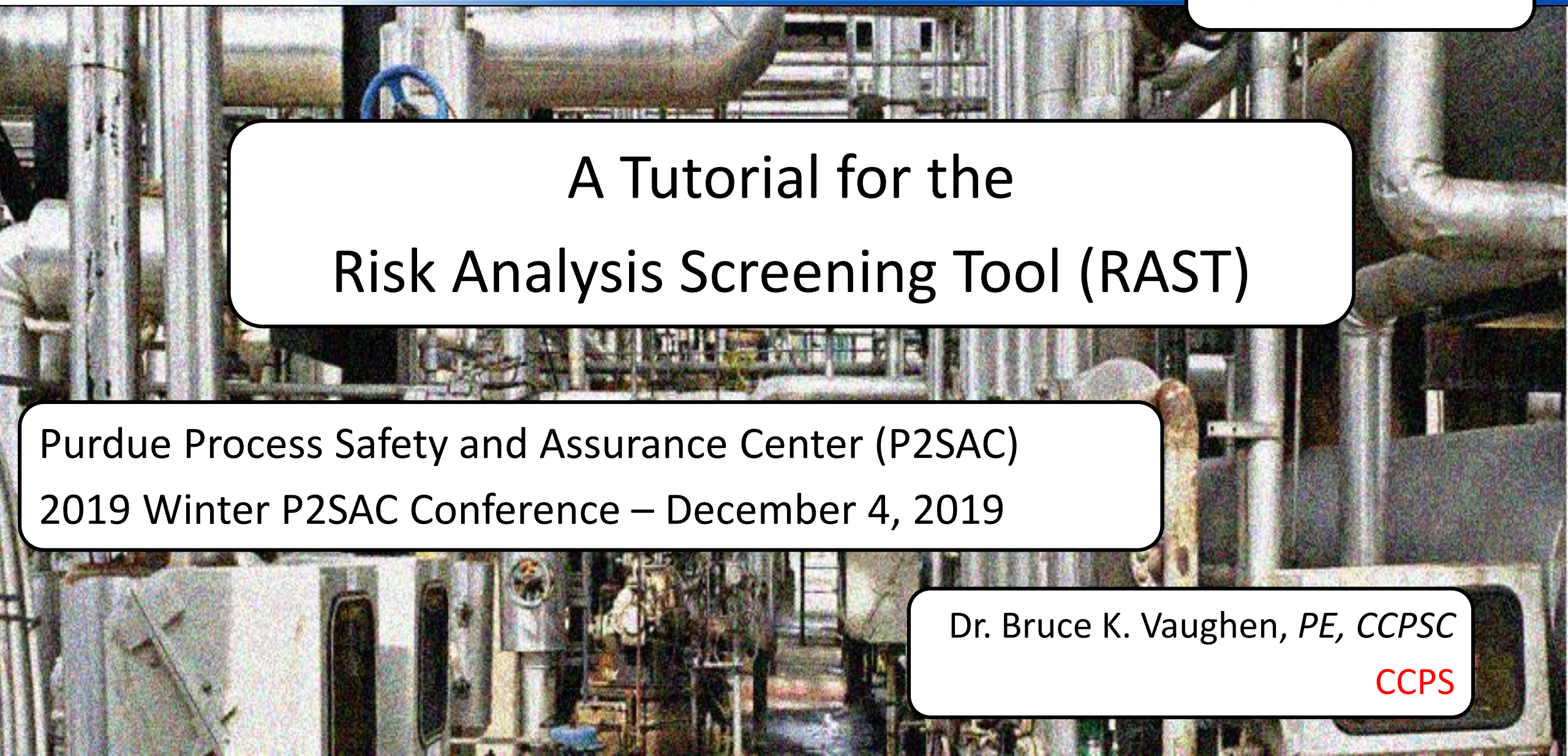

A Tutorial for the Risk Analysis Screening Tool (RAST)

Purdue Process Safety and Assurance Center (P2SAC)

2019 Winter P2SAC Conference – December 4, 2019

Dr. Bruce K. Vaughen, *PE, CCPSC*

CCPS

Tutorial Outline

- **Process Safety**
- **The Process Hazards Analysis (PHA)**
- **The Risk Analysis Screening Tool (RAST)**
- **Some RAST Features for the Fearless**
- **Summary and Questions?**

Tutorial Outline

- **Process Safety**
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Process Safety

- Mission
- Types of process hazards
- Potential consequences and impact
- Evaluation of risk
- Prioritization of risk reduction efforts

Mission of Process Safety Professionals

To reduce process safety risks:

- Harm to people
- Environmental damage, and
- Asset or business losses

Focusing on incidents that can cause:

- Runaway reactions
- Toxic releases
- Fires, and
- Explosions

Types of Process Hazards

Incidents occur with loss of:

- Containment of hazardous materials and energies
- Control of hazardous chemical reactions and interactions
- Control of hazardous processing conditions (i.e., energies)

Leading to

- Runaway reactions
- Toxic releases
- Fires, and
- Explosions

Potential Consequences and Impact

Consequences	Impact
Harm to people	Fatalities, injuries
Environmental damage	Treatment and Clean up (land, water)
Asset or business losses	Property damage, market share losses

Qualitative

Quantitative

Tutorial Outline

- Process Safety
- The Process Hazards Analysis (PHA)
- The Risk Analysis Screening Tool (RAST)
- Some RAST Features for the Fearless
- Summary and Questions?

The Process Hazards Analysis (PHA)

PHAs are part of an effective process safety program:

- Used to identify and evaluate hazards and risks associated with processes and operations
- Can use *qualitative* techniques to identify and assess the process hazards
- Process safety risks are reduced with PHA recommendations
- Can use *quantitative* techniques to help prioritize the risk reduction efforts

The PHA Technique

One of many PHA technique often follows a Hazards Identification and Risk Analysis (HIRA) method:

1. What are the hazards?
2. What can go wrong?
3. What are the potential consequences?
4. How likely is it to happen?
5. Is the risk tolerable?

The PHA Team

There must be members on the PHA Team who can address the HIRA questions:

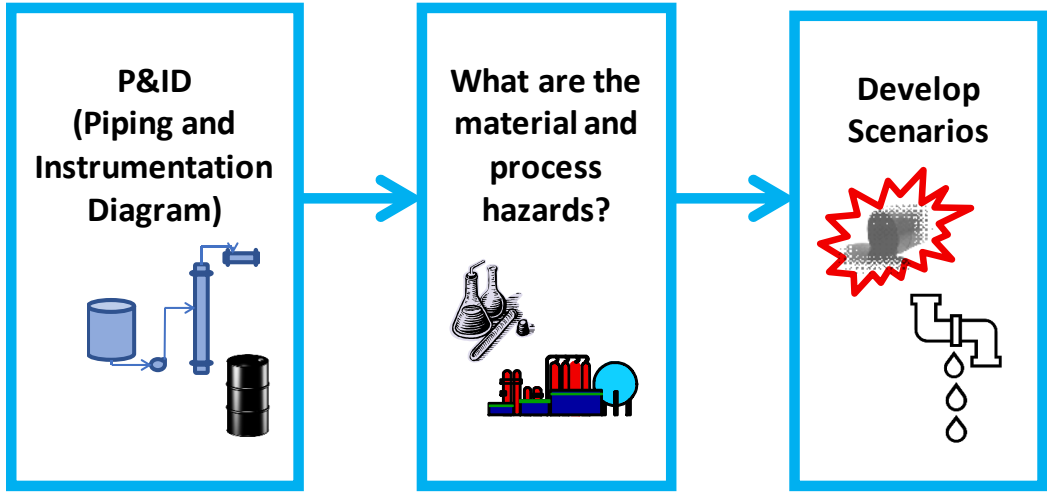
1. Process engineer (familiar with area chemistries, process and engineering designs)
2. Area operator (familiar with operating the process)
3. Area maintenance (i.e., mechanic, electrician, familiar with inspections, tests, and preventive maintenance)
4. Area supervisor (for consistency among shift operators)
5. Other personnel (e.g., rotating equipment expert, control systems expert, as needed)

The PHA Team

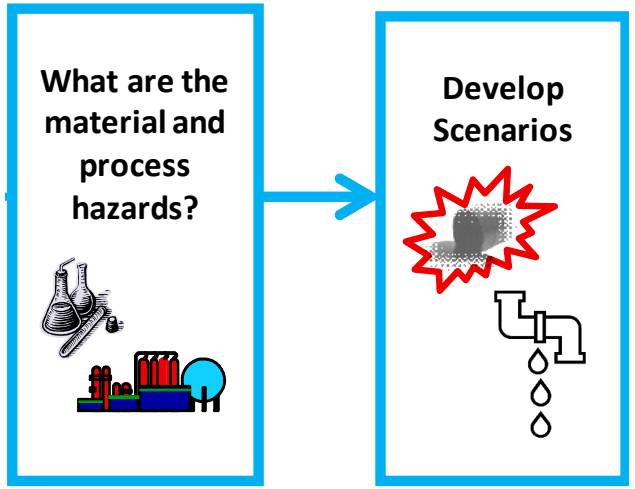
These PHA Team member(s) develop the scenarios:

1. Process safety, in particular
    a. The potential process hazards, chemistries, unit operations, equipment and process design parameters (including P&IDs)
    b. How to run a PHA and how to document the risk evaluations
    c. And answer: *What can go wrong?*

"Nodes" on the P&IDs



The PHA Team



These PHA Team member(s) also help develop scenarios:
What can go wrong?

1. From process operations (an operator)
    a. Operating conditions
    b. How to respond safely to out-of-specification conditions
2. From process maintenance (a mechanic *and* an electrician)
    a. Equipment maintenance schedules (i.e., preventive maintenance)
    b. Specifications for equipment testing and inspections
    c. How to manage responses to failed inspections

The PHA - *continued*

Some PHA techniques:

1. What if/Checklist
2. Hazard and Operability Studies (HAZOP)
3. Failure Mode and Effect Analysis (FMEA)
4. Others…

Hazard and Operability Studies (HAZOP)

HAZOP (*See Glossary Handout)*:

A Structured approach using guidewords to evaluate potential *deviations* from normal (expected) operating design conditions, for example:

Flow: No Flow (*i.e., when flow is expected*), High Flow

Pressure: Vacuum, Low Pressure, High Pressure

(*More Detailed: Handout 1)*

Remember Incidents Slide earlier?

2. What can go wrong?

1. What are the hazards?

Incidents occur with loss of:

- Containment of
- Control of
- Control of

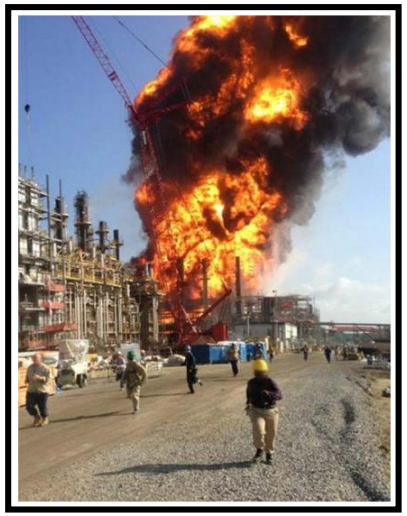
hazardous materials and energies
hazardous chemical reactions and interactions
hazardous processing conditions (i.e., energies)

3. What are Consequences?

Leading to

- Runaway reactions
- Toxic releases
- Fires, and
- Explosions

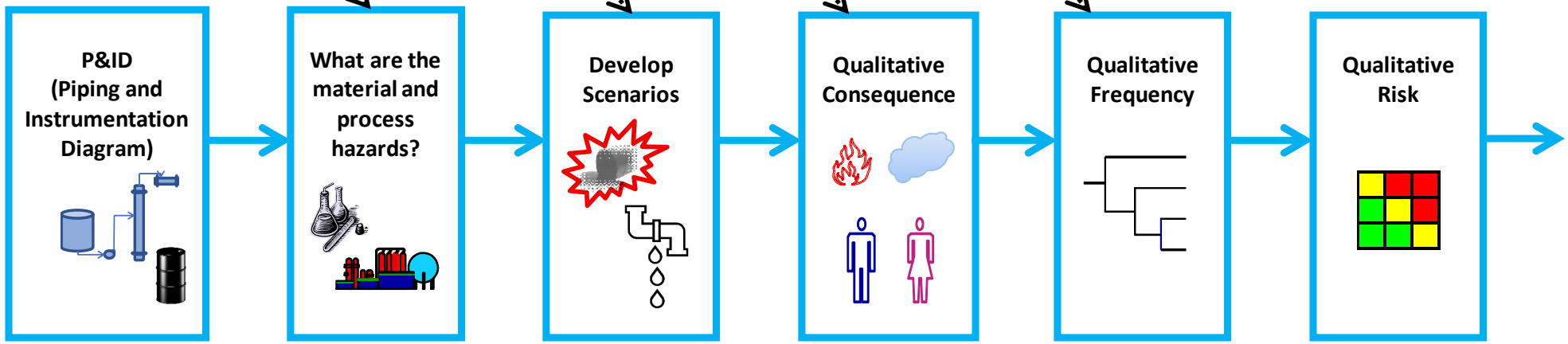
Harm to people
Environmental damage
Asset or business losses



Using a HIRA: PHA Team Develops PHA Scenarios

What are the hazards?
What can go wrong?

What are the potential consequences?
How likely is it to happen?



Scenarios

Consequences

Frequencies

Risks

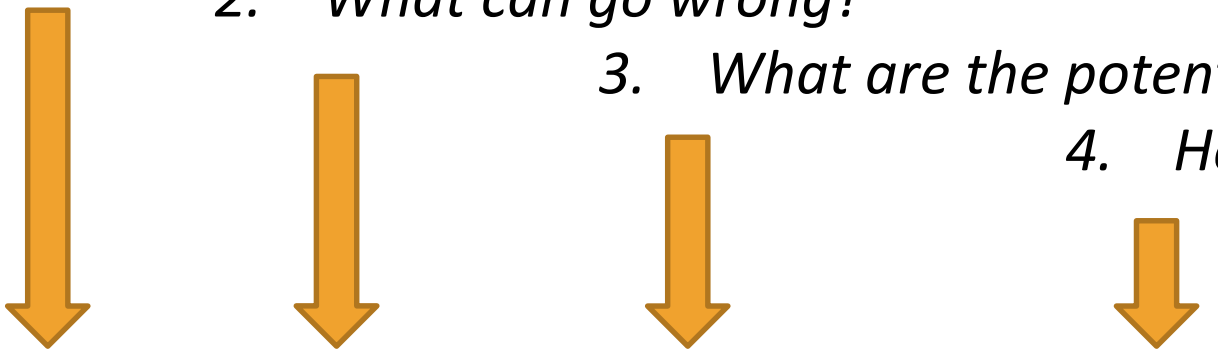
Is the Risk Tolerable?

Recommendations

Documenting the HAZOP Discussion

The PHA Team documents their scenarios with a HAZOP table:

1. *What are the hazards?*
2. *What can go wrong?*
3. *What are the potential consequences?*
4. *How likely is it to happen?*



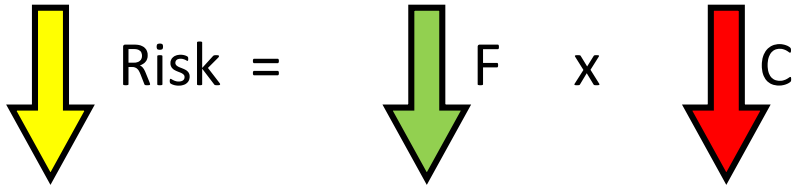
Parameter: *Flow*	**Deviation**	**Cause**	**Consequence (Worst Case)**	**Likelihood (No Safeguards)**	**Risk (No Safeguards)**	**Safeguards (PHA Team Continues)**
Guideword:	High Flow					
More						

(See: Handout 2;

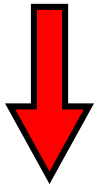
Note defined as a "structured" PHA technique due to Guidewords in Handout 1)

A Simplified Risk Equation

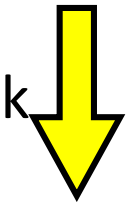
Risk is a function of the Consequence (impact) and the Frequency (likelihood) of the event



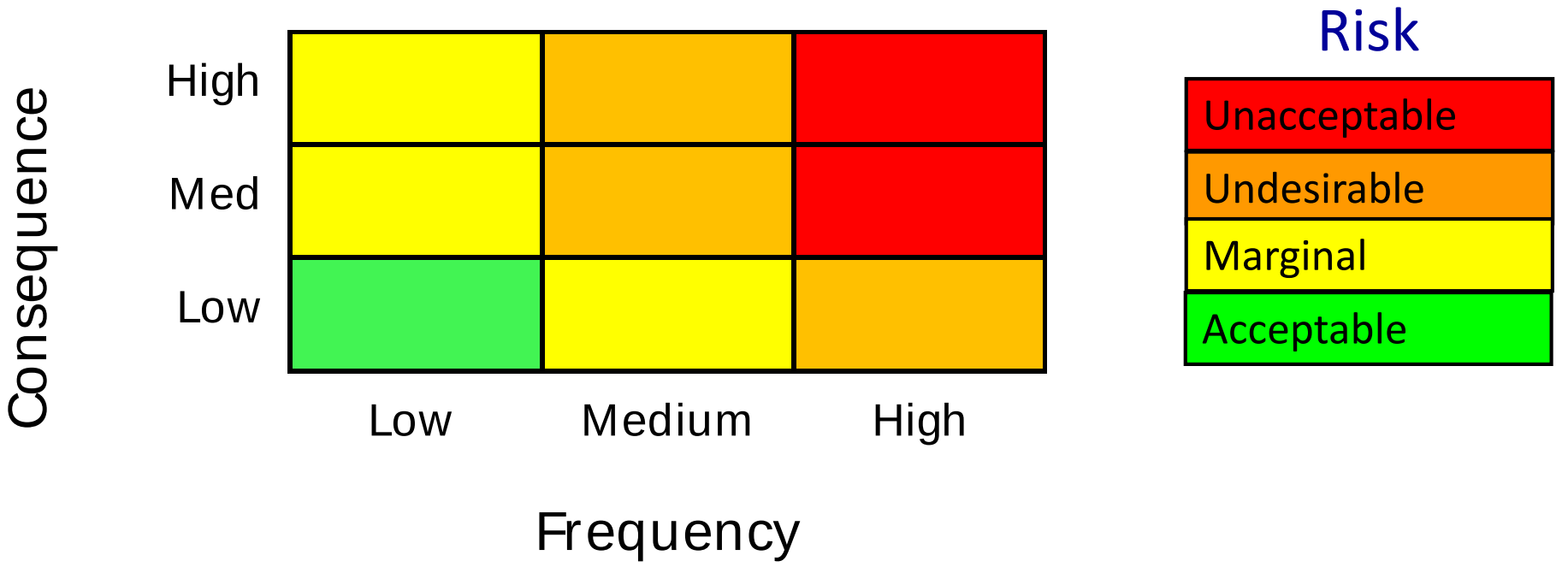
Reduce F with preventive controls
(prevent the incident from occurring)



Reduce C with inherently safer design
and then additional mitigative controls
(reduce incident magnitude)

