can identify the maximum extent of the hazard for PHAs
  - Quantitative FSS results should be referenced when the PHA is revalidated to create more accurate qualitative consequence evaluation
  - FSS scenario modeling can be used as reference point for PHA

Information Flow Between Studies

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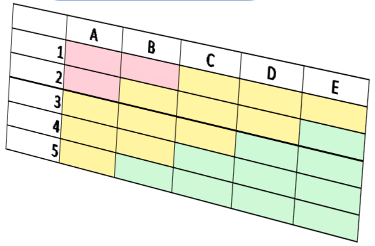
PHA → **FSS**

- Unique Process Hazards
  - Decomposition, Runaway, Internal Deflagration
- Safeguards
  - Detection/Isolation

FSS → **PHA**

- Quantitative Consequence Results
  - Unmitigated consequence results
  - Consequences of mitigated scenarios (detected/isolated events)



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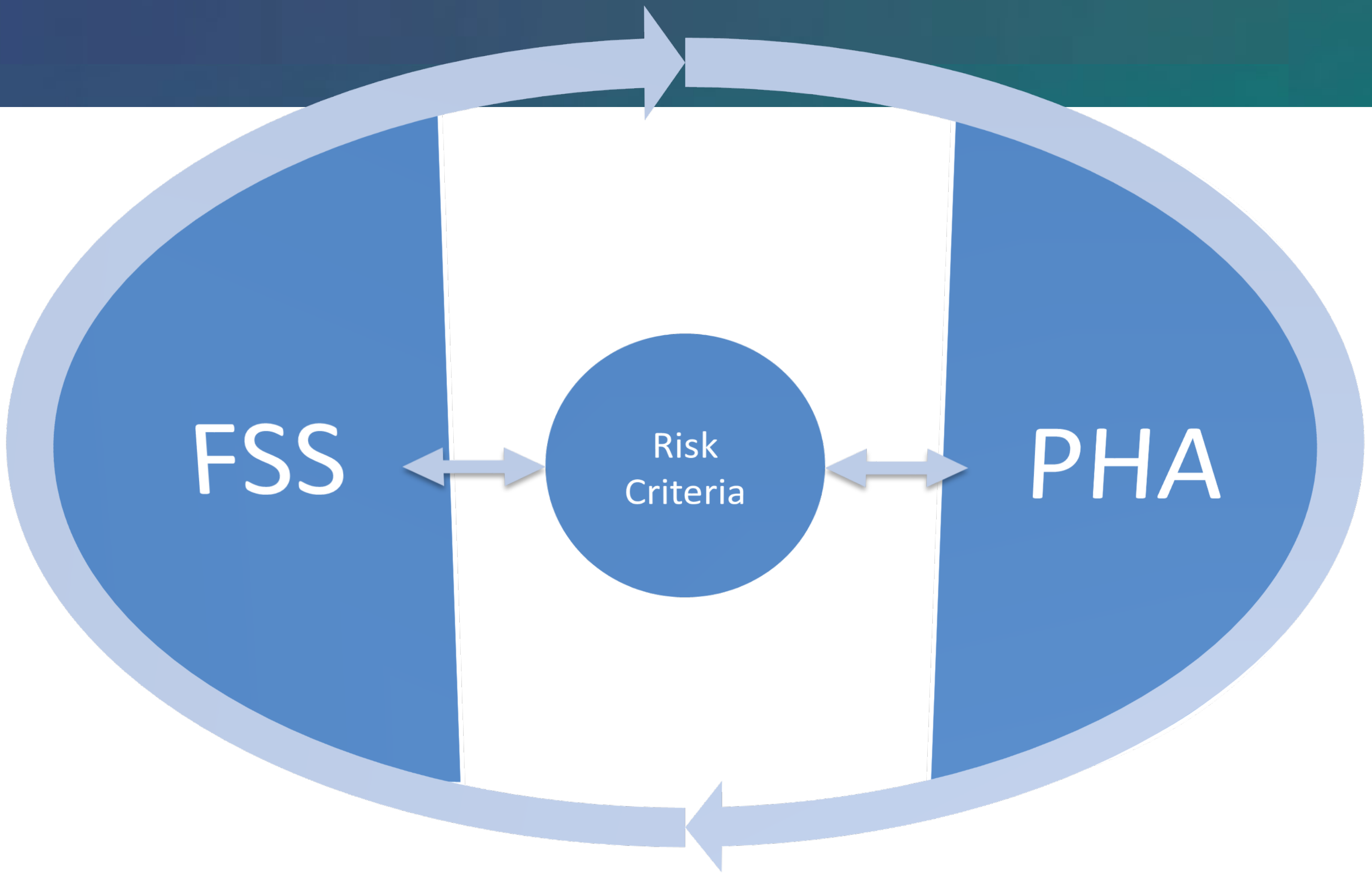
Risk Criteria

