ADDRESSING ENABLERS IN LAYERS OF PROTECTION ANALYSIS (LOPA)

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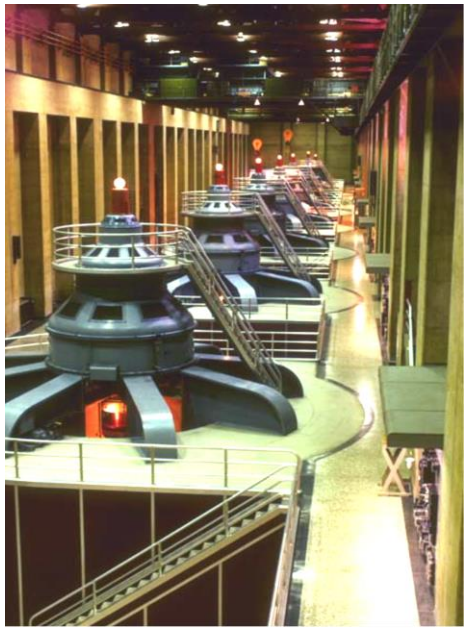

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OVERVIEW

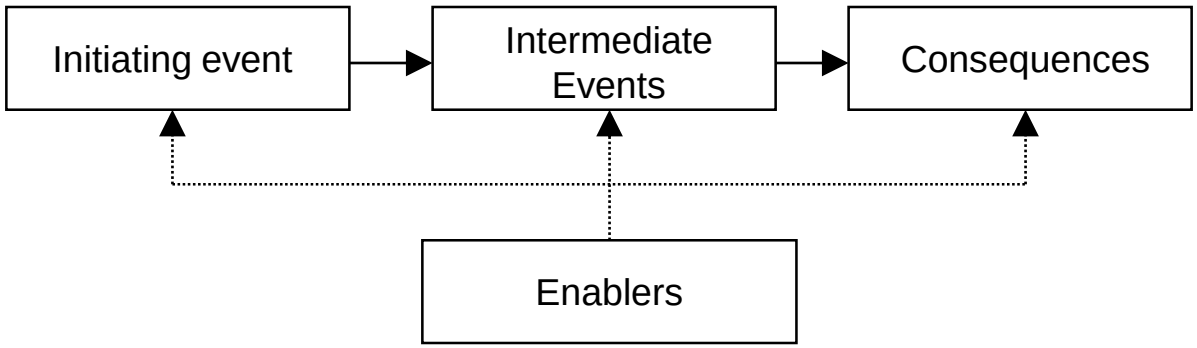
- LOPA history and scope
- Conventional enablers
- Other enablers
- Benefits of addressing enablers

LOPA HISTORY

- Originally conceived as a simple risk analysis method
  - At best produces an order of magnitude risk estimate
- LOPA has evolved from its original form
  - Current applications seek greater rigor and incorporate more detail
- Now being used to support the determination of Safety Integrity Levels (SILs)
  - IEC 61511 / ISA 84 standard
  - Refinement warranted

LOPA SCOPE

- Evaluates the risk of individual hazard scenarios. Combines:
  - Initiating event frequency
  - Failure probabilities of protection layers
  - Consequence severity



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LOPA SCOPE (CONTD.)

- Some practitioners include certain enablers
  - Enabling events and conditions
  - Conditional modifiers
  - Time-at-risk factors
- Other practitioners do not address enablers. Believe:
  - Uncertainties are too great
  - Risk may be underestimated
  - Effort is too great

LOPA SCOPE (CONTD.)

- Enablers can be key elements of scenarios
  - Often part of actual incidents
- Exclusion can result in overly conservative results
- Inclusion produces more accurate risk estimates
  - Conservative assumptions can be made to help avoid risk underestimation
  - Effort to include them actually is not substantial

CCPS 2001 DEFINITION OF ENABLING EVENTS AND CONDITIONS

- Enabling events and conditions do not directly cause a scenario
  - Required to be present or active for the scenario to proceed
    - E.g. a bypassed high level alarm that allows overflow of a tank

Note: They make scenarios possible and influence their risk by reducing their likelihoods.