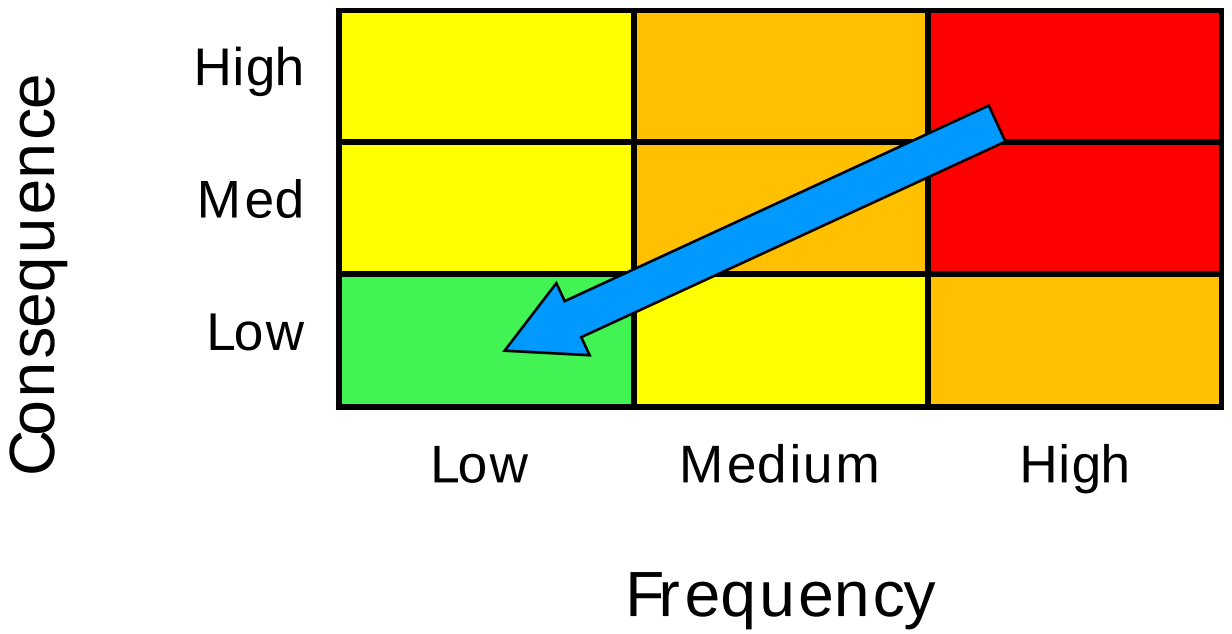
Goal: To reduce Risk 

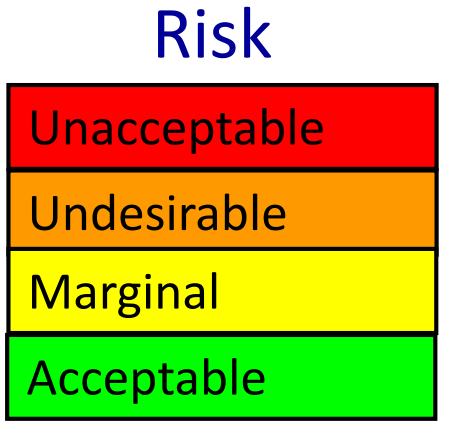
A Qualitative Risk Matrix



Risk = F x C

A Qualitative Risk Matrix





Risk = F x C

The PHA - *continued*

PHA Team example scenario development:

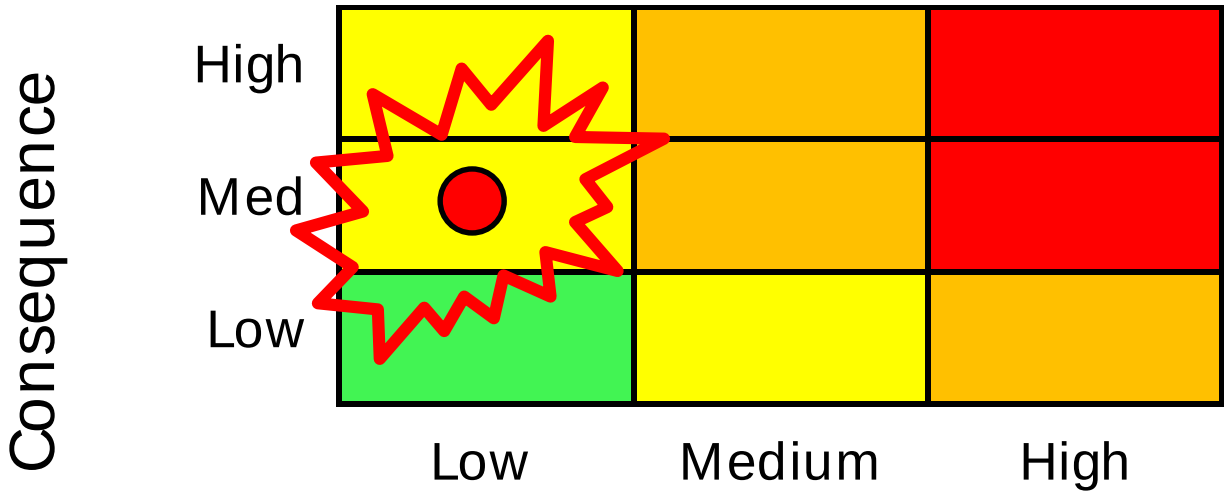
1. Hazard? Flammable material
2. Wrong? Valve opens unexpectedly (the scenario or event)
3. Consequence? Medium; Small release to atmosphere
4. Frequency? Low likelihood that this event will occur
5. Risk? Evaluate on a qualitative risk matrix

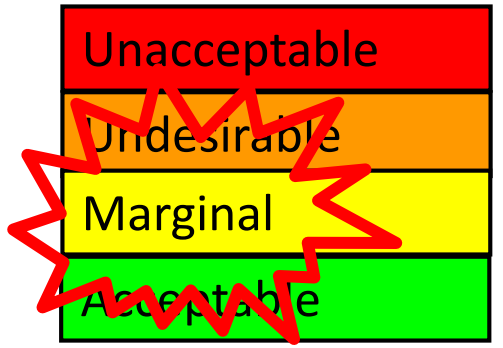
A Qualitative Risk Matrix

Scenario/Event

Low Frequency

Medium Consequence





Marginal Risk

PHA Team discussion continues: are there safeguards to reduce Consequence or Frequency?

Is the Risk Tolerable?

Recommendations

Documenting the HAZOP Discussion - *continued*

The PHA Team documents their scenarios with a HAZOP table:

1. *What are the hazards?*
2. *What can go wrong?*
3. *What are the potential consequences?*
4. *How likely is it to happen?*
5. *Is the risk tolerable?*

Parameter: *Flow*	**Deviation**	**Cause**	**Consequence (Worst Case)**	**Likelihood (No Safeguards)**	**Risk (No Safeguards)**	**Safeguards (PHA Team Continues)**
Guideword:	High Flow					
More						

(See: Handout 2)

Case Study – Qualitative Assessment

Exercise:

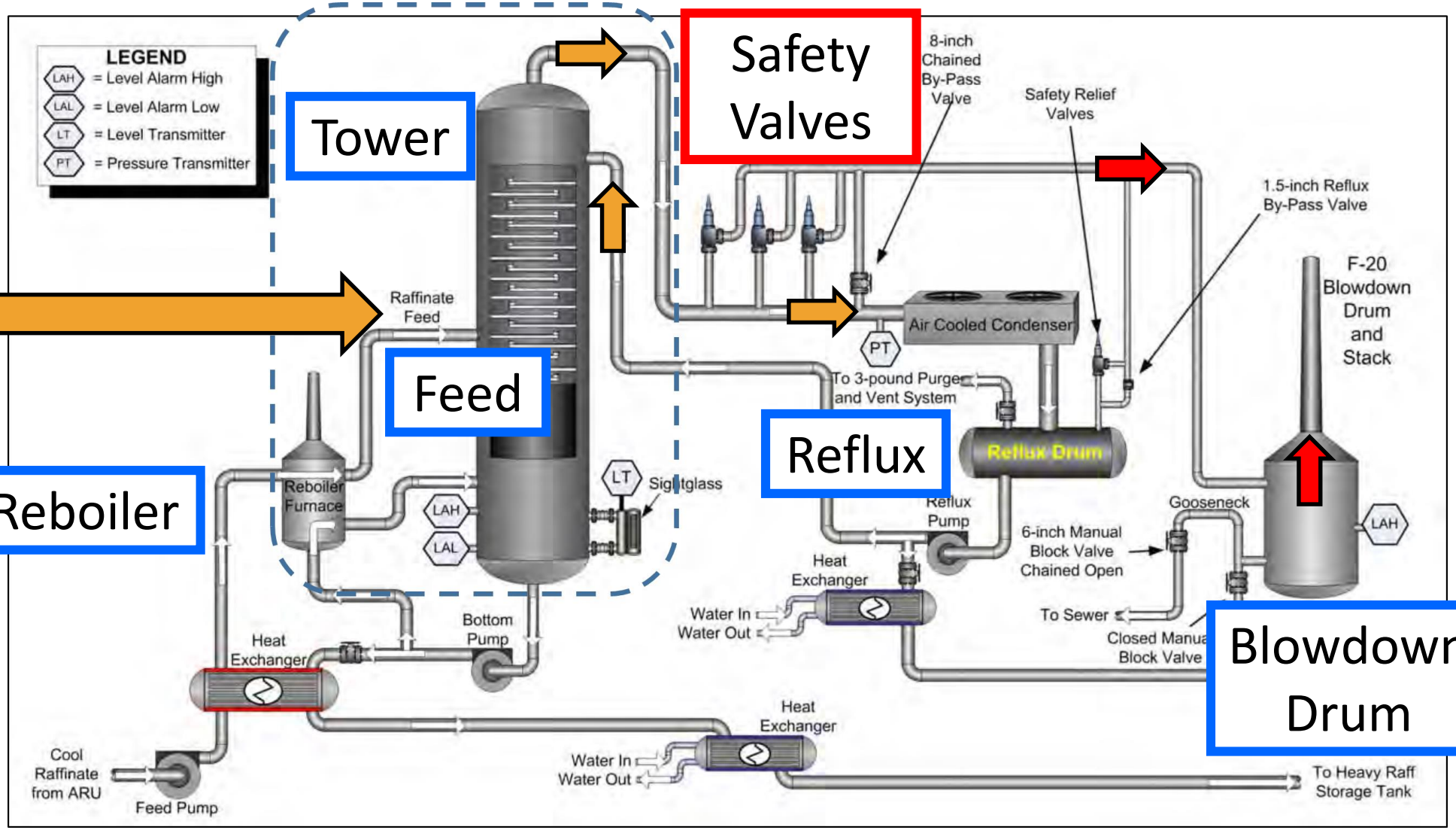
Feed

Flow

No

High

(Fill out Handout 2)



Tutorial Outline

- Process Safety
- The Process Hazards Analysis (PHA)
- The Risk Analysis Screening Tool (RAST)
- Some RAST Features for the Fearless
- Summary and Questions?

The Risk Analysis Screening Tool (RAST)

- What is RAST?
- How RAST Supports the PHA Team
- A Brief RAST Overview

What is RAST?

RAST is the "Risk Analysis Screening Tool"

Recognize that RAST is

1) *Tool* to help PHA Teams assess process hazards and risk
2) *Screening* Tool using *linearized theoretical* equations
3) *Risk Analysis* used to help *Screen* between scenario risks

   (Helps PHA Teams *prioritize* PHA Recommendation)
4) *Tool* which helps a company with different divisions assess risk using a common risk framework and matrix

What is RAST?

RAST is software and manual that was

- Donated by Dow Chemical for *your personal computer/laptop*
- Donated with CHEF software and manual, the

  Chemical Hazards Engineering Fundamentals (Tool/Aid)
- Again: RAST is risk *screening* software that
  - ✓ Uses the linearized theoretical equations from CHEF
  - ✓ Uses the Hazard Identification and Risk Analysis (HIRA) method
  - ✓ Provides both qualitative and semi-quantitative risk evaluations

The RAST and CHEF Website

- RAST Overview
- CHEF Overview
- Case Studies
- Terms and Conditions
- Download and Install
- RAST User and CHEF Manuals
- Frequently Asked Questions (FAQs)
- RAST Development History

Software downloadable *at no cost* from CCPS Website

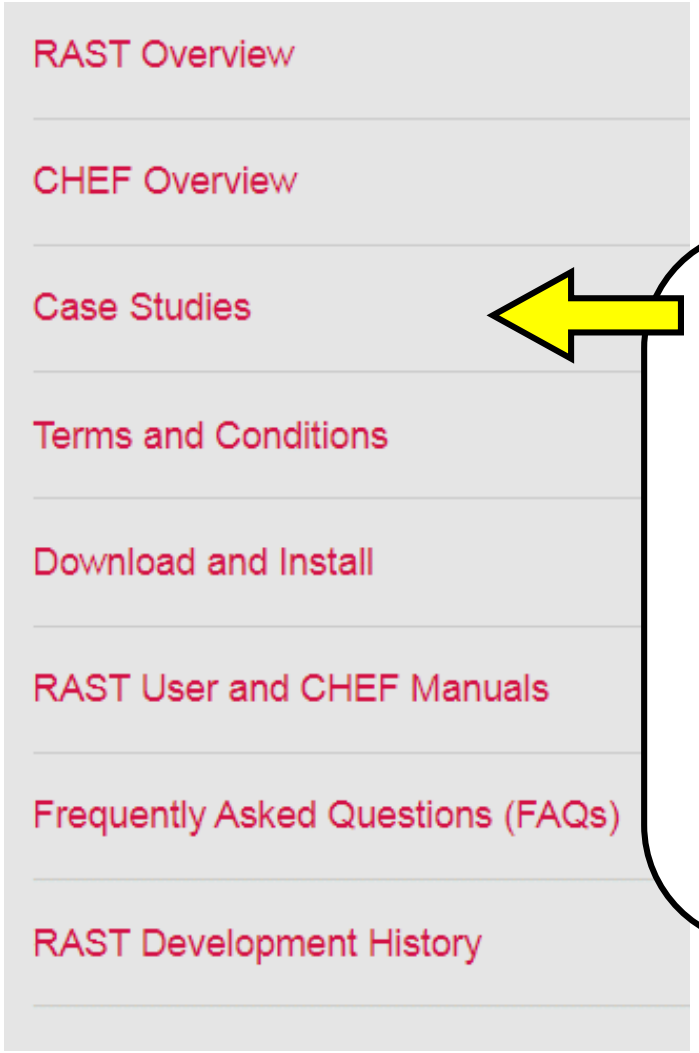
https://www.aiche.org/ccps/resources/risk-analysis-screening-tool-rast-and-chemical-hazard-engineering-fundamentals-chef

(See Handout 3)

RAST Download software

RAST User's Manual (with example)
CHEF User's Manual
Theory from Crowl and Louvar
And data from literature
CHEF Calculation Aid (Excel workbook)

Website - *continued*



(See Handout 3)

Case Studies

- Vapor Cloud Explosion (BP Texas City)
- Outdoor Toxic Release (Chlorine, DPC Enterprises)
- Confined Space Explosion (CAI and Arnel)
- Runaway Reaction and Physical Explosion (T2 Laboratories)

Based on US Chemical Hazards and Safety Board (US CSB) Incident Investigation reports

How RAST Supports a PHA Team

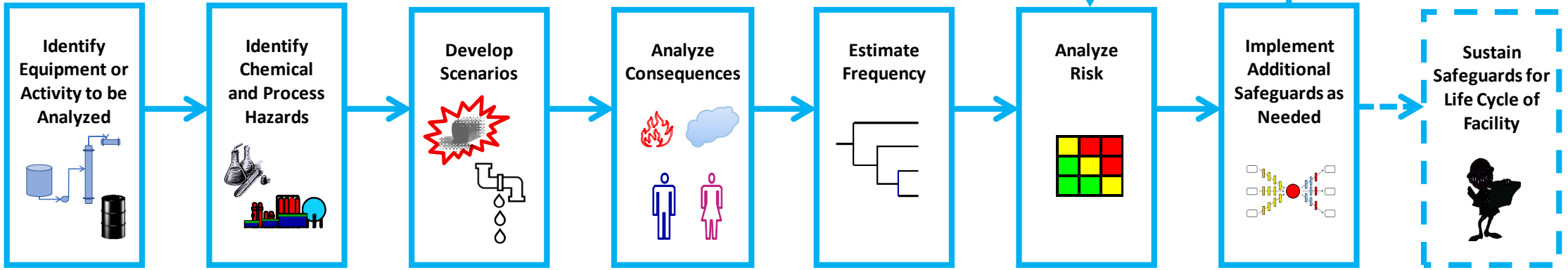
Both the PHA and RAST

- Use the “Hazard Identification and Risk Analysis (HIRA)” method

- To identify hazards and evaluate risk
    1) to help make certain that risks to employees, the public, or the environment are *consistently controlled*
    2) within the organization's *risk tolerance*

Scenario Development: PHAs and RAST

What are the hazards?
What can go wrong?



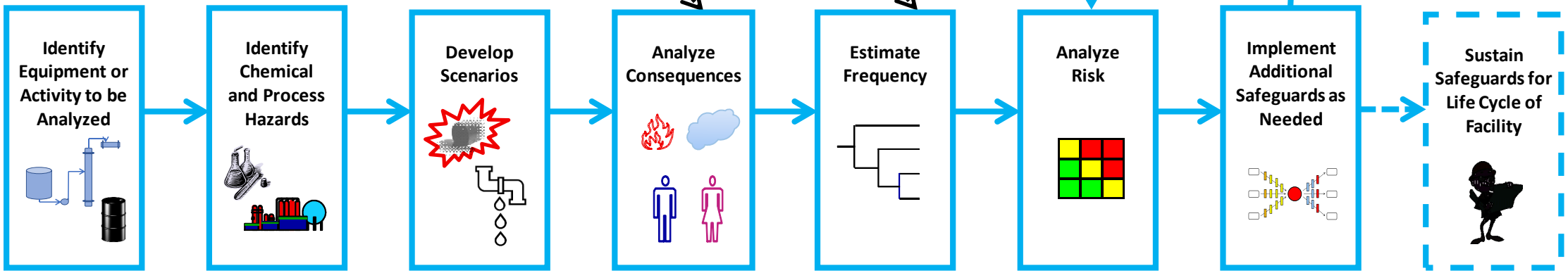
P&ID

Scenarios

RAST validates scenario development

Analyzing Risk: PHAs and RAST

What are the potential consequences?
How likely is it to happen?