CONSEQUENCE		EVENT FREQUENCY				
		10-0 - 10-1	10-1 - 10-2	10-2 - 10-3	10-3 - 10-4	10-4 - 10-5
		1	2	3	4	5
Multiple Fatalities	A	V	IV	III	III	II
Single Fatality	B	IV	IV			
Perm Disab	C	III	III	III	II	I
Lost Time	D	III	III	II	I	I
Recordable Injury	D	II	II	I	I	I
First Aid or Less	E	II	I	I	I	I

- Risk Criteria
  - The acceptable frequency for aggregate risk criteria must inevitably be greater than that used in PHAs
    - Aggregate risk is the SUM of all process hazard scenario risks with the potential to impact a location
    - Expect aggregate risk criteria to be 10-100x higher than the PHA risk criteria
      - Dependent on the number of hazards which could impact a location
    - F-N pairs could be compared directly to a risk matrix


FSS
Risk
Criteria
PHA

Development Slide – Remove - Abstract

- The PHA process has been implemented in industry for decades, and PHA stakeholders are already fluent in risk communication. PHAs provide an accepted framework in organizations which details scenarios to be evaluated, credible safeguards, and the organization's acceptable risk criteria. Siting studies may consider risk in the same way as PHAs, but organizations typically fail to align the two assessments.

- PHAs already contain the hazard scenarios and safeguards and the organization's risk criteria. Aligning the PHA scenarios and safeguards with the siting study can improve the quality of the siting study; generic release scenarios are generally included in a siting study but could be improved by process-specific hazard scenarios from the PHA. PHA recommendations can create an unnecessary cost to the organization if the consequences and risk ranking is not accurate. Conversely, PHA scenarios that fail to identify major risk potential may result in increased risk exposure for personnel and the business. Aligning the qualitative risk criteria from the PHA and the siting study quantitative risk criteria can allow PHA scenarios consequences and level of risk to be accurately identified, result in cost-effective and more accurate risk reduction recommendations, and improve the organization's ability for consistent risk-based decision making.

Development Slide - remove

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- Stakeholders are already fluent in risk communication, and the PHA process has been implemented in industry for decades. Siting Studies may consider risk in the same way that risk is evaluated in HAZOPs and LOPAs. A risk-based siting study has the advantage of allowing a more prudent expenditure of capital to address risk drivers.
- **A Thought Exercise**: How many recommendations were in your last PHA, how much did it cost to resolve the recommendations? Imagine if your PHA was consequence-based. You would have to develop safeguards to mitigate against the unmitigated consequences, and your safeguards would be not be considered or counted.
- PHAs provide a framework for a methodology already accepted by the organization. That framework details
  - The scenarios to be evaluated
  - The risk criteria
  - Criteria for acceptable safeguards (the PHAs themselves contain the lists of safeguards)
- Risk-Based Siting Studies must have
  - Scenarios to evaluate
  - Risk Criteria
  - Evaluation of Safeguards
- Scenario Selection for Siting Studies
  - Generic Failures consider leaks or ruptures of equipment, independent of cause. A study based solely on generic failures will fail to include process-specific scenarios which are generally considered in the PHA, such as: runaway reactions, internal deflagrations, mixing hazards,
  - Scenario-Based Failures can be identified from the from the PHA. Conversely, note that many PHAs do not consider generic leak/rupture scenarios with no defined cause.
- Risk Criteria for Siting Studies
  - PHAs consider risk for each individual scenario, while risk-based siting studies generally aggregate risk to develop risk contours or societal risk curves. Because the siting risk-criteria is compared to aggregate risk, the tolerable risk frequencies will be higher for a defined consequence.
- Safeguards for Sting Studies
  - The event frequency/likelihood for scenario-based failures from the PHA can be based on the mitigated frequency identified in the PHA. The mitigated frequency considers the design/action of accepted safeguards.