CCPS 2001 CONDITIONAL MODIFIERS

- $P_{ignition}$ Probability that a flammable / explosive material will be ignited
- $P_{present}$ Probability that a person will be present to be exposed to a hazard
- P_{injury} Probability that harm will occur if an individual is exposed

Probabilities are used to reduce the frequency of the scenario.

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CCPS 2001 AT-RISK FACTORS

- Account for the time period in which a process is at risk
  - E.g. process is in a particular mode, phase or step
- Scenario frequencies are adjusted using the fraction of time the risk is present
  - Receptors are at risk for only this time period
- Otherwise, risk may be grossly overestimated

EFFECT OF CONVENTIONAL ENABLERS

- Reduce the frequency of a scenario
  - Or, modify its consequences
- Conservative analyses assume their probability of occurrence is 1
- May be substantially less than 1
  - May reduce scenario risk significantly

BROADER DEFINITION OF ENABLERS

- Include other factors that can have a significant impact on risk:
  - Management systems
  - Intermediate events
  - Incident outcomes
  - Release conditions
  - Givens

EFFECT OF BROADER ENABLERS

- Decrease *or increase* the scenario frequency
  - E.g. lack of PM on equipment that increases its failure rate
- Some can also alter scenario consequences

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MANAGEMENT SYSTEM ENABLERS

- Failures in the systems set up to manage safety throughout the lifecycle of a process
- Fundamentally, failures by people
- Givens for scenarios, when present

EXAMPLES OF MANAGEMENT SYSTEM ENABLERS

- Inadequate procedures
  - E.g. test and inspection frequencies may be set too low
- Inadequate training of personnel
- Inadequate skills or knowledge of personnel
- Failures in the execution of procedures
  - E.g. PM is not conducted per requirements
- Mis-operation of equipment
  - E.g. stressing a pump by using it outside its operating limits

EFFECT OF MANAGEMENT SYSTEM ENABLERS

- May increase initiating event frequencies or probabilities of failure of protection layers, e.g.
  - Pump is operated outside its limits
  - Initiating event frequency for pump mechanical failure is adjusted upwards to account for mis-operation

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INTERMEDIATE EVENT ENABLERS

- Account for the probabilities of different scenarios that result from the same initiating event
  - E.g. probability of vessel rupture from overpressure depends on various factors
    - Vessel fails in one scenario
    - Vessel does not fail in another scenario
      - Consequences may still be of concern
- Enablers are used to represent the probability of occurrence of the different intermediate events

INCIDENT OUTCOME ENABLERS

- Outcomes of hazard scenarios may vary, e.g.
  - Fire versus explosion
  - Type of fire
  - Type of explosion
- Each scenario outcome should be modeled individually
  - Adjust relative frequencies using probabilities of the different outcomes
  - May also change the consequences

RELEASE CONDITION ENABLERS

- Scenarios may vary according to conditions and circumstances at the time of release
  - Incident outcome cases, e.g. wind direction
- Can adjust the scenario frequency for the probability of the release conditions
  - May also change the consequences

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GIVENS

- Some enablers are actually fixed aspects of a scenario
  - E.g. management system enablers
- Givens are always part of the scenario
  - Other enablers are variable in nature
- For example, for ignition sources for a fire scenario:
  - Boiler house is a given
  - Hot work is an enabler
- Many givens do not adjust the frequency of scenarios
  - Make scenarios possible by their presence

BENEFITS OF ADDRESSING ENABLERS

- Model real-world scenarios better
- Provide more risk reduction credit
  - Classical LOPA is very conservative

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ENABLERS IN A LOPA WORKSHEET

Number	1		
Description	Tank level transmitter fails and overfill tank, TK-104, with fire and employee impacts.		
Process Mode	Tank filling		
Consequence	Description	Type	Level
	Overfill tank, TK-104	EMP	2
Hazardous Event	High level in tank, TK-104.		
Hazard Type	Fire		
Events	Item	Type	Value
	Initiating Event		**Frequency**
	Level transmitter, LT TK-104, fails to detect high level	EQP	1×10^{-1}
	Enablers (regular, at-risk factors, and conditional modifiers)		**Value**
	Lack of PM on level transmitter LT TK-104	REG	5
	Probability of ignition	CM	5×10^{-1}
	Probability of personnel in affected area	CM	5×10^{-1}
	Probability of harm from exposure	CM	1
	Independent Protection Layers		**PFD**
	High level shutoff for TK-104	SIF	1×10^{-1}
	Operator action to stop pump, P-100	HUM	1×10^{-1}
	Safeguards (non-IPL)		
	Plant fire brigade	HUM	