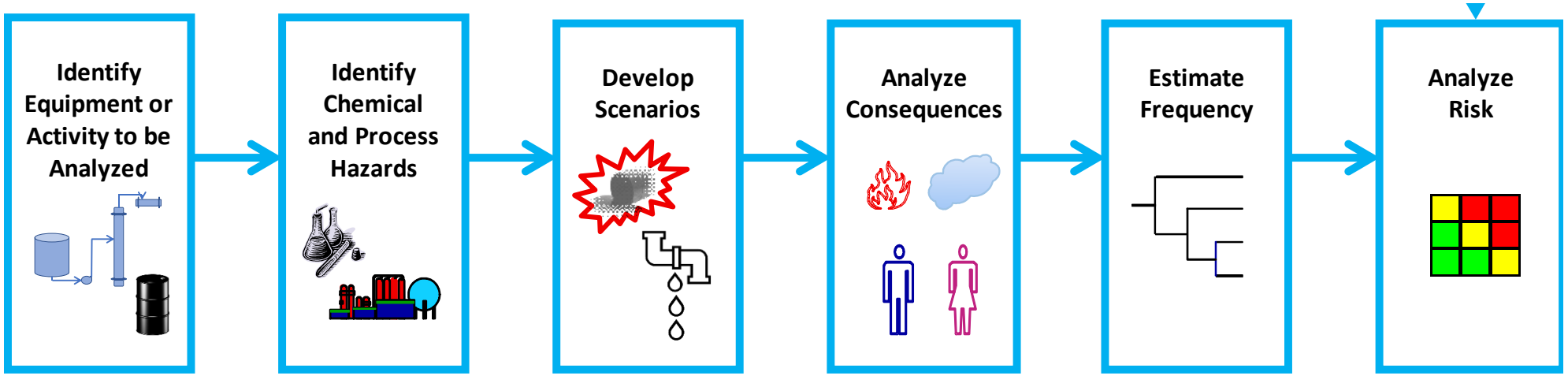


Consequences Risks
Frequencies

RAST/CHEF helps *quantify*
Consequence, Frequency and Risk

A Brief RAST Overview

Minimal data entry (input) is *required* for screening calculations



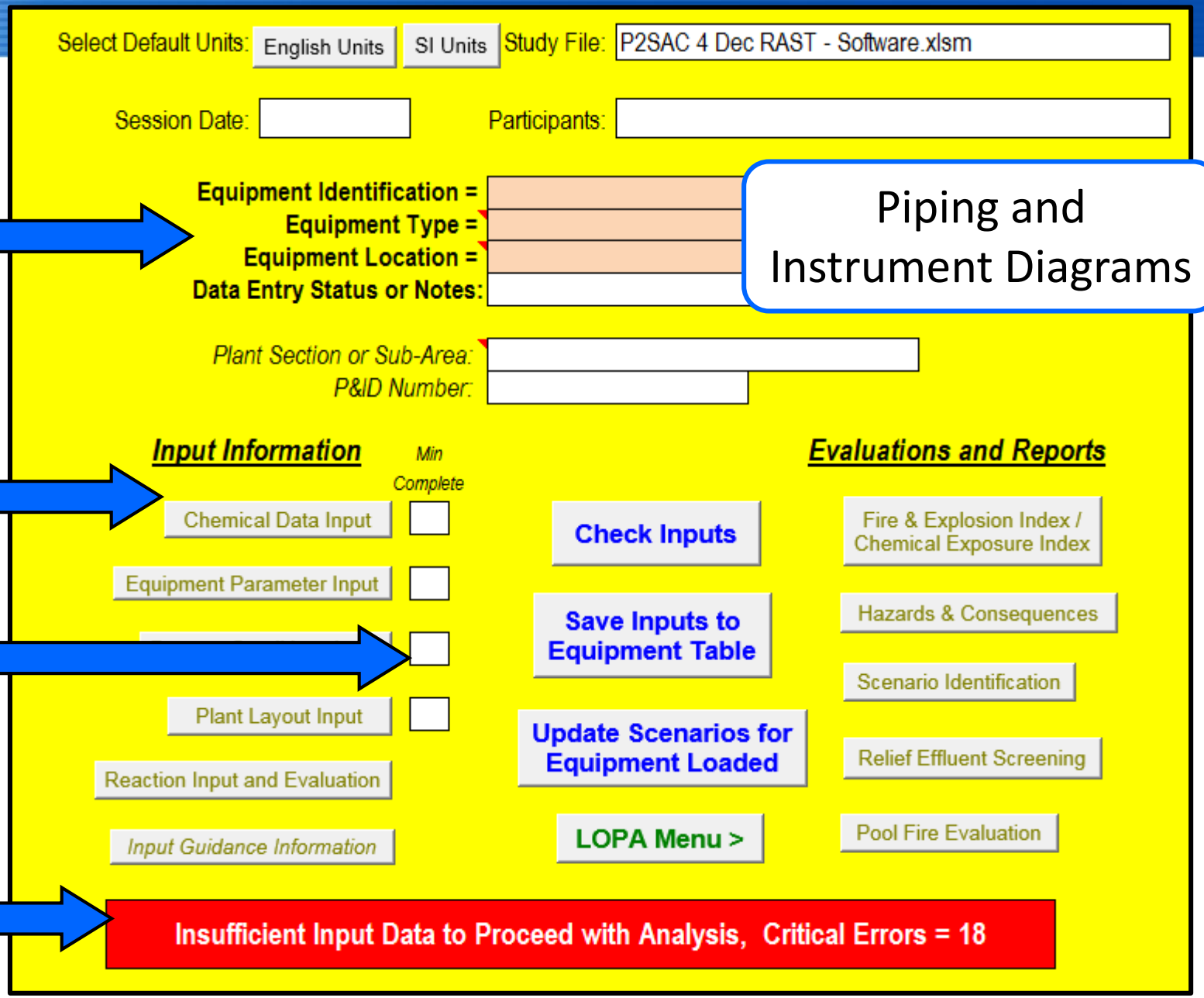
Screen from the RAST Main Menu

Orange boxes are "Min Input" data

Minimal data entry (input) is *required* for screening calculations

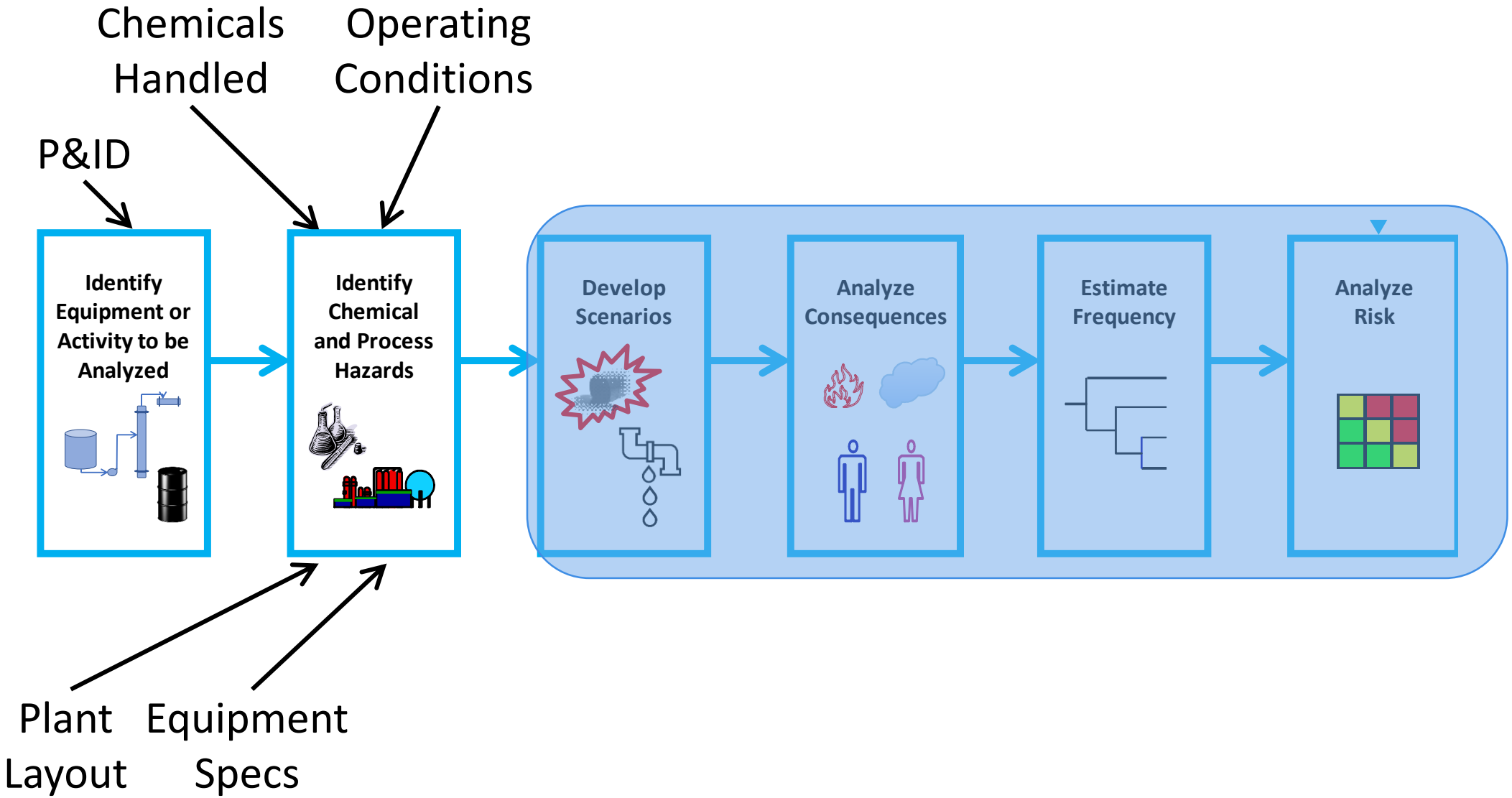
"Min Complete" box white

Note: Critical Errors ☹



Piping and Instrument Diagrams

Identify Chemical and Physical Hazards



Using RAST to Support a PHA Team

Using RAST in a PHA

1. What are the hazards?
   a. Already identified by PHA Team
   b. Entered into the RAST software:
      Chemical and physical hazards
      Information from P&IDs, chemical reactivity, equipment files, etc.
      The more information input, the more "refined" the estimates and screening analysis

Screen from the RAST Main Menu

RAST has internal “chemical reactivity” modeling and >250 chemicals in a pre-populated list (User can enter new chemicals)

Chemical Data
Equipment Parameters
Process Conditions
Plant Layout

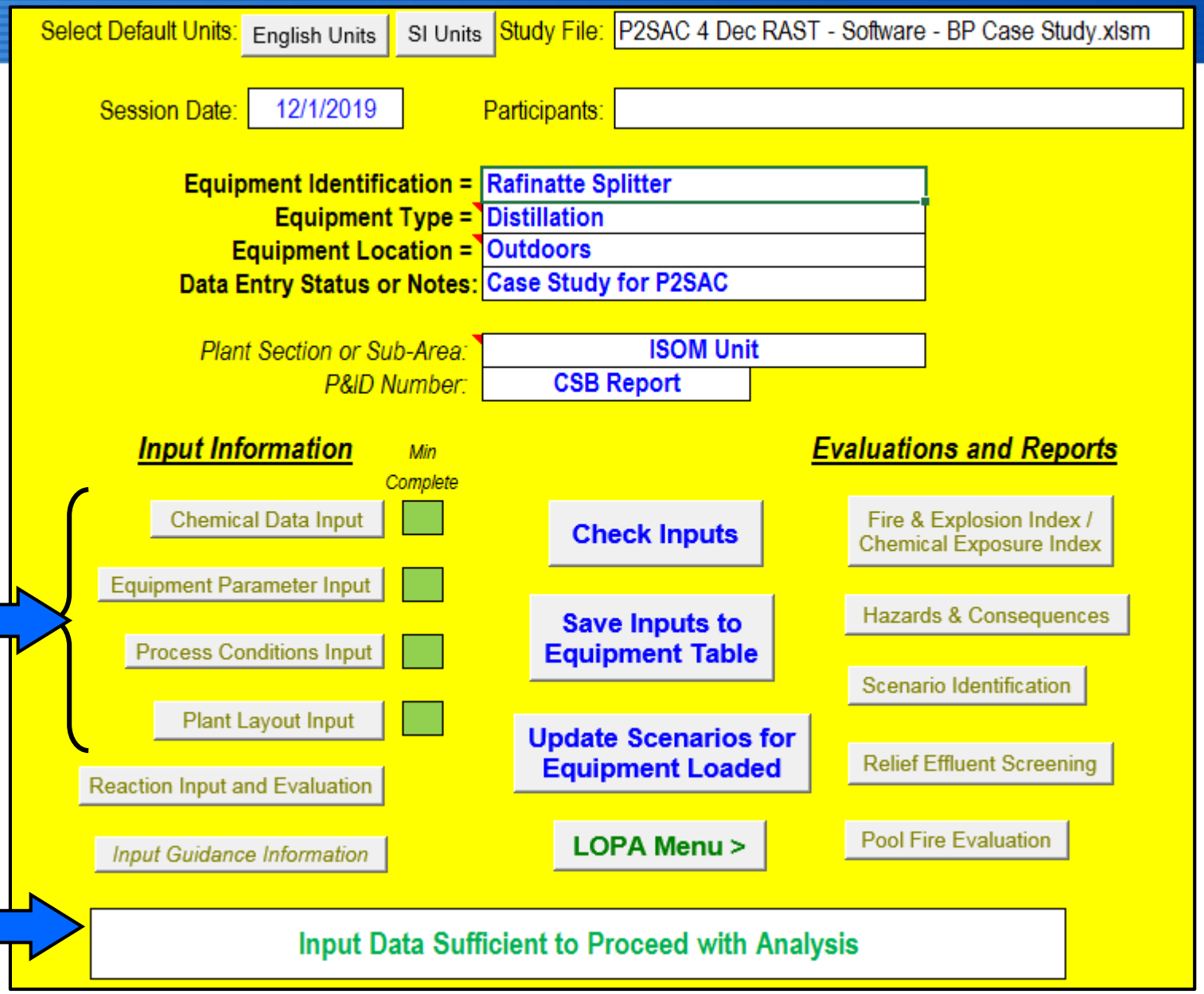
Reactivity Inputs (if part of HIRA)

Screen from the RAST Main Menu

Once Minimum Inputs completed, then RAST can proceed to develop scenarios

Minimum Inputs satisfied

Green! ☺



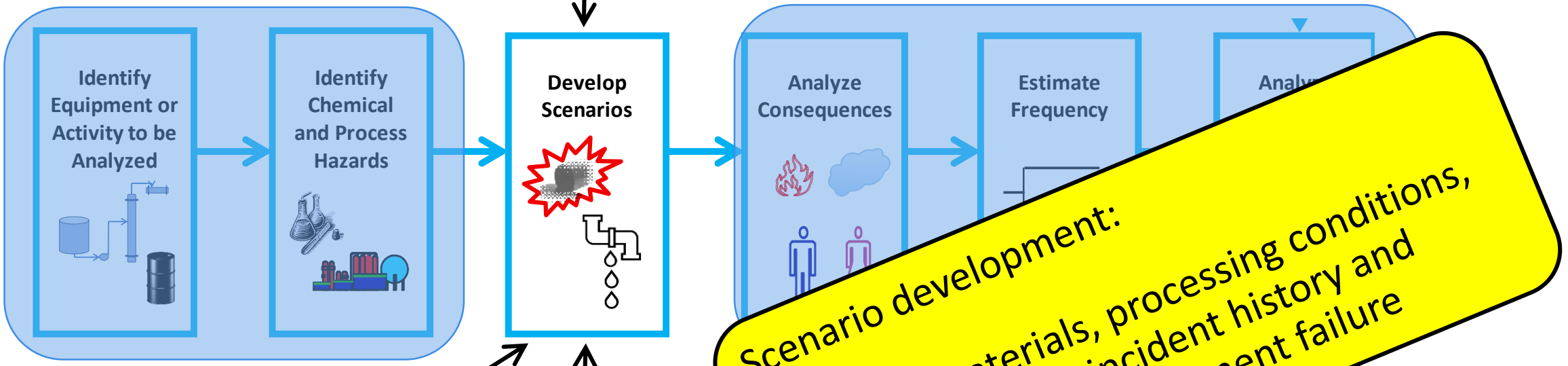
Using RAST to Support a PHA Team

Continuing with using RAST in a PHA

2. What can go wrong?
    a. Already identified by PHA Team
    b. RAST can be used to help identify causes
        - *Add Historical Incidents (causes)*
        - *Add Equipment integrity issues (causes)*
        - *Validate PHA Team-generated scenarios*
        - *Suggest other potential scenarios*

RAST for Validating Scenarios

Process Hazards Analysis (PHA),
Hazards and Operability Study (HAZOP)



Historical Incidents

Equipment Integrity Failures

Scenario development:

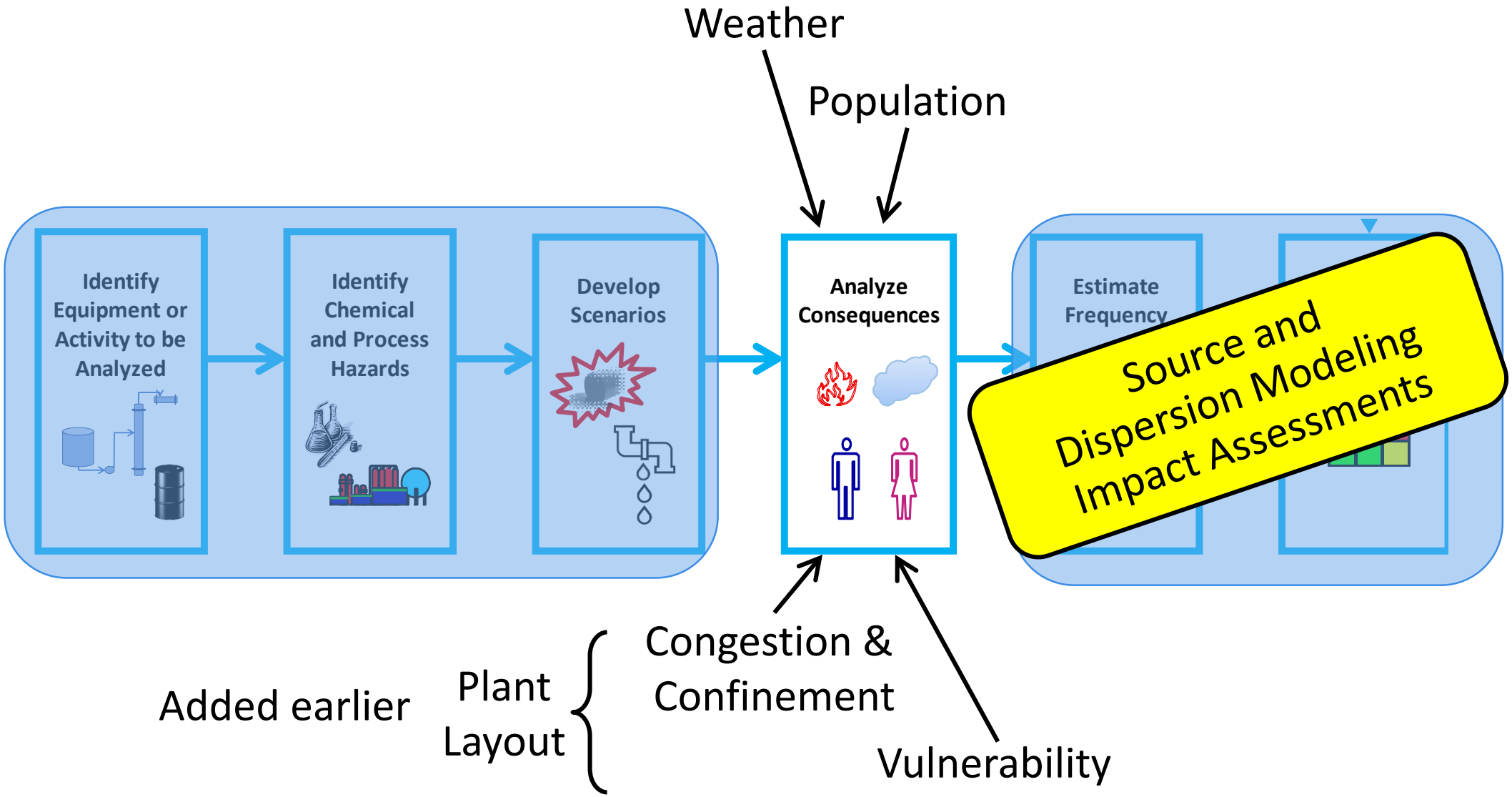
Based on materials, processing conditions, area and industry incident history and potential types of equipment failure

Using RAST to Support a PHA Team

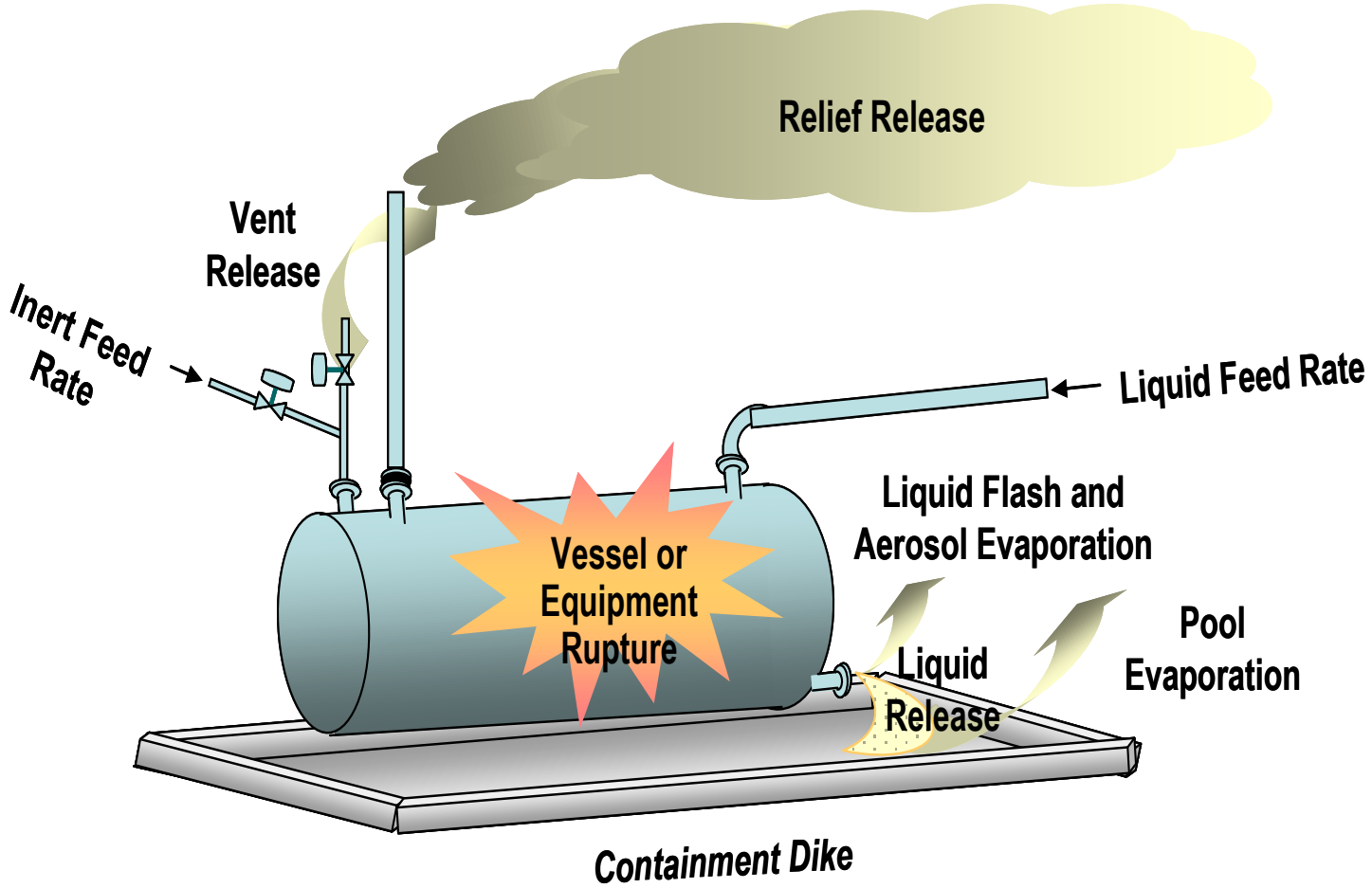
Continuing with using RAST in a PHA

3. What are the potential consequences?
   a. Already identified qualitatively by PHA Team
   b. RAST can be used to help evaluate consequences
      - *What is the scenario's impact to people, environment, business?*