- Generic failures can consider the safeguards in the facility which allow for detection and isolation of the release by evaluating mitigated and unmitigated releases with different frequencies defined.

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Background

- Background
  - PHA has been applied decades
  - Methodologies for PHA have changed little in recent years
  - PHA tools remain the same
  - Facility Siting has been identified as an area of study for decades, but methods have developed significantly
  - [PHA history , FSS history – pha more established, longer history, FSS newer, less widely understood/Difficult concept]
  - PHAs are risk-based, siting studies *may* be risk-based

Elements of Studies

PHA

- Initiating Events
- Definitions of Unique Process Hazards
- Hazard Scenarios
- Qualitative Consequence Descriptions/Rankings
- Qualitative or Semi-Quantitative Frequency Analysis
- Risk Criteria
- Criteria for acceptable safeguards (the PHAs themselves contain the lists of safeguards)

Facility Siting

What is required?

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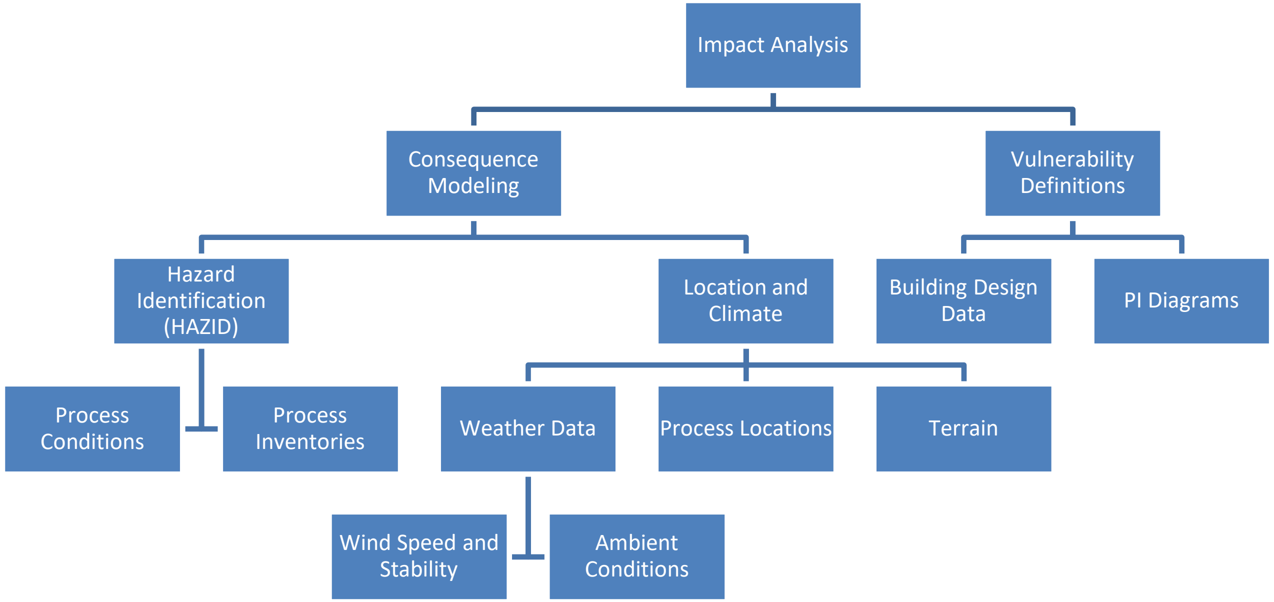
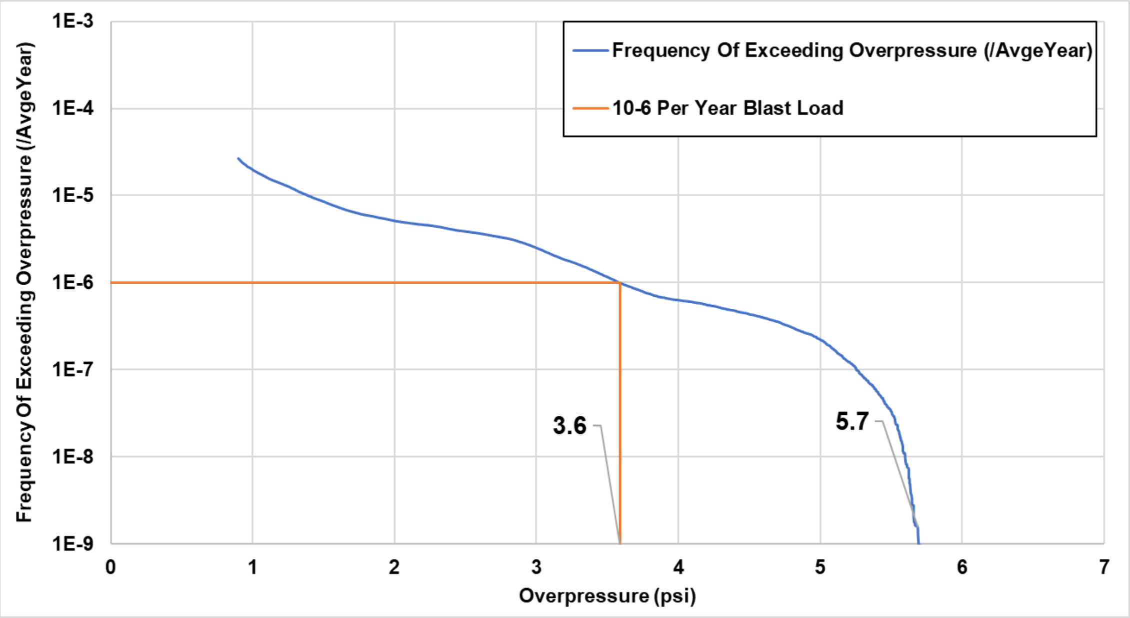
- OSHA PSM 29 CFR 1910.119 requires assessment of facility siting under the Process Hazard Analysis element
- OSHA considers API 752/ 753 / 756 to be RAGAGEP for facility siting
  - API RP 752 – Permanent Buildings
  - API RP 753 – Portable Buildings
  - API RP 756 – Tents
- Siting studies may be:
  - Consequence-based
    - Based on maximum-credible events and their impacts to occupied buildings
  - Risk-based
    - Based on risk considering the impact ***and likelihood*** of a range of hazard scenarios