Summary	Item	Value
	Frequency of Mitigated Consequence	1.3×10^{-3}
	Risk Tolerance (Scenario)	1×10^{-6}
	Risk Reduction Required	8×10^{-4}
	Risk Reduction Factor	1.3×10^{3}

ISSUES IN USING ENABLERS

- Availability of needed information from PHA
- Values of probabilities and other multipliers

INFORMATION NEEDED FROM PHA

- PHA practices need to change to support LOPA
- LOPA teams will need to develop needed information
  - Necessarily, scenarios are discussed at a greater level of detail in LOPA than PHA

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VALUES FOR ENABLER MULTIPLIERS

- Values used should reflect actual experience with the process
- Judgment may be needed as data may be sparse
  - Values used should be justified with available process data and/or expert opinion
  - As for other failure data

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GUIDELINES FOR ENABLERS

- Address only enablers that impact scenario risk by more than an order of magnitude
  - E.g. if an alarm is in a disabled state 10% of the time
- Enablers that together produce an order of magnitude risk reduction may be credited
  - Exercise care to avoid non-conservative results owing to possible dependencies

GUIDELINES FOR ENABLERS (CONTD.)

- For enablers representing multiple alternative scenario paths:
  - If one path has a probability of occurrence of 0.5 or above
    - Multiplier may be assumed to be 1 for convenience and conservatism
  - Use such multipliers when the effect on the scenario risk is substantial
    - I.e. when their probabilities are 0.1 or less

GUIDELINES FOR ENABLERS (CONTD.)

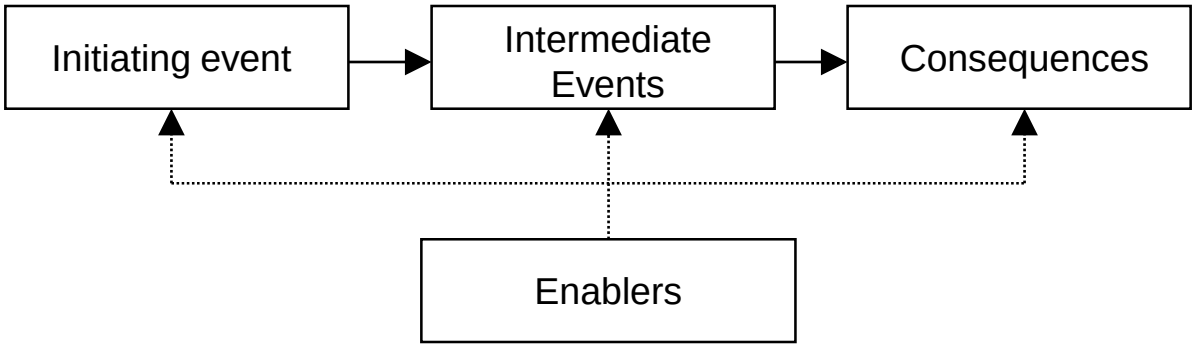
- Multiple enablers together may reduce the risk of a scenario substantially
  - Enablers should not be used arbitrarily to meet risk tolerance criteria. Resist achieving tolerable risk by:
    - Reducing an enabler value
    - Adding an enabler
  - All data used in LOPA must be credibly justified and should favor conservative values

GUIDELINES FOR ENABLERS (CONTD.)

- Do not double count enablers that have already been accounted for through:
  - Scenario consequences
  - Assumptions made in PHA or LOPA
- Consider imposing restrictions on the number and amount of credit from enablers, e.g.
  - No more than 3 enablers can be credited
  - No more risk reduction than a factor of 100 can be claimed

CONCLUSIONS

- Various enablers may be part of hazard scenarios
- They should be modeled appropriately and suitable credit taken for risk reduction



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