RAST - Analyze Consequence and Impact



RAST - Analyze Consequences - *continued*



Source Modeling

Details are
in the CHEF User's Manual

RAST uses different source models for modeling vapor and liquid releases

RAST - Analyze Consequences - *continued*

Selecting a source (discharge) model to determine the release rate

Hole Size

Modeling the discharge from a hole of specified diameter, process pressure, and fluid density

Overflow or Specified Rate

Modeled by the feed rate or other specified release rate

Excessive Heat

By dividing the heat input by the heat of vaporization

Rupture

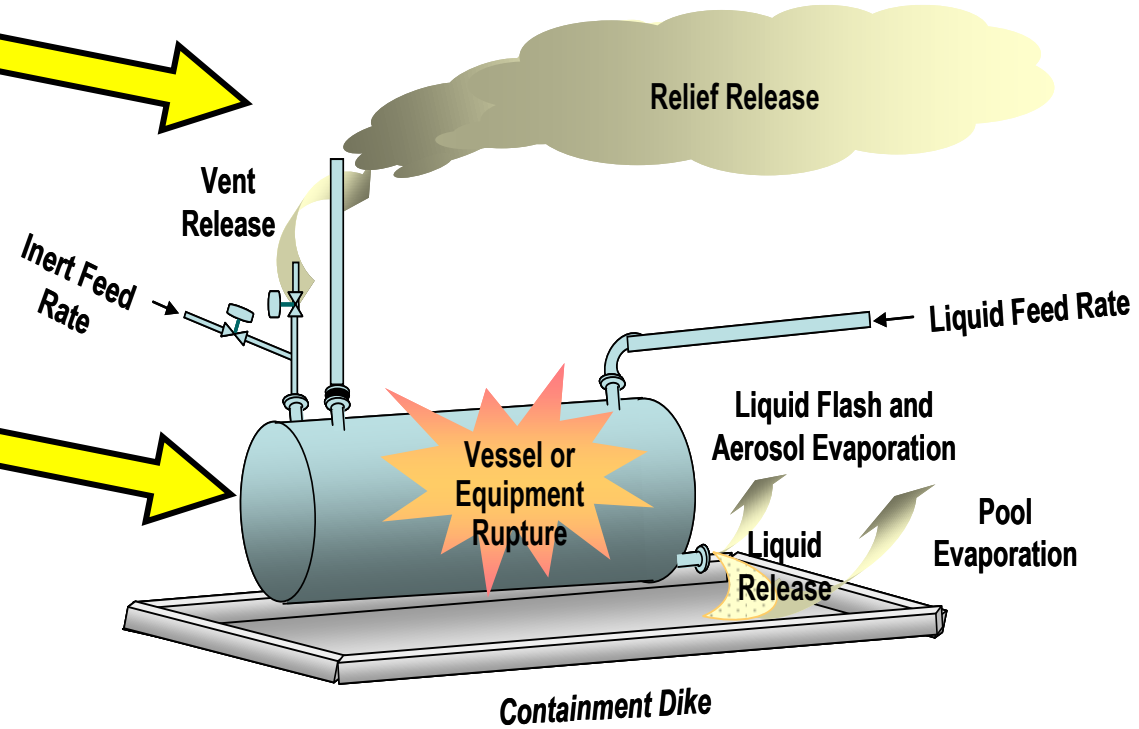
By the sudden release of the entire contents

RAST - Analyze Consequences - *continued*

Different source parameters influence the different source models

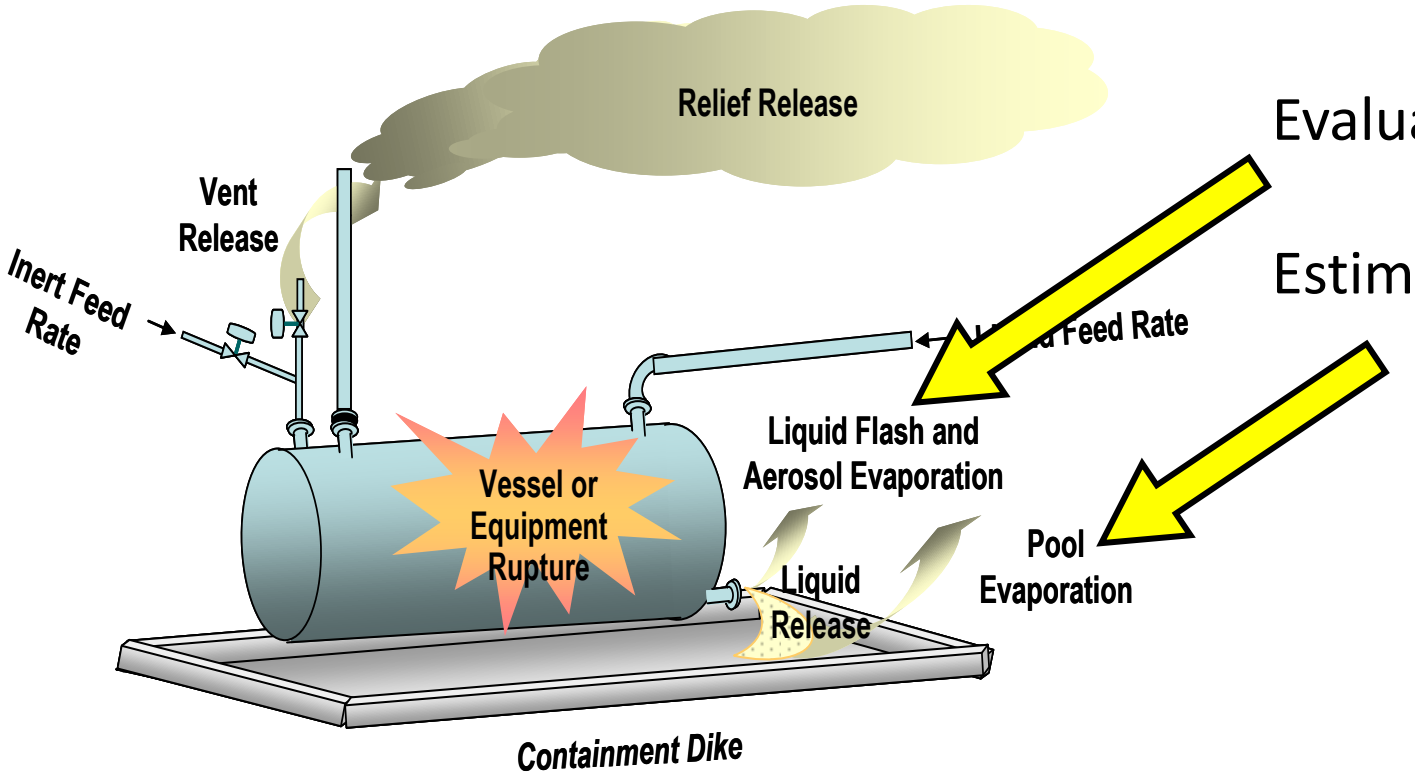
Estimates of Vapor Release Rate
- Based on Hole Size
- Based on Vaporization of Liquid

Estimates of Liquid Release Rate
- Based on Hole Size
- Based on Catastrophic Failure
- Based on Flashing Liquid Flow
  - Evaluates Flash Fraction
- Tests for Two-Phase Flow



RAST - Analyze Consequences - *continued*

Source modeling also



Evaluates Aerosol Evaporation Fraction

Estimates of Evaporation from a Liquid Pool

RAST - Analyze Consequences - *continued*

Selecting a dispersion model to determine "downwind" concentrations

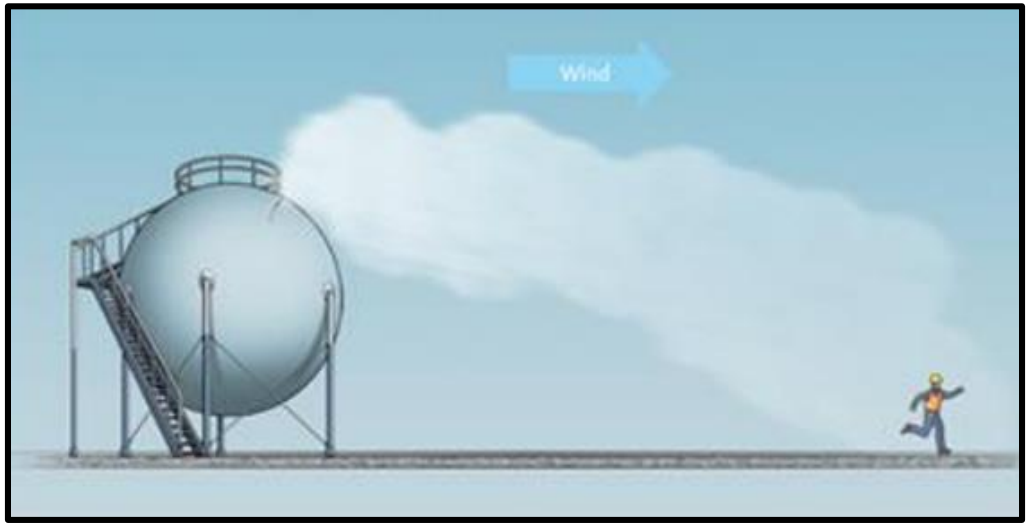
Dispersion Modeling

Vapor dispersion rates

- Continuous versus instantaneous release from the source

Atmospheric dispersion modeling

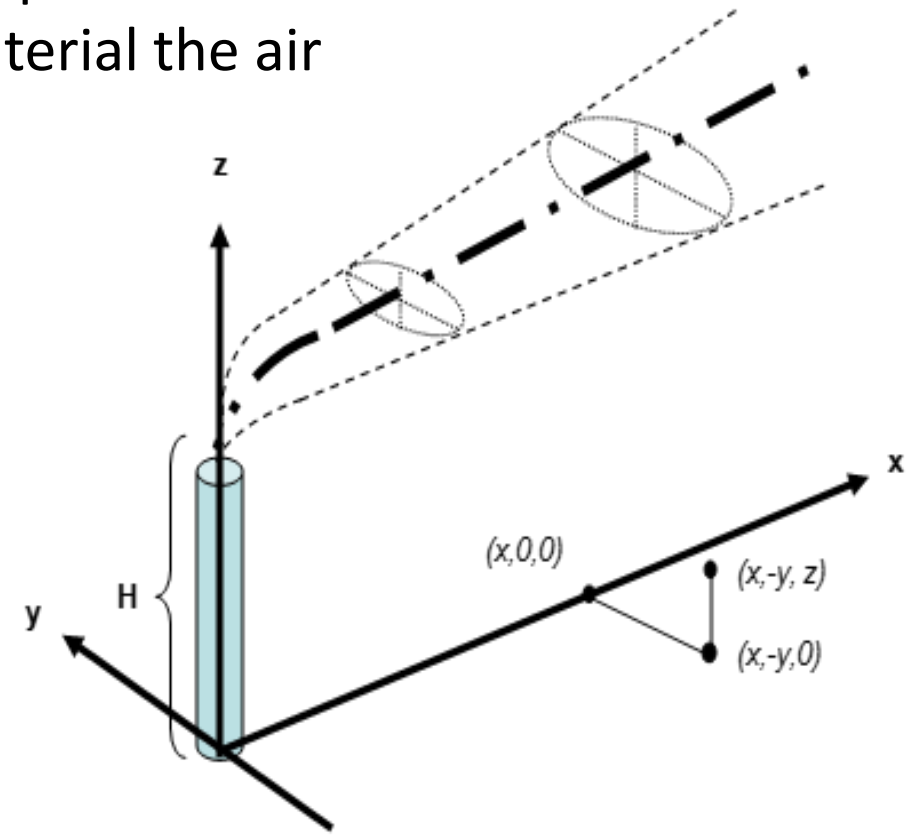
- Release elevation
- Released material's momentum and buoyancy
- Wind direction
- Atmospheric stability
- Surface (terrain) roughness and wind speed
- Plume concentrations ("averaging time")



Weather parameters entered in RAST at this point

RAST - Analyze Consequences - *continued*

For example, in neutrally buoyant models, the atmospheric stability relates to vertical mixing of the released material the air



Are the atmospheric conditions

- Stable?
  - RAST selects “Class D” Neutral Conditions
- Unstable?
  - RAST selects “Class F” Moderately Stable Conditions

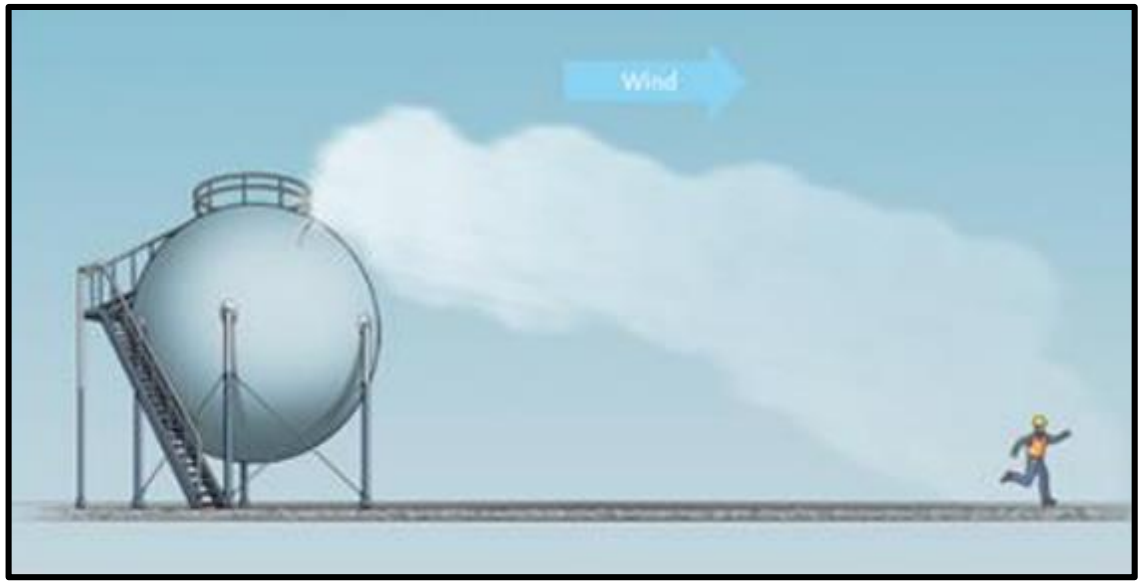
RAST - Analyze Consequences - *continued*

For toxic releases:

Are there toxic concentrations downwind?

For flammable releases:

Are there flammable or explosive concentrations downwind?

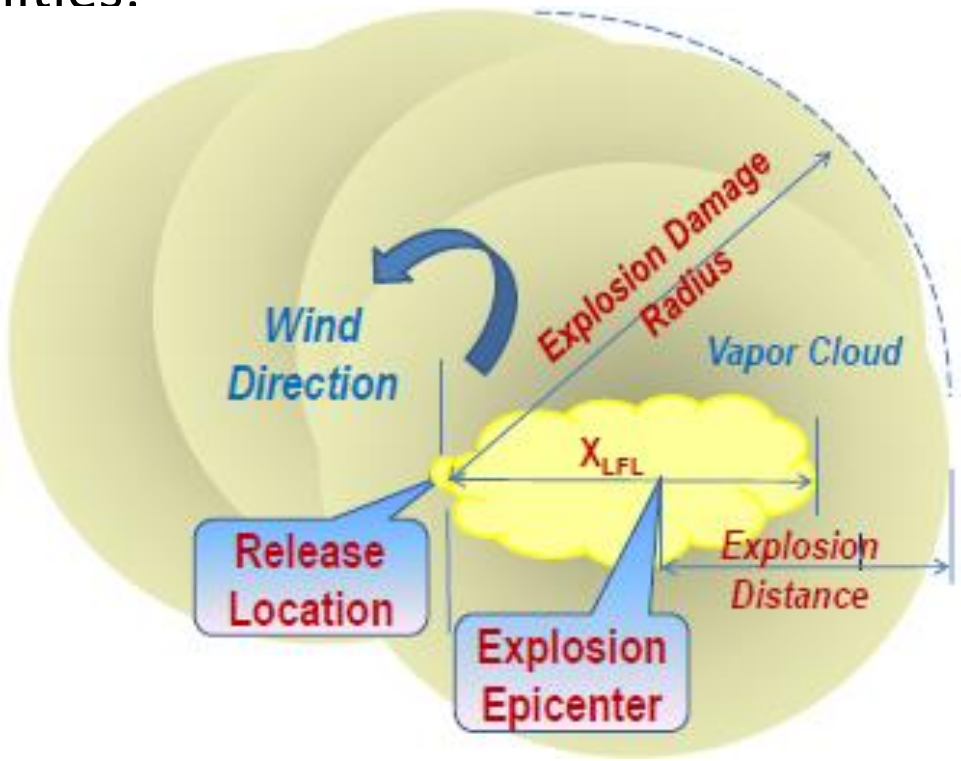


RAST - Analyze Consequences - *continued*

If explosive, what are the potential blast overpressures?