Consequence-Based Siting



- Study is based on Maximum Credible Events (MCEs)
  - Large but credible failures/releases
- Buildings are designed to withstand maximum impacts
  - Design for maximum blast load
- Reduces costs to perform study
- Increases costs to meet siting criteria

Consequence v. Risk



- Add pictures of blast-hardened buildings

Facility Siting Project Flow

- Kick-Off Meeting
- Site Visit
  - HAZID
  - Building Survey
  - Site Survey
    - *Ignition Sources*
    - *Confinement and Congestion*
    - *Process Area Layout*
    - *Dikes/Drains/Curbs*
- Consequence Modeling
  - Dispersion
    - Gaussian, CFD
  - Blast Modeling
    - TNO, BST
  - Fire Modeling
- Frequency Analysis
- Results Review
  - Conclusions
  - Recommendations
- Reporting
  - Management Review
- Follow-up
  - Action Tracking

Facility Siting Pitfalls

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- Studies which fail to consider **all** process hazards
- Risk-based study considering only MCEs
  - Fails to consider more likely hazardous scenarios
- Incomplete scenario selection
  - Studies considering only hazard scenarios, fail to consider general leak/release scenarios
  - Screening scenarios by likelihood (Remember, risk is cumulative!)
- Standard release/hazard frequencies

Siting Follow-Ups: Taking Action

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- Communication is key
- Siting results can be overwhelming and confusing for stakeholders
  - Management may not be familiar with hazard contours, FN curves, or individual risk results
- Siting studies may require significant capital to resolve issues/risks
- Ensure the time is allocated to review the results and communicate them throughout the organization
  - Stakeholders may need to be educated on the requirements, methods, and results
- Failure to communicate the results clearly often results in lack of follow-up
  - Managers who do not understand will not buy-in
  - No action = No benefit

AcuTech PROCESS RISK MANAGEMENT

What do my results mean and how do I use them?