RAST provides simplified modeling capabilities:

- Vapor Cloud Explosions (VCE)



RAST - Analyze Consequences - *continued*

Parameters include

- Congestion

Congestion parameters entered in RAST at this point

RAST - Analyze Impact

Once the consequences have been understood, then RAST evaluates the *impact* to people and property: *How bad could it be?*

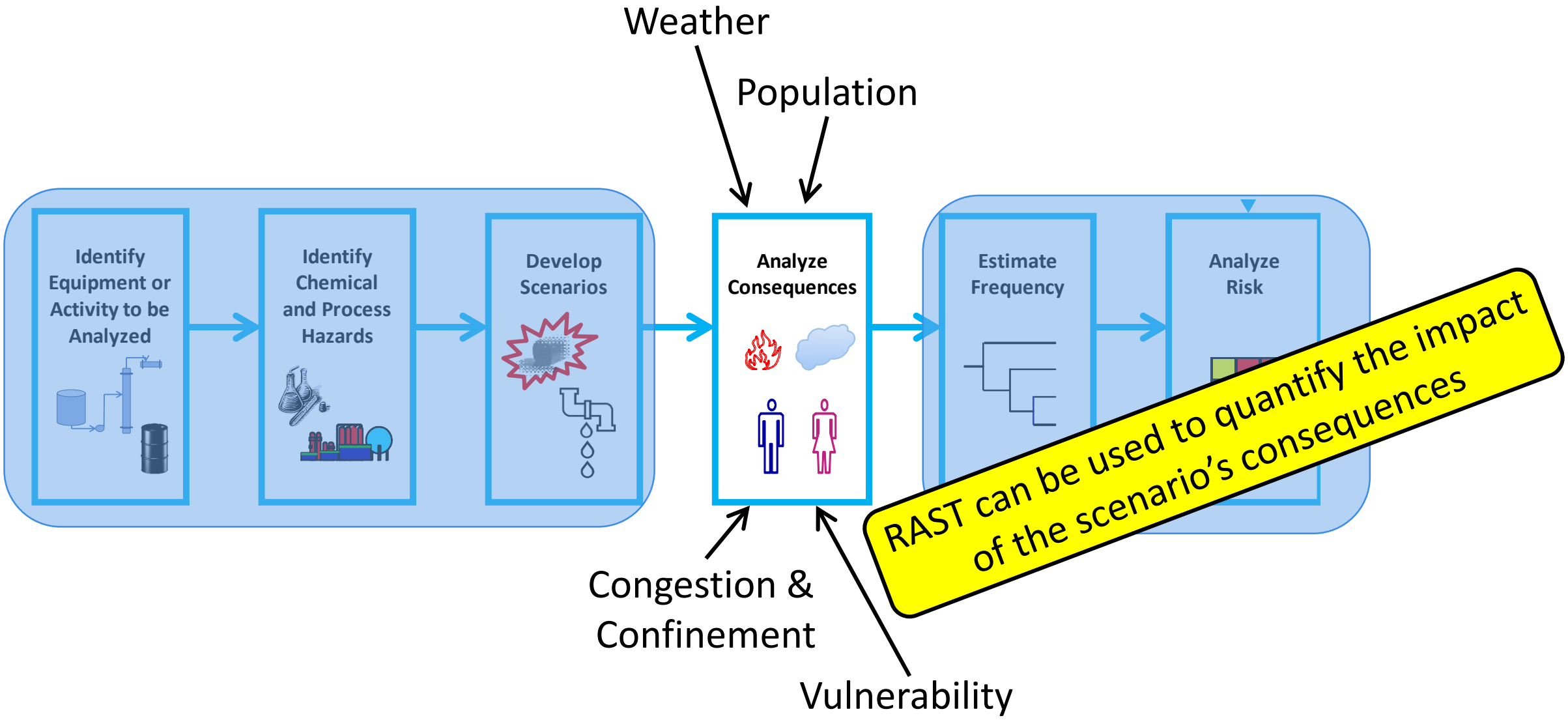
Impact Assessments

- **Flash (or Jet) Fire**: Function of flammable cloud and fire
- **Vapor Cloud Explosion**: Function of flammable cloud and release rate
- **Building Explosion:** Function of flammable cloud indoors
- **Physical Explosion:** Function of blast overpressure and distance
- **Toxic Vapor Release:** Function of exposure to toxic concentrations

Addresses probability of people being exposed

Vulnerability parameters entered in RAST at this point

Summary – Analyze Consequences and Impact

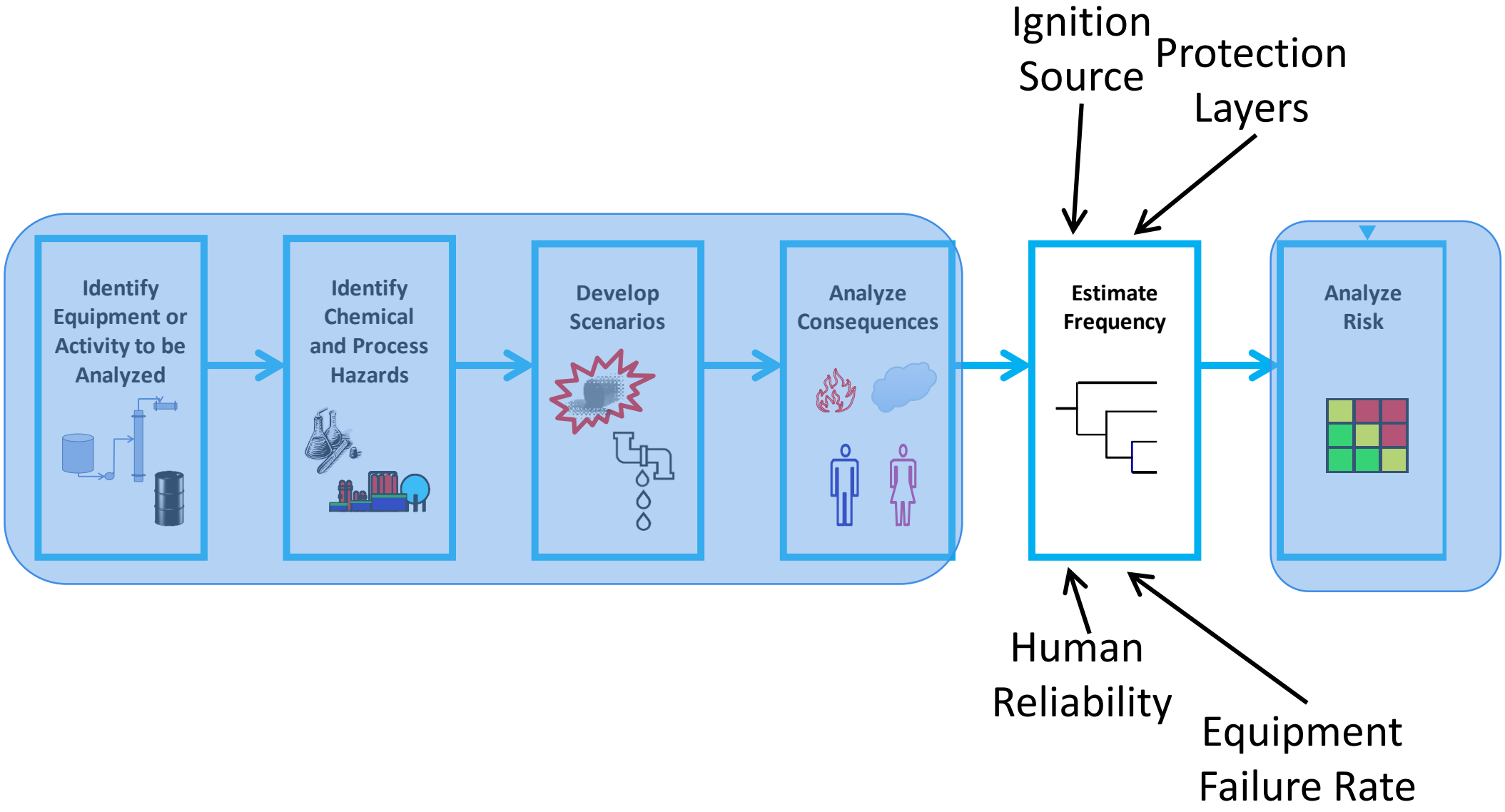


Using RAST to Support a PHA Team

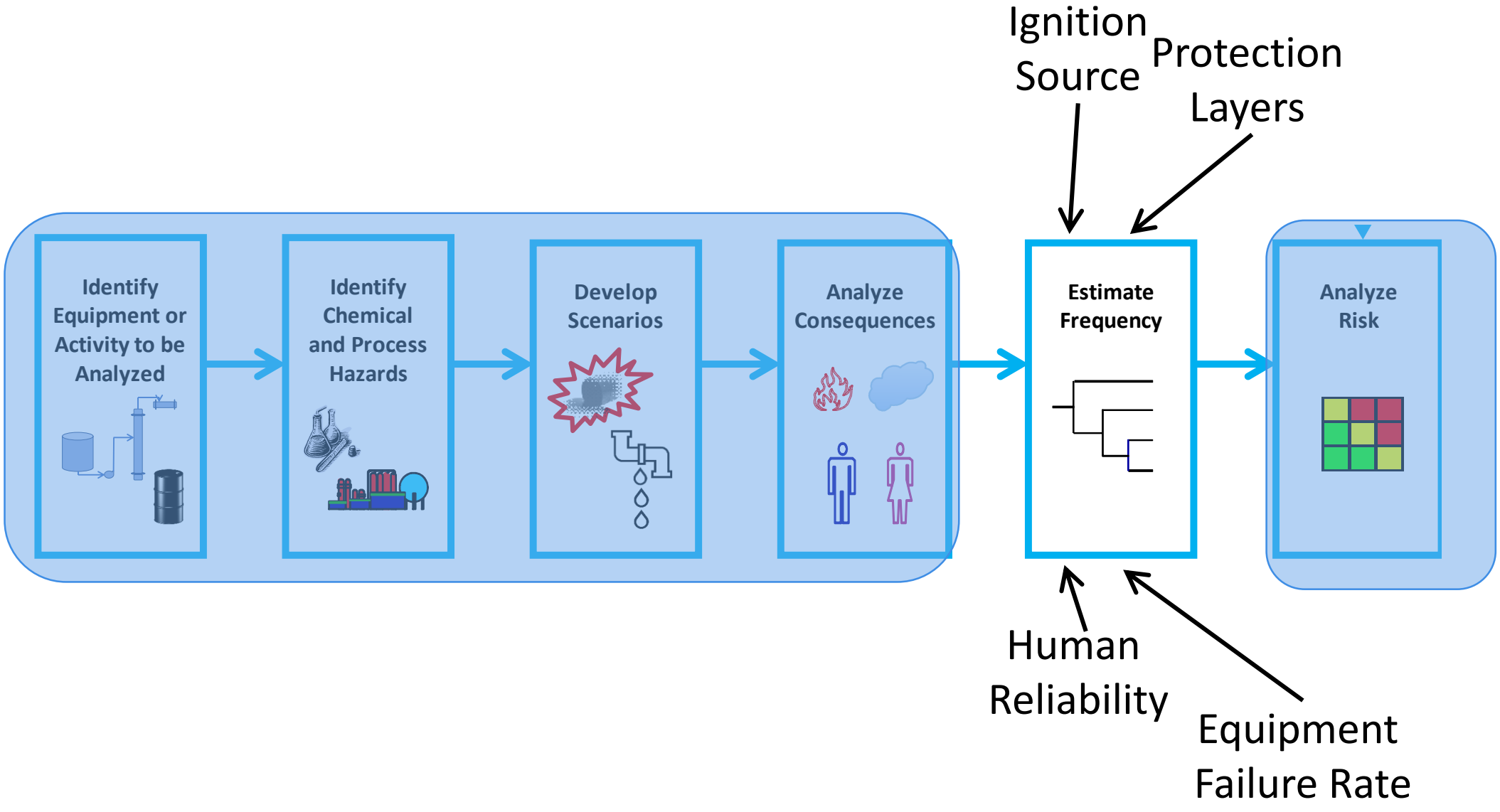
Continuing with using RAST in a PHA

4. How likely is it to happen?
    a. Already identified qualitatively by PHA Team
    b. RAST can be used to help estimate frequency of the event
        - *What is the event rate? (e.g., how many events/year?)*

RAST – Estimates of Frequency



RAST - Estimate Frequency



RAST – Estimate Frequency

How often does the cause happen? (see HAZOP table in Handout 2)

1. *What are the hazards?*
2. *What can go wrong?*
3. *What are the potential consequences?*
4. *How likely is it to happen?*

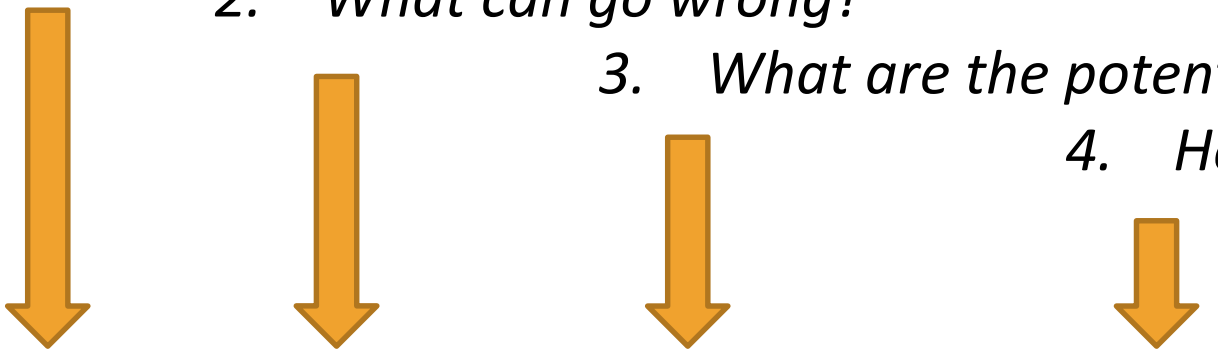
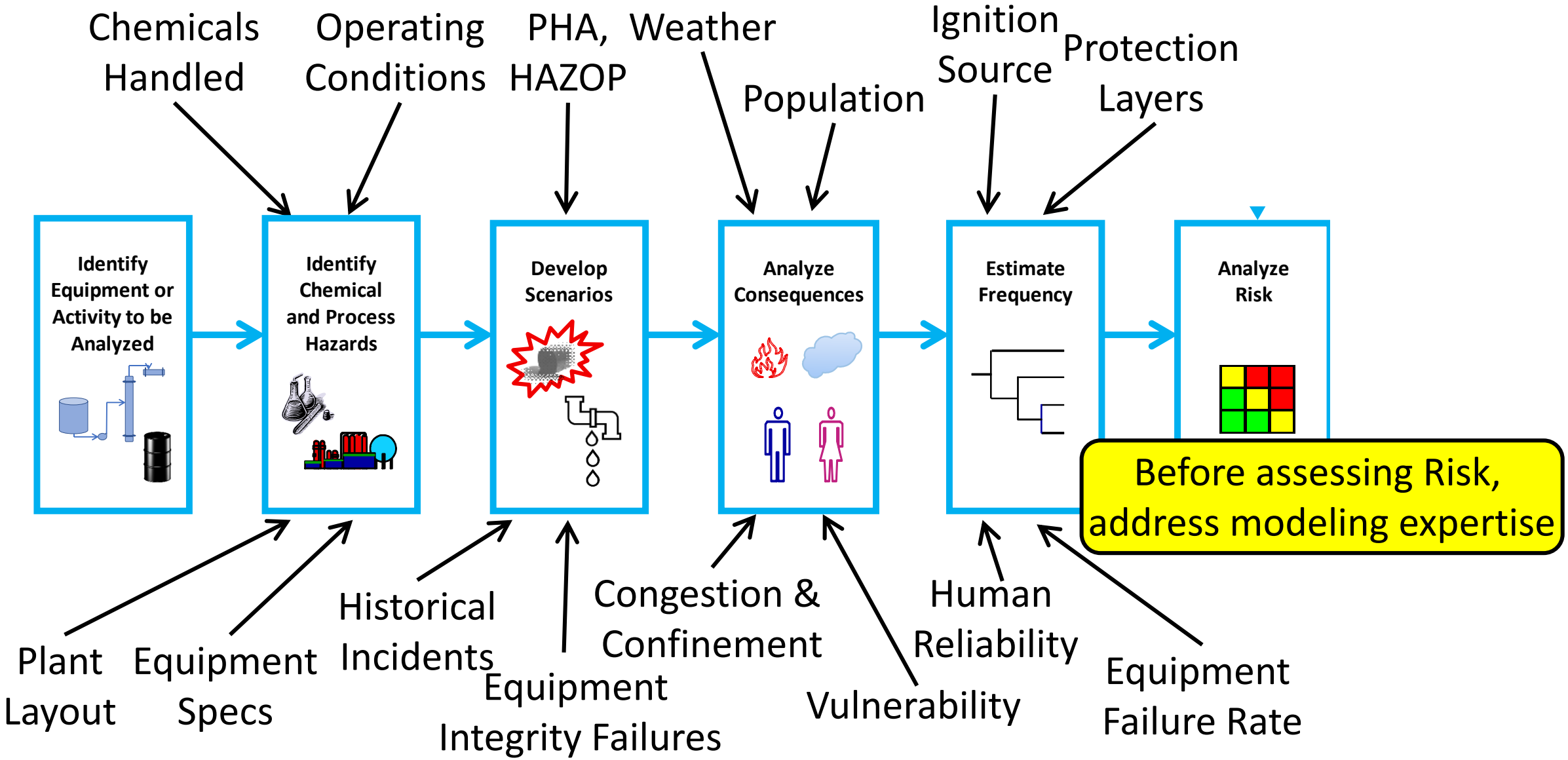


Table 2A - For Case Study Dicussion in RAST Tutorial						
Parameter: *Flow*	**Deviation**	**Cause**	**Consequence (Impact) (Worst Case)**	**Likelihood (Frequency) (No Safeguards)**	**Semi-Quantitative Risk (No Safeguards)**	**Safeguards (PHA Team Continues)**
Guideword:	High Flow					
More						

Addresses probability of people being exposed

Vulnerability parameters entered in RAST at this point

RAST - Analyze Risk – Quantitative Screening



Difference in PHA Team Members

	Qualitative	RAST (Quantified)
Process Engineer	√	√
Operator	√	√
Mechanic and Electrician	√	√
Equipment specialist(s) failure modes	(√)	√
Source and dispersion modeling specialists		√
Consequence Analysis specialist		√
Risk Analysis specialists		√

And someone trained on how to use RAST

(See Handout 4 – Next Slide)

Difference Between Qualitative and RAST

Default and User-defined Options within the Risk Analysis Screening Tool (RAST)			
Default Industry Guidance		**Options for the User-defined Entries**	
n/a	*Specific to equipment or equipment group under review (User defined)*	Yes	User enters equipment types, chemicals handled, processing conditions, and equipment layout
Yes	Provides guidance on hazard severity sufficient to warrant a hazard evaluation	Yes	Option for Users to enter new chemicals, reactivity data, and mixture properties
		Yes	Option for Users to enter facility-specific equipment design parameters and detailed processing conditions

(See Handout 4)

Difference Between Qualitative and RAST

Default and User-defined Options within the Risk Analysis Screening Tool (RAST)			
Default Industry Guidance		**Options for the User-defined Entries**	
Yes	Provides a comparitive list of possible scenarios for analysis	Yes	Option for Users to enter facility-specific scenarios based on experience
Yes	Evaluates the loss event using standard, but simplified, release and dispersion models	Yes	Option for Users to enter detailed release and dispersion modeling results, if available (Note 4)
Yes	Estimates incident outcome, impact zone, and worst-case consequence	Yes	Option for Users to enter specific consequence based on other qualitative or detailed quantitative analysis

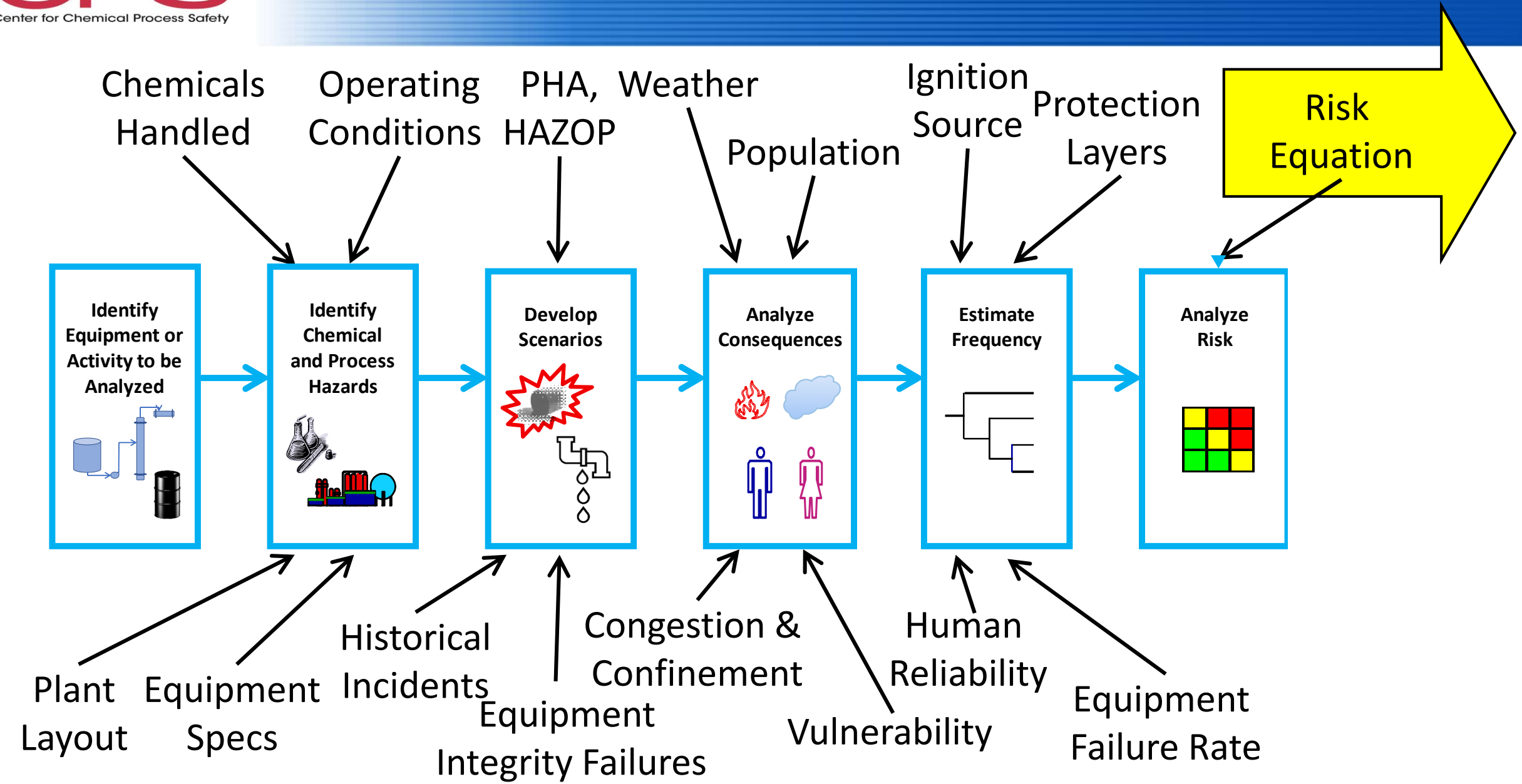
(See Handout 4)

Difference Between Qualitative and RAST

Default and User-defined Options within the Risk Analysis Screening Tool (RAST)			
Default Industry Guidance		**Options for the User-defined Entries**	
Yes	Provides possible initiating event frequencies and enabling conditions or modifiers	Yes	Option for Users to enter specific initiating event frequencies and specific enabling conditions or modifiers
Yes	Estimates individual and cumulative scenario risk and compares to a tolerable risk criteria to help identify gaps	Yes	Option for Users to enter specific risk tolerance levels (i.e., a different risk matrix)

(See Handout 4)

RAST - Analyze Risk – Quantitative Screening



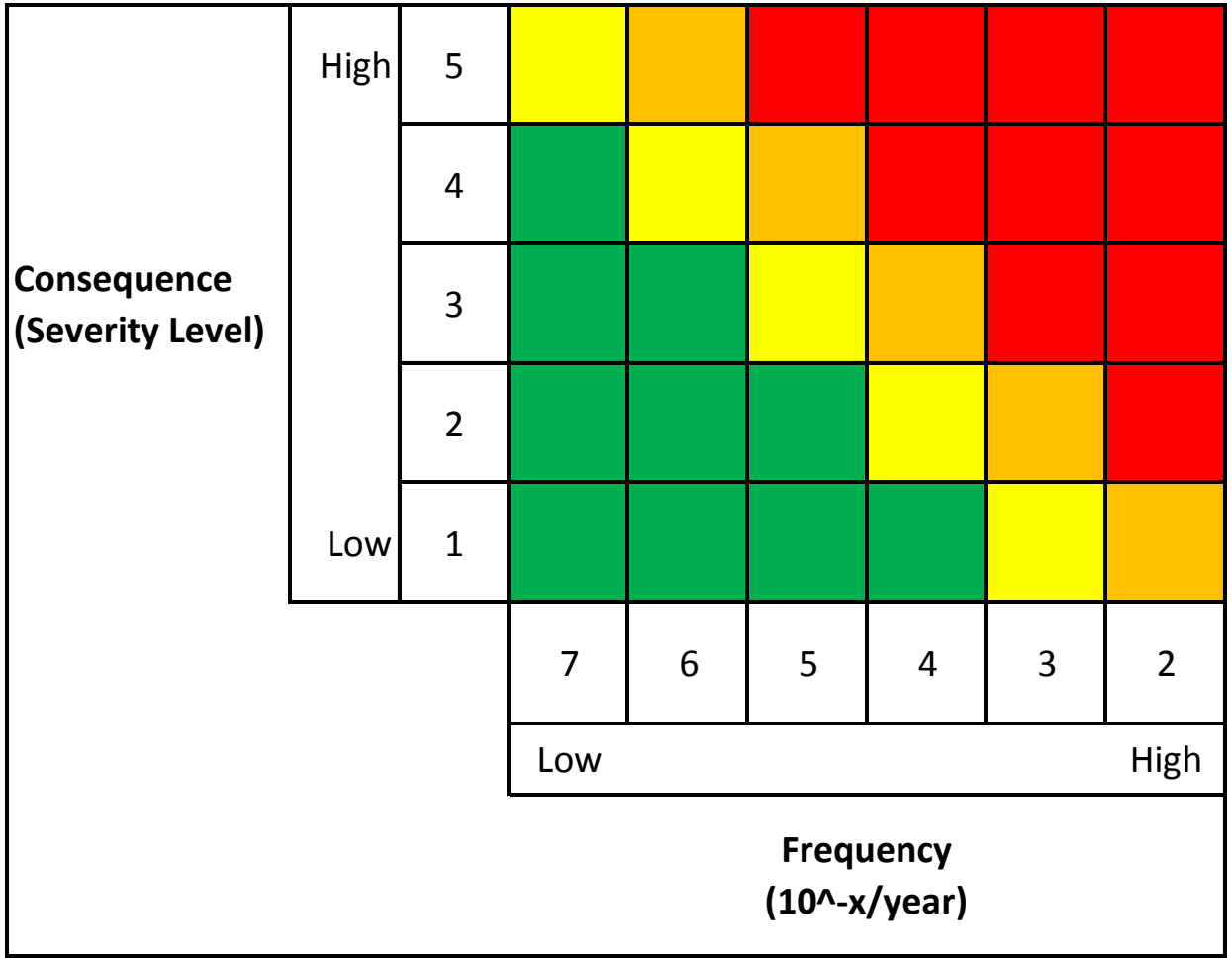
Using RAST to Support a PHA Team

Continuing with using RAST in a PHA

5. Is the risk tolerable?
   a. Already identified qualitatively by PHA Team
   b. RAST can be used to help estimate a quantified Risk for screening between PHA Recommendations or further study

Risk = F x C

Using RAST in a PHA

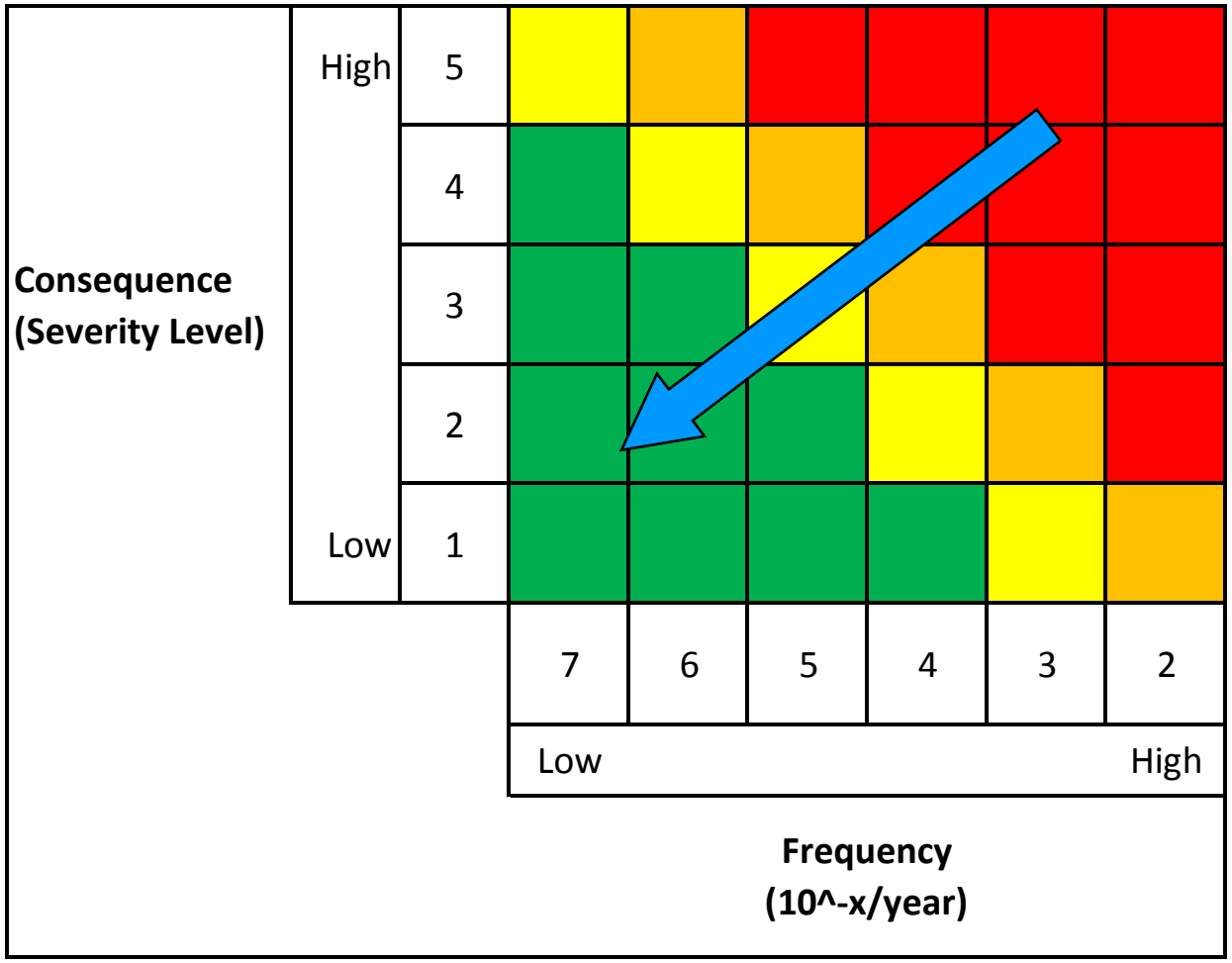


The RAST Risk Matrix

- *Order of magnitude levels*
- *"Quantitative" screening*

Legend	
Acceptable	
Tolerable - Offsite	
Tolerable - Onsite	
Unacceptable	

Using RAST in a PHA



Same Goal as Qualitative

- *Reduce Consequence*
- *Reduce Frequency*
- *Reduce Risk*

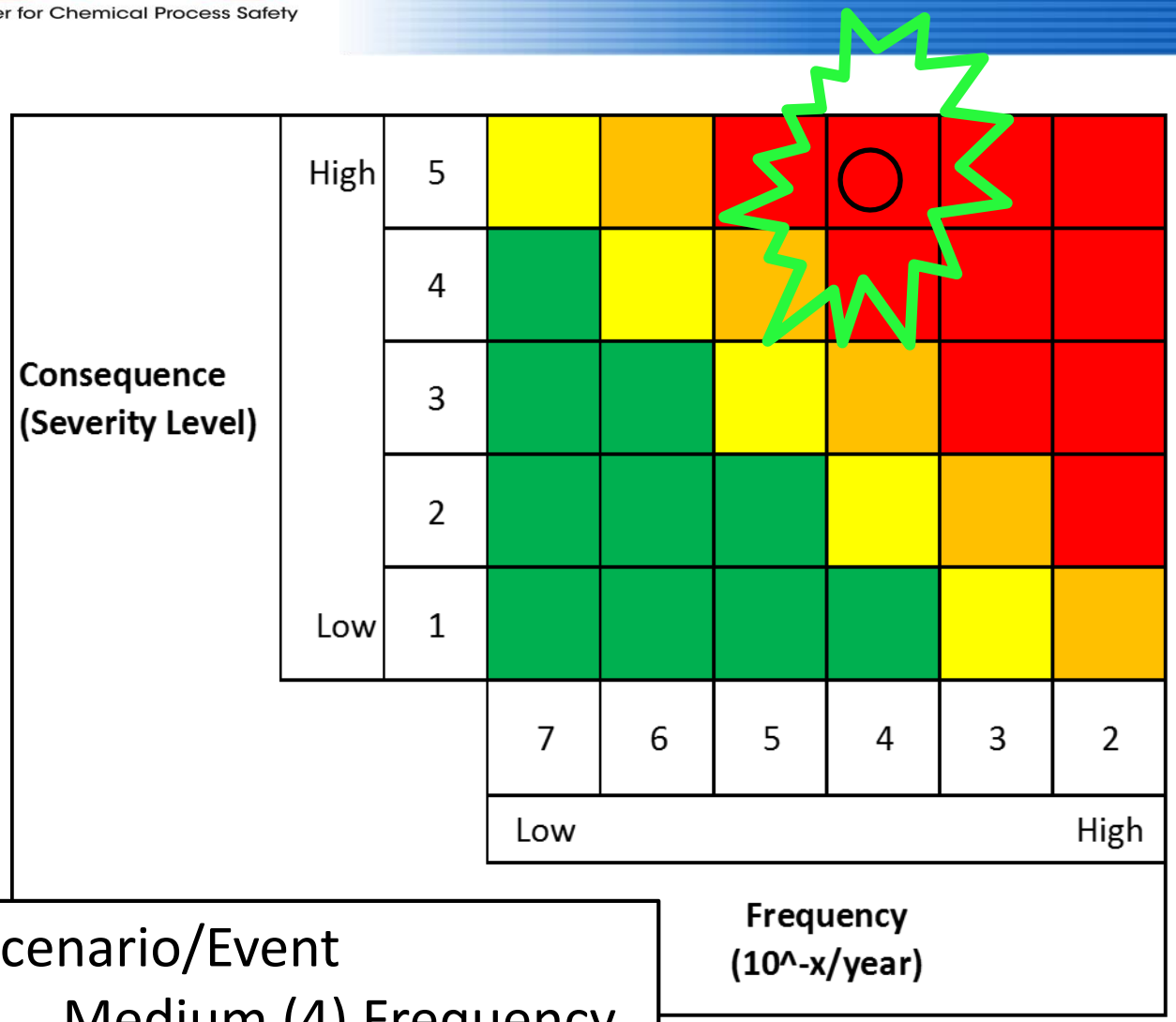
Risk = F x C

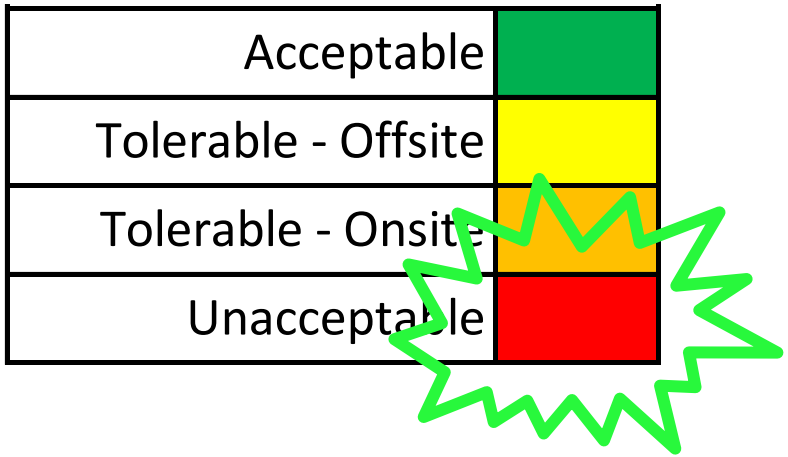
Using RAST in a PHA

Another PHA Team scenario, with RAST quantifying Risk:

1. Hazard? Flammable material
2. Wrong? Pump fails unexpectedly (the scenario or event)
3. Consequence? High; Large release (loss of containment); “5”
4. Frequency? Medium likelihood that this event will occur; “4”
5. Risk? Evaluate on a quantitative risk matrix

Example on the Quantitative Risk Matrix



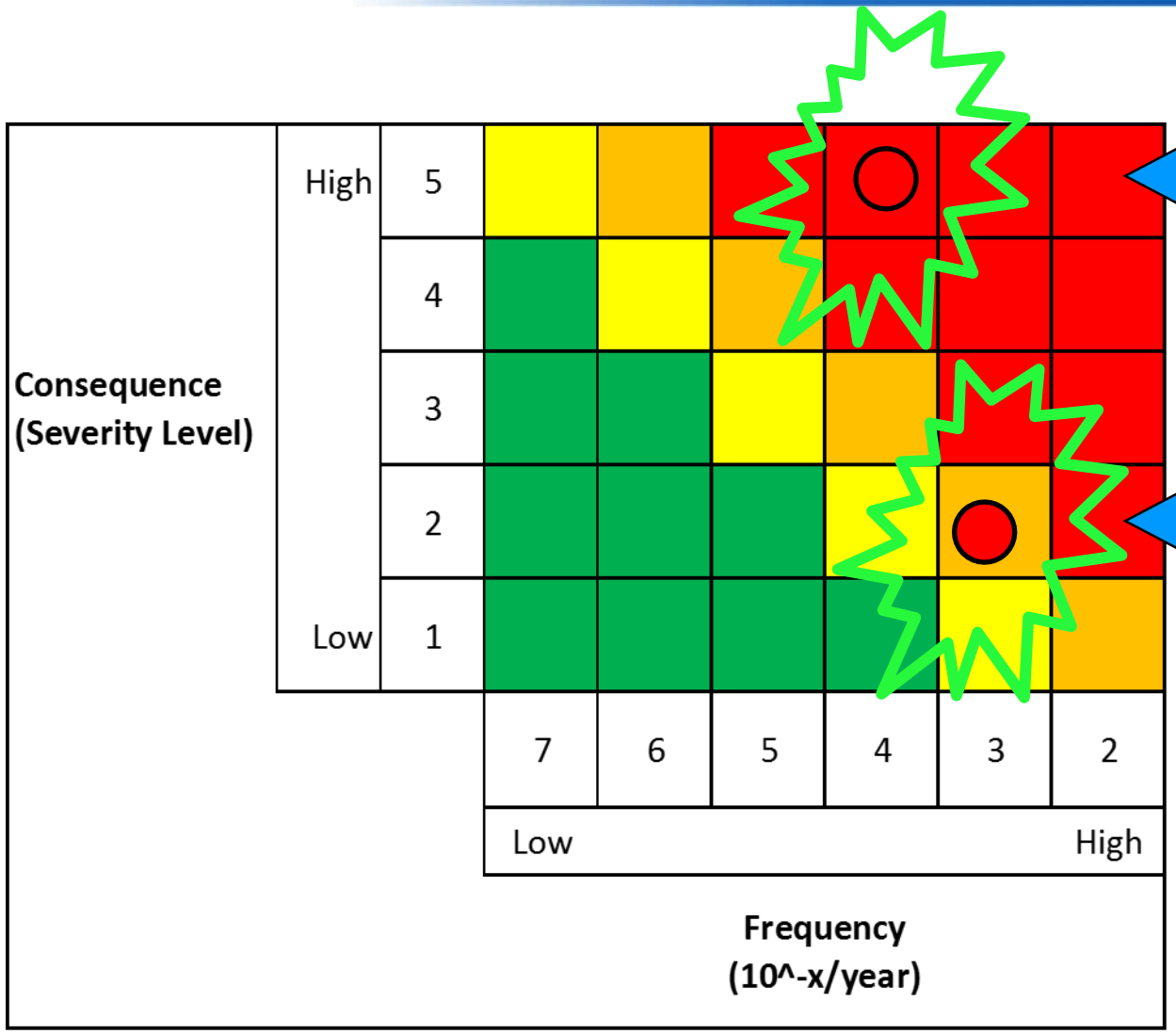


Unacceptable Risk

Scenario/Event
Medium (4) Frequency
High (5) Consequence

Requires PHA
Recommendation(s)

Examples on the Quantitative Risk Matrix



RAST Risk Screening Result #1

RAST Risk Screening Result #2

Prioritize PHA Recommendation(s)

Tutorial Outline

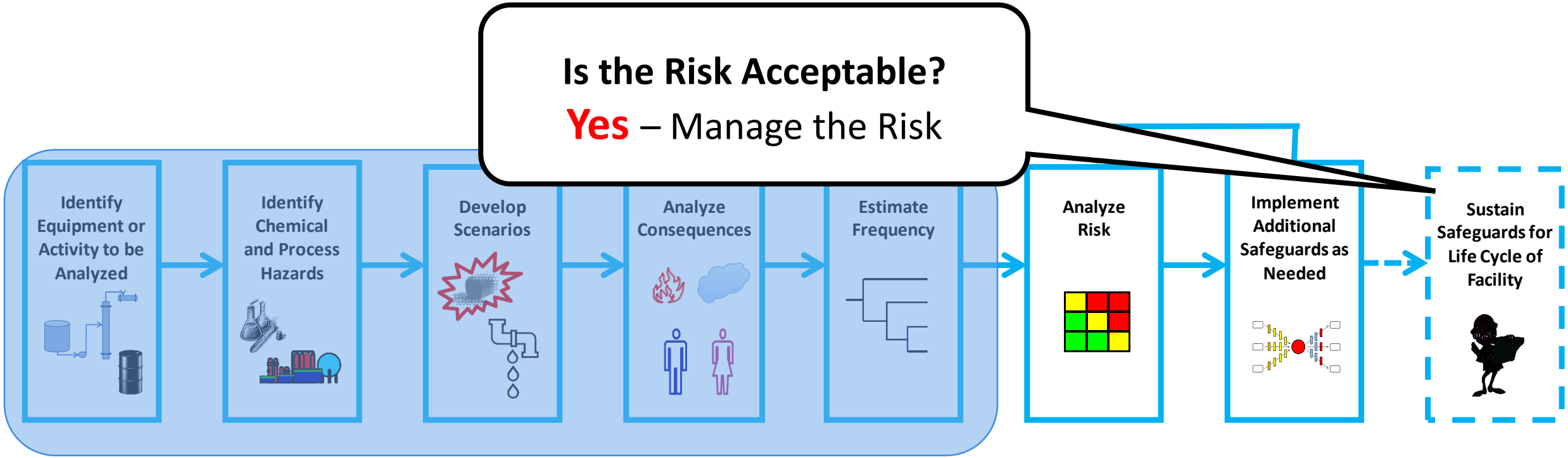
- Process Safety
- The Process Hazards Analysis (PHA)
- The Risk Analysis Screening Tool (RAST)
- Some RAST Features for the Fearless
- Summary and Questions?