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- Don’t focus on only one solution!
- Evaluate ***ALL*** options to mitigate impacts/risks
  - Building Retrofit
    - Blast walls
    - HVAC Upgrades
    - Positive Pressure
  - Relocation
    - Relocate to new blast-resistant building
    - Relocation of non-essential personnel away from hazards
  - Fire Protection (active/passive)
  - Process Safeguards
    - Safety Instrumented Systems
    - Gas Detection
  - Process Relocation
    - Locate the most-hazardous operations away from buildings

AcuTech PROCESS RISK MANAGEMENT

Q&A

Questions?

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Photos

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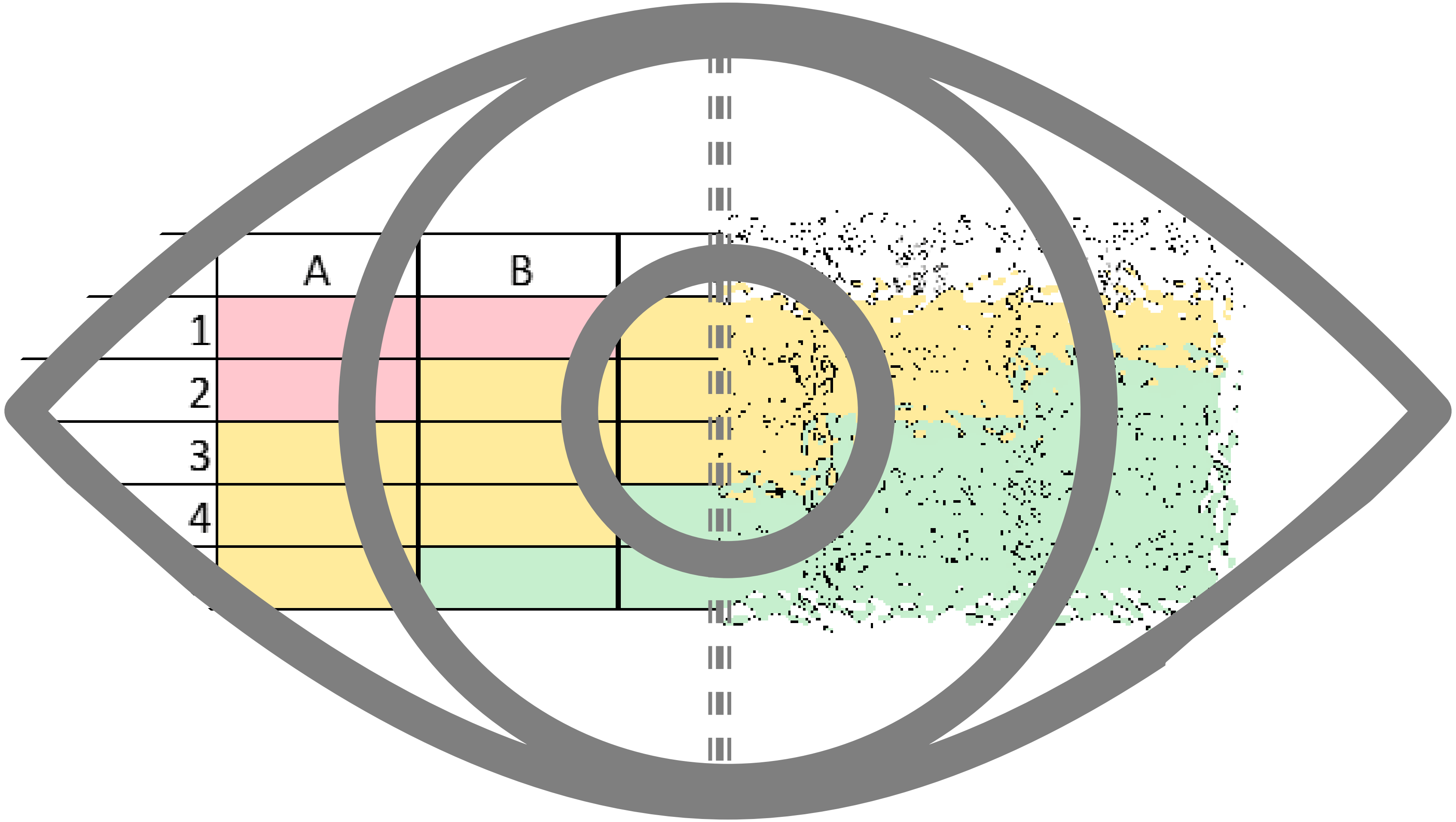
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