Additional RAST Features

Being “Fearless”

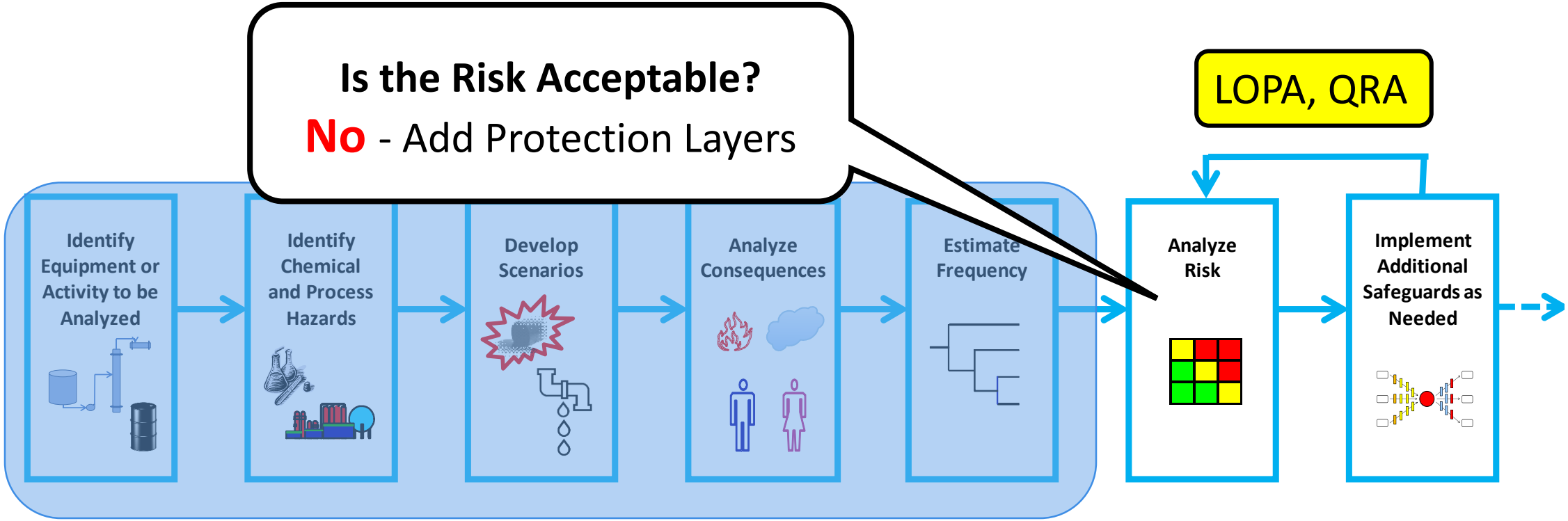
Be aware of the hazards, but not afraid of them!

Moving on beyond the PHA/RAST efforts…



Sustaining safeguards is a part of the overall Process Safety and Risk Management program

RAST helps identify additional safeguards



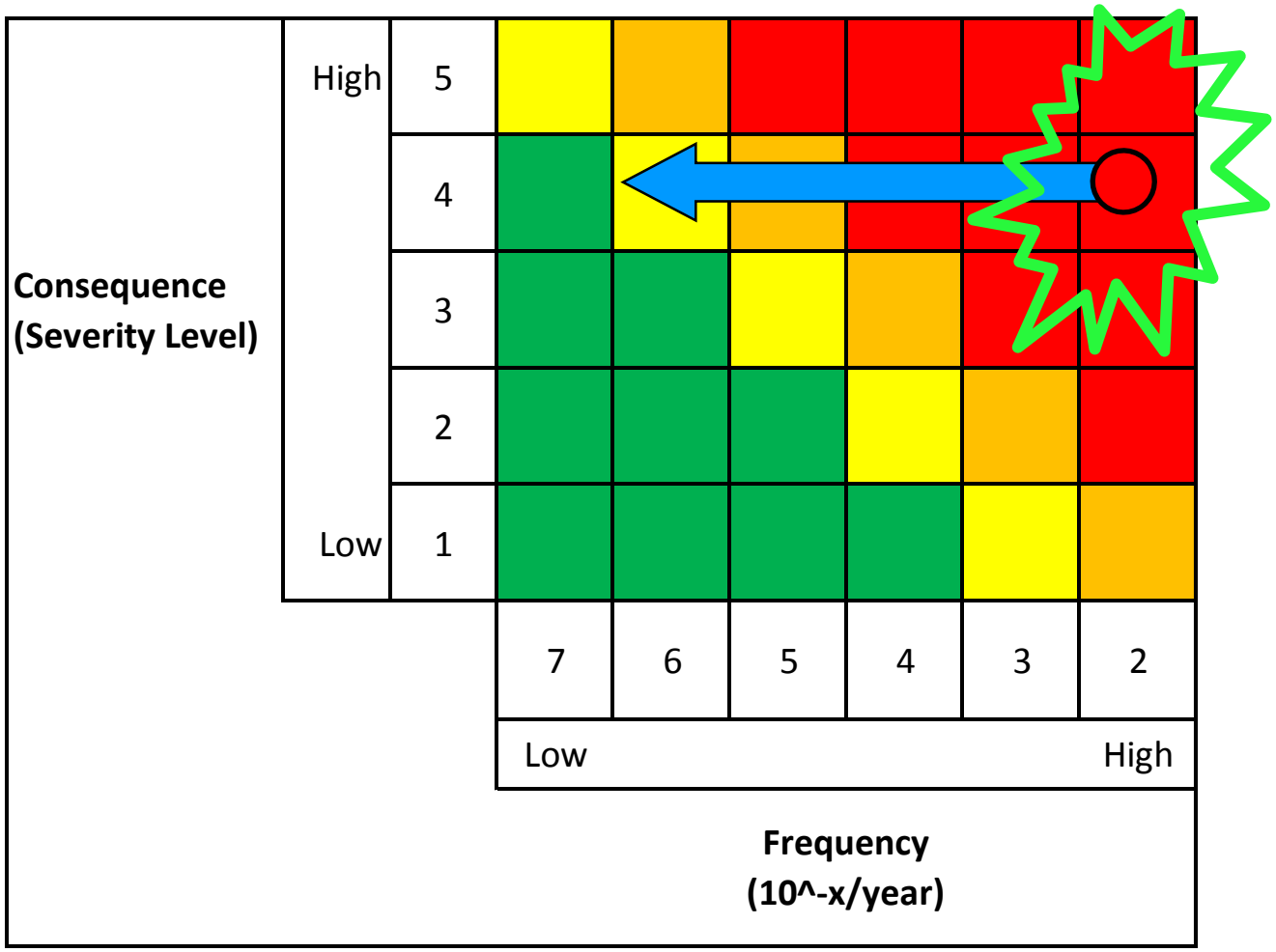
RAST provides option for a Layer of Protection Analysis (LOPA)
RAST allows entries from a Quantitative Risk Analysis (QRA)

Option for LOPA in RAST

Default and User-defined Options within the Risk Analysis Screening Tool (RAST)			
Default Industry Guidance		**Options for the User-defined Entries**	
Yes	Provides possible initiating event frequencies and enabling conditions or modifiers	Yes	Option for Users to enter specific initiating event frequencies and specific enabling conditions or modifiers
Yes	Estimates individual and cumulative scenario risk and compares to a tolerable risk criteria to help identify gaps	Yes	Option for Users to enter specific risk tolerance levels (i.e., a different risk matrix)
Users can stop here for a qualitative hazards review or they can continue with S7 to perform a LOPA, if needed.			
Yes	Provides capability to perform a Layer of Protection Analysis (LOPA) on selected scenarios	Yes	Option for Users to 1) Perform a LOPA on selected scenarios, and 2) Enter QRA results, if available *(Note 4)* .

(See Handout 4)

Using RAST For a LOPA



Focus on Frequency

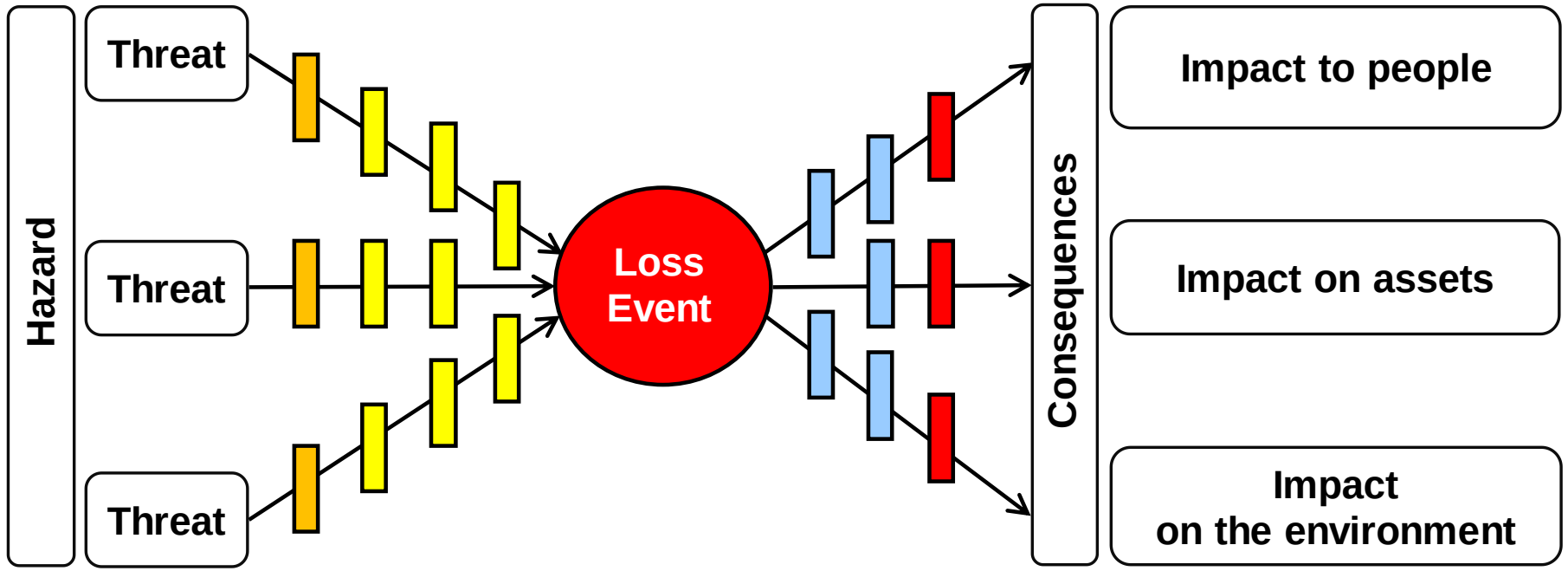
- *Reduce Consequence*
- *Reduce Frequency*
- *Reduce Risk*

Risk = F x C

By adding Independent Protection Layers (IPLs)

Other RAST Features - *continued*

RAST uses a Bow Tie method
to help screen for and identify potential safeguards or barriers



Other RAST Features - *continued*

RAST Documentation ("Reports") include:

- Assumptions and limits based on
  - *industry guidance* (*default values*)
  - *company-specific guidance* (*overrides defaults*)

- Scenarios used to establish tolerable risk
  (*provides list of possible scenarios*)

- Safeguards and protection layers needed to sustain tolerable risk
  (*can use the Layer of Protection Analysis - LOPA*)

Other RAST Features - *continued*

If RAST's LOPA is used to determine Independent Protection Layers (IPLs) needed to sustain tolerable risk,

- Report can list the Independent Protection Layers (IPL)
- IPLs are the basis and are used for developing asset integrity programs
  - Inspections and tests
  - Preventive maintenance programs

Manage risk by maintaining protection layers

Case Study – Quantitative Assessment

Exercise:

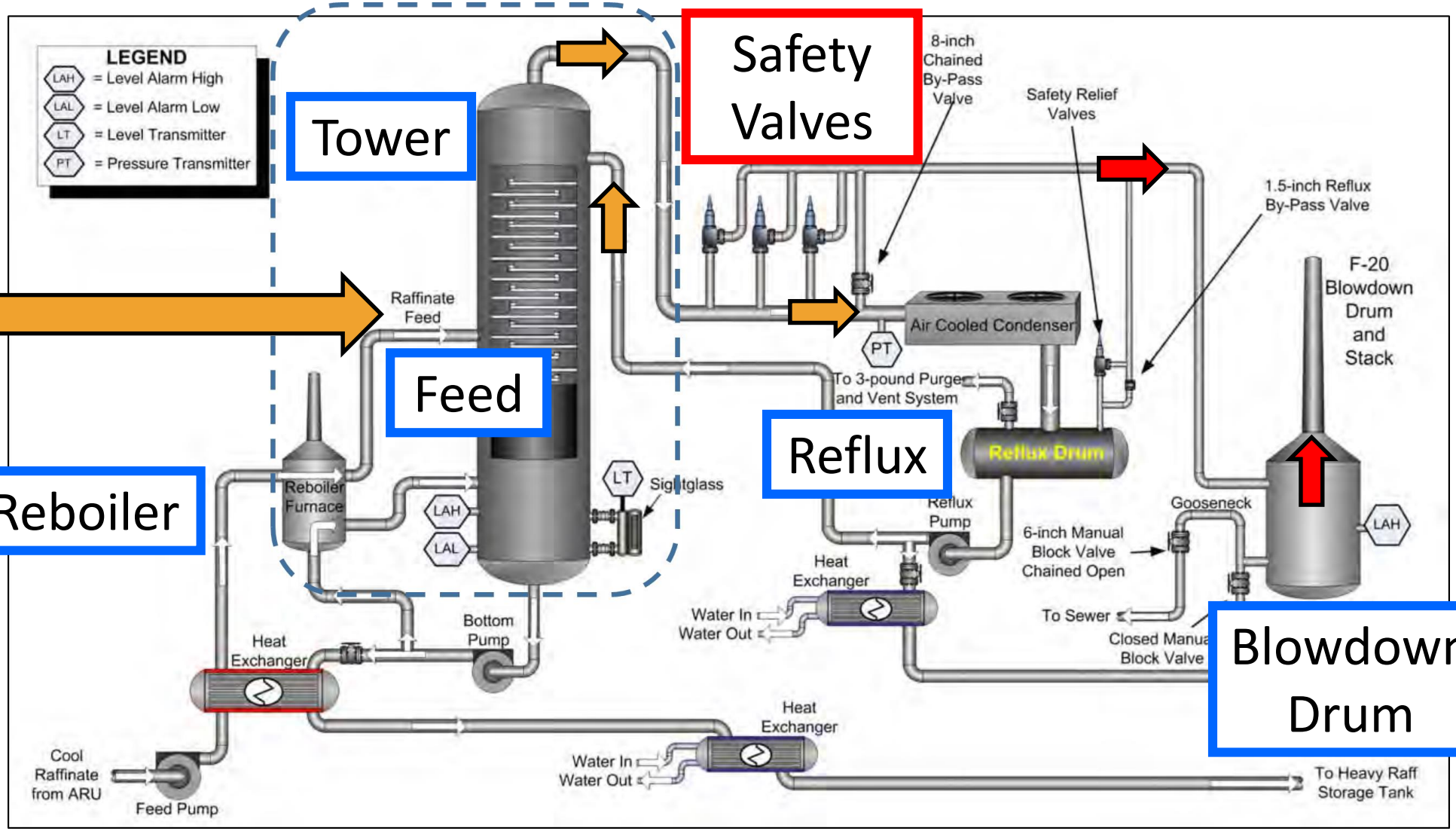
Feed

Flow

No

High

(Fill out Handout 2)



Case Study from Website

- RAST Overview
- CHEF Overview
- Case Studies
- Terms and Conditions
- Download and Install
- RAST User and CHEF Manuals
- Frequently Asked Questions (FAQs)
- RAST Development History

(See Handout 3)

Case Studies

- Vapor Cloud Explosion (BP Texas City)
- Outdoor Toxic Release (Chlorine, DPC Enterprises)
- Confined Space Explosion (CAI and Arnel)
- Runaway Reaction and Physical Explosion (T2 Laboratories)

Based on US Chemical Hazards and Safety Board (US CSB) Incident Investigation reports

Case Study – Quantitative Assessment

SCENARIO NO	Cross Ref	Scenario Type	Initiating Event General Description	Loss Event	Outcome	Outcome Descriptors	Consequence	Tolerable Frequency Factor	Gap in Layers of Protection	Worst Case Scenario for Further Analysis
12.01		Overflow – Flooding or Plugging	BPCS Instrument Loop Failure	Equipment Rupture at Operating Temperature	Flash Fire or Fireball	Modeled as Instantaneous Release at a Distance to Severe Flammable Impact (0.5 LFL, BLEVE, or Dust Fireball) of 1060 m	Severity Level-5	6	5	High TF & IPL
13.01		Overflow – Flooding or Plugging	BPCS Instrument Loop Failure	Equipment Rupture at Operating Temperature	Vapor Cloud Explosion	Modeled as Instantaneous Release impacting on site personnel at a Explosion Distance to 1 psi Overpressure of 563 m including Explosion Overpressure at Low Strength Occupied Bldg 1 (psi) of 3.2	Severity Level-5	6	5	High TF & IPL
12.02		Overflow – Flooding or Plugging	Mechanical Failure	Equipment Rupture at Operating Temperature	Flash Fire or Fireball	Modeled as Instantaneous Release at a Distance to Severe Flammable Impact (0.5 LFL, BLEVE, or Dust Fireball) of 1060 m	Severity Level-5	6	5	High TF & IPL
13.02		Overflow – Flooding or Plugging	Mechanical Failure	Equipment Rupture at Operating Temperature	Vapor Cloud Explosion	Modeled as Instantaneous Release impacting on site personnel at a Explosion Distance to 1 psi Overpressure of 563 m including Explosion Overpressure at Low Strength Occupied Bldg 1 (psi) of 3.2	Severity Level-5	6	5	High TF & IPL
10.01		Overflow – Flooding or Plugging	BPCS Instrument Lo… Failure	…verfill Release	Vapor Cloud Explosion	impacting on site personnel at a Explosion Distance to 1 psi Overpressure of 291 m including Explosion Overpressure at Low Strength Occupied Bldg 1 (psi) of 1.9	Severity Level-5	6	5	High TF & IPL

One of the RAST suggested scenarios

Case Study – Quantitative Assessment

CONSEQUENCE SUMMARY

RAST Version 2 *Date: 12/1/2019*

Loss Event for: Distillation; Rafinatte Splitter Containing Pentane (n-) : Overfill Release

Explosion Summary:

VCE or Building Explosion Energy, kcal	2.4E+07
VCE or Building Explosion Distance to 1 psi Overpressure, m	288.5
Maximum Distance to LFL Concentration, m	202.1
Blast Overpressure at Center of Occupied Building 1, psi	3.2
Blast Overpressure at Center of Occupied Building 2, psi	0.0
Distance to Severe Thermal Radiation Impact, m	
Rupture Explosion Energy, kcal	
Distance to Direct Blast Impact (10 psi), m	
Maximum Fragment Range, m	
Rupture Distance to 1 psi Overpressure, m	
Rupture Overpressure at Center of Occupied Building 1, psi	0.0
Rupture Overpressure at Center of Occupied Building 2, psi	0.0

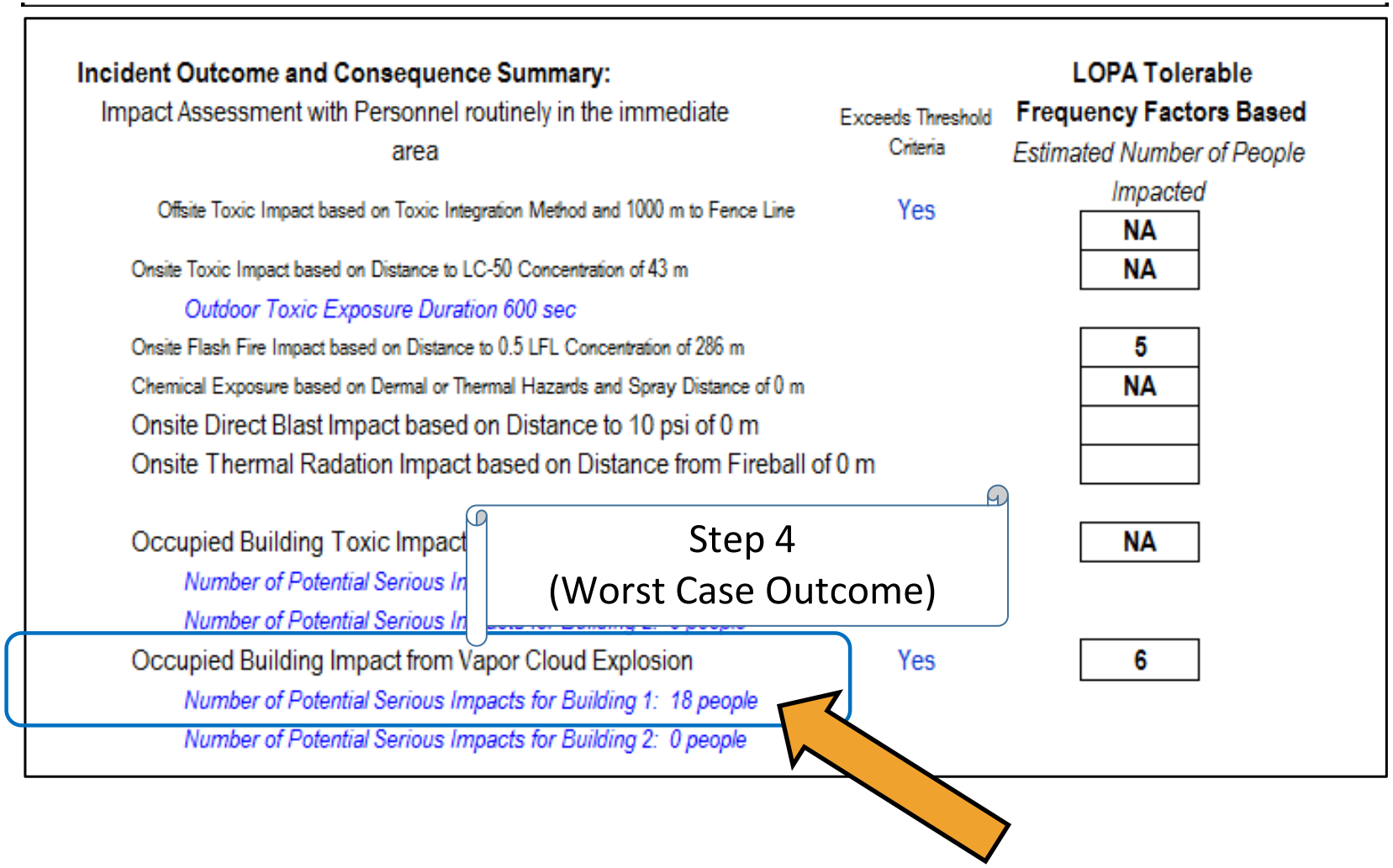
Probability of Ignition (POI)

Potential Explosion Impact to Occupied Building

obability of Explosion (POX)

Trailers won't survive this overpressure

Case Study – Quantitative Assessment



Incident Outcome and Consequence Summary: Impact Assessment with Personnel routinely in the immediate area	Exceeds Threshold Criteria	LOPA Tolerable Frequency Factors Based *Estimated Number of People Impacted*
Offsite Toxic Impact based on Toxic Integration Method and 1000 m to Fence Line	Yes	NA
Onsite Toxic Impact based on Distance to LC-50 Concentration of 43 m		NA
Outdoor Toxic Exposure Duration 600 sec		
Onsite Flash Fire Impact based on Distance to 0.5 LFL Concentration of 286 m		5
Chemical Exposure based on Dermal or Thermal Hazards and Spray Distance of 0 m		NA
Onsite Direct Blast Impact based on Distance to 10 psi of 0 m		
Onsite Thermal Radation Impact based on Distance from Fireball of 0 m		
Occupied Building Toxic Impact		NA
Number of Potential Serious In		
Number of Potential Serious In		
Occupied Building Impact from Vapor Cloud Explosion	Yes	6
Number of Potential Serious Impacts for Building 1: 18 people		
Number of Potential Serious Impacts for Building 2: 0 people		

Step 4
(Worst Case Outcome)

"Conservative" number of fatalities

Tutorial Outline

- Process Safety
- The Process Hazards Analysis (PHA)
- The Risk Analysis Screening Tool (RAST)
- Some RAST Features for the Fearless
- Summary and Questions

Tutorial Summary

- **Process Safety – Mission**
- **The Process Hazards Analysis (PHA) – Qualitative**
- **The Risk Analysis Screening Tool (RAST) – Quantitative**
- **Some RAST Features for the Fearless – LOPA**

Process Safety Mission Revisited

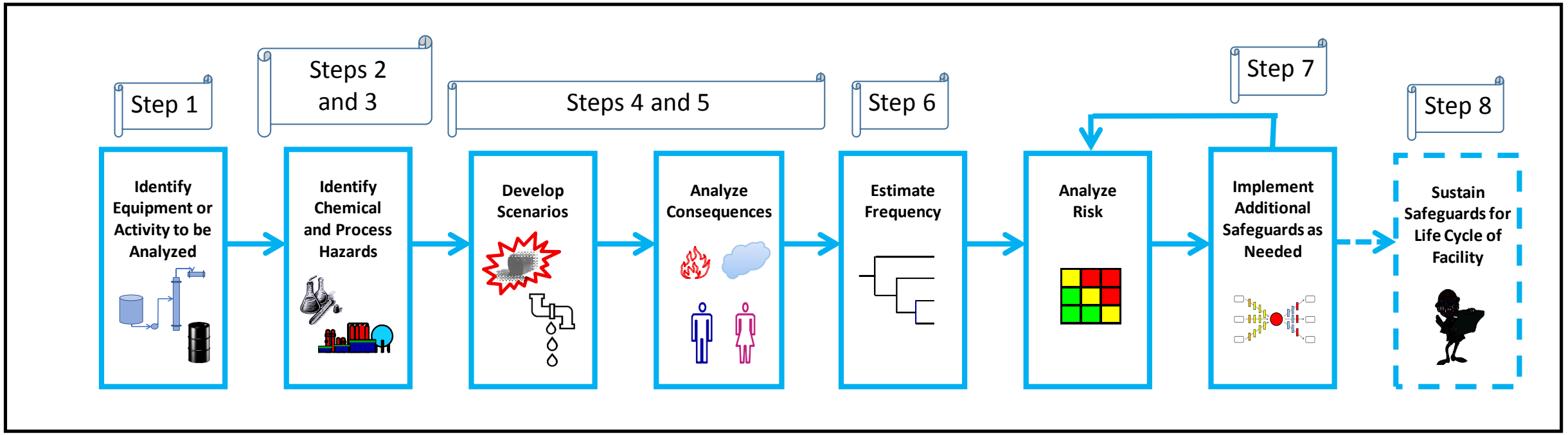
Our goal is to reduce process safety risks

The result is preventing incidents

Less harm to people, the environment, and property

Fewer – and less severe - incidents!

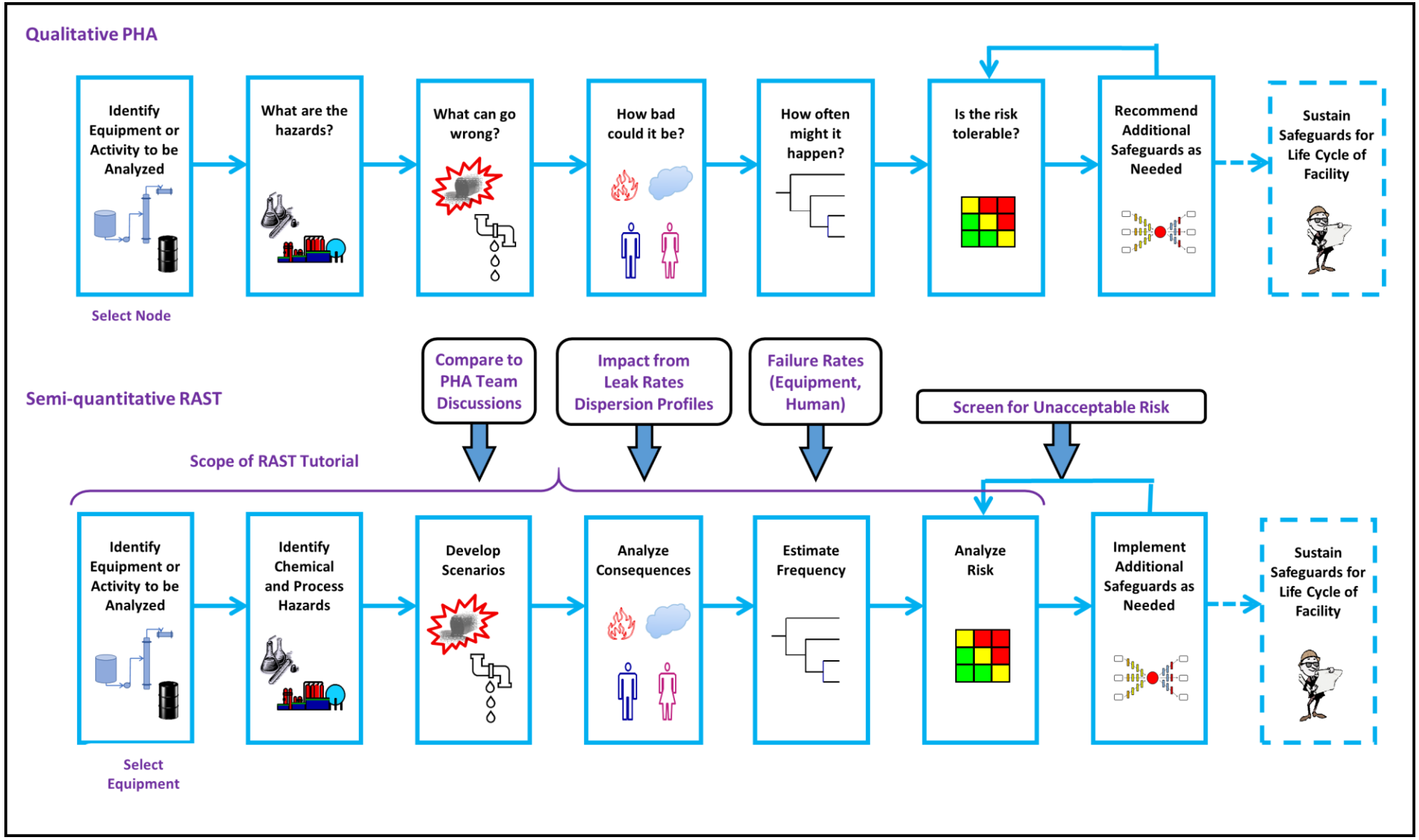
HIRA and RAST Summary



(See Handout 5)

(Corresponds to Table 3 in Handout 4)

PHA (Qualitative) supported by RAST (Quantitative)

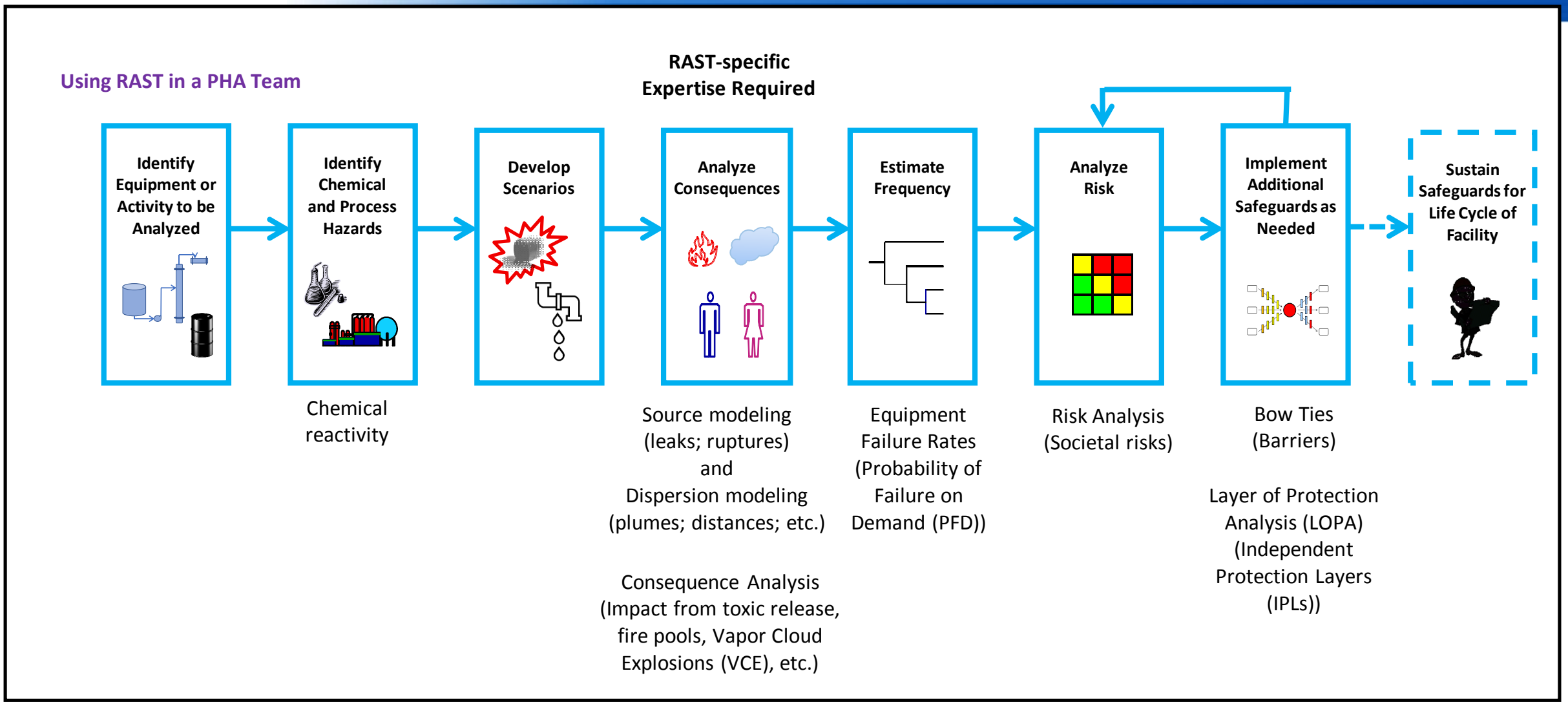


PHA Team Qualitative

RAST Screening Quantitative

(See Handout 6)

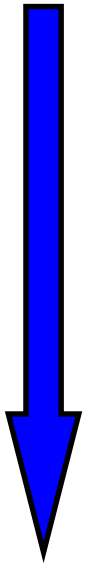
RAST-specific Expertise for Results Analysis



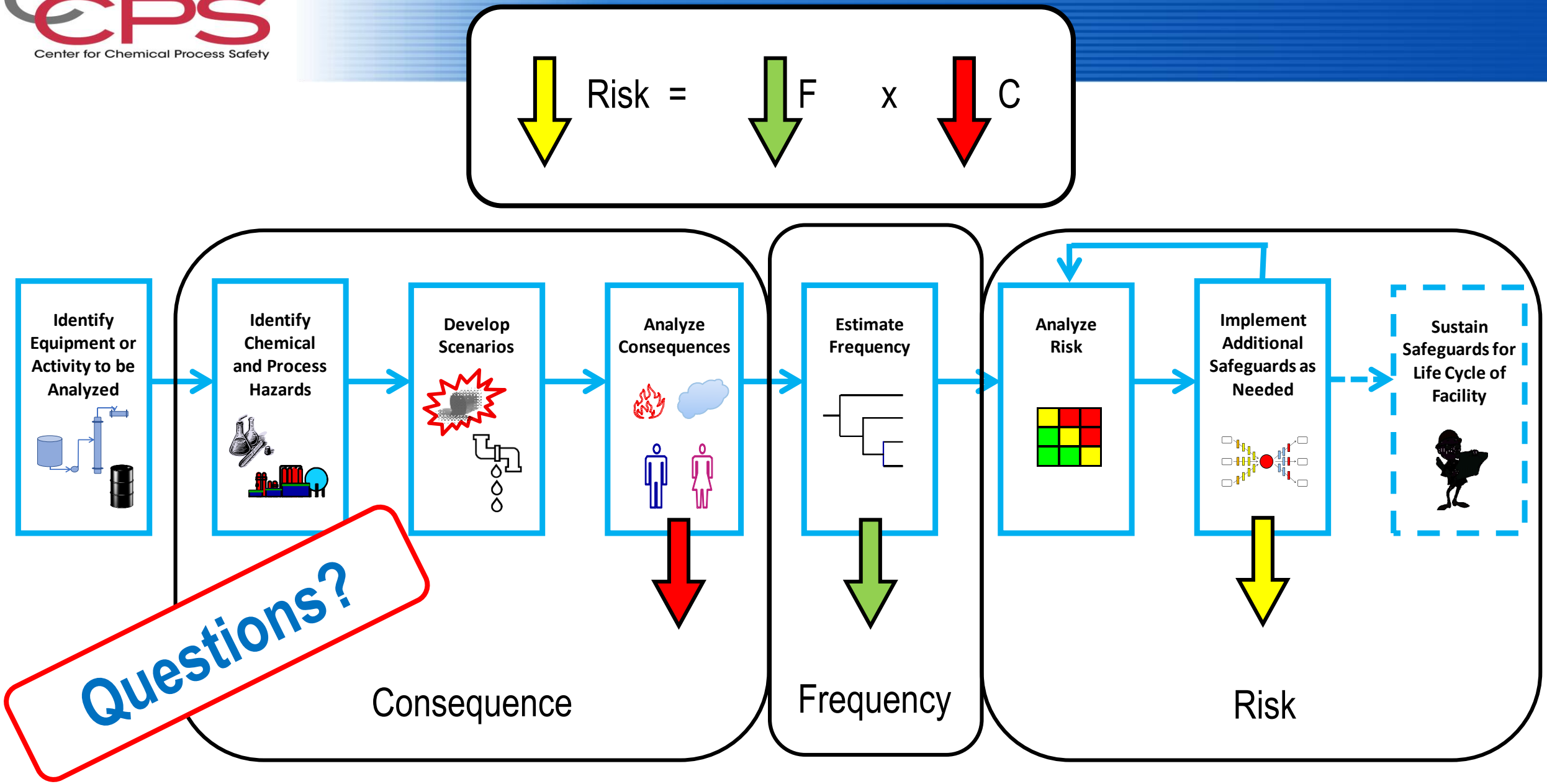
(See Handout 7)

When is RAST used?

Increasing Process Risk Analysis **Detail**



Detail Level	Type of Risk Assessment
Qualitative	Process Safety Review
	Checklist Analysis
	Hazards and Operability Study (HAZOP)
	Safeguard or protection layers (in HAZOP)
	Barrier Analysis (e.g. Bow Tie)
	Risk Analysis Screening Tool (RAST)
Simplified (semi-quantitative)	Layers of Protection Analysis (LOPA)
	Risk Analysis Screening Tool (RAST)
Quantitative Risk Analysis (QRA)	Fault Tree Analysis
	Detailed Dispersion Modeling
	Detailed Explosion Modeling
	Human Vulnerability Analysis


Risk = F x C
Identify Equipment or Activity to be Analyzed
Identify Chemical and Process Hazards
Develop Scenarios
Analyze Consequences
Estimate Frequency
Analyze Risk
Implement Additional Safeguards as Needed
Sustain Safeguards for Life Cycle of Facility
Consequence
Frequency
Risk
Questions?