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Guidance on Safety and Risk Management of Large Liquefied Natural Gas (LNG) Spills Over Water

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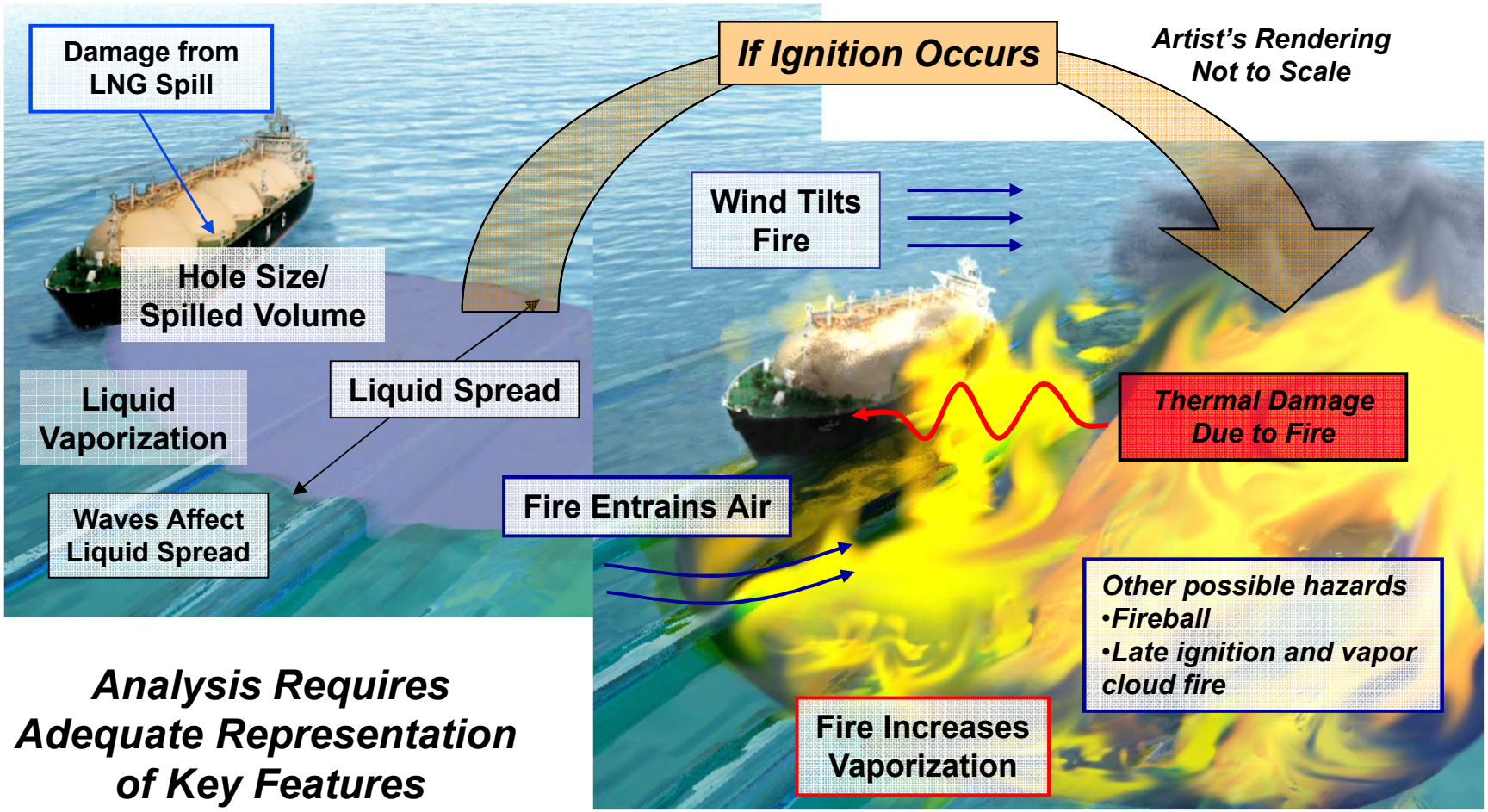
Application of Guidance Information and Results

- The information and results presented are intended to be used as guidance for conducting site-specific hazard and risk analyses
- The results are not intended to be used prescriptively, but rather as a guide for using performance-based approaches to analyze and responsibly manage risks to the public and property from potential LNG spills over water

Key Features of LNG Spills Over Water



Analysis Requires Adequate Representation of Key Features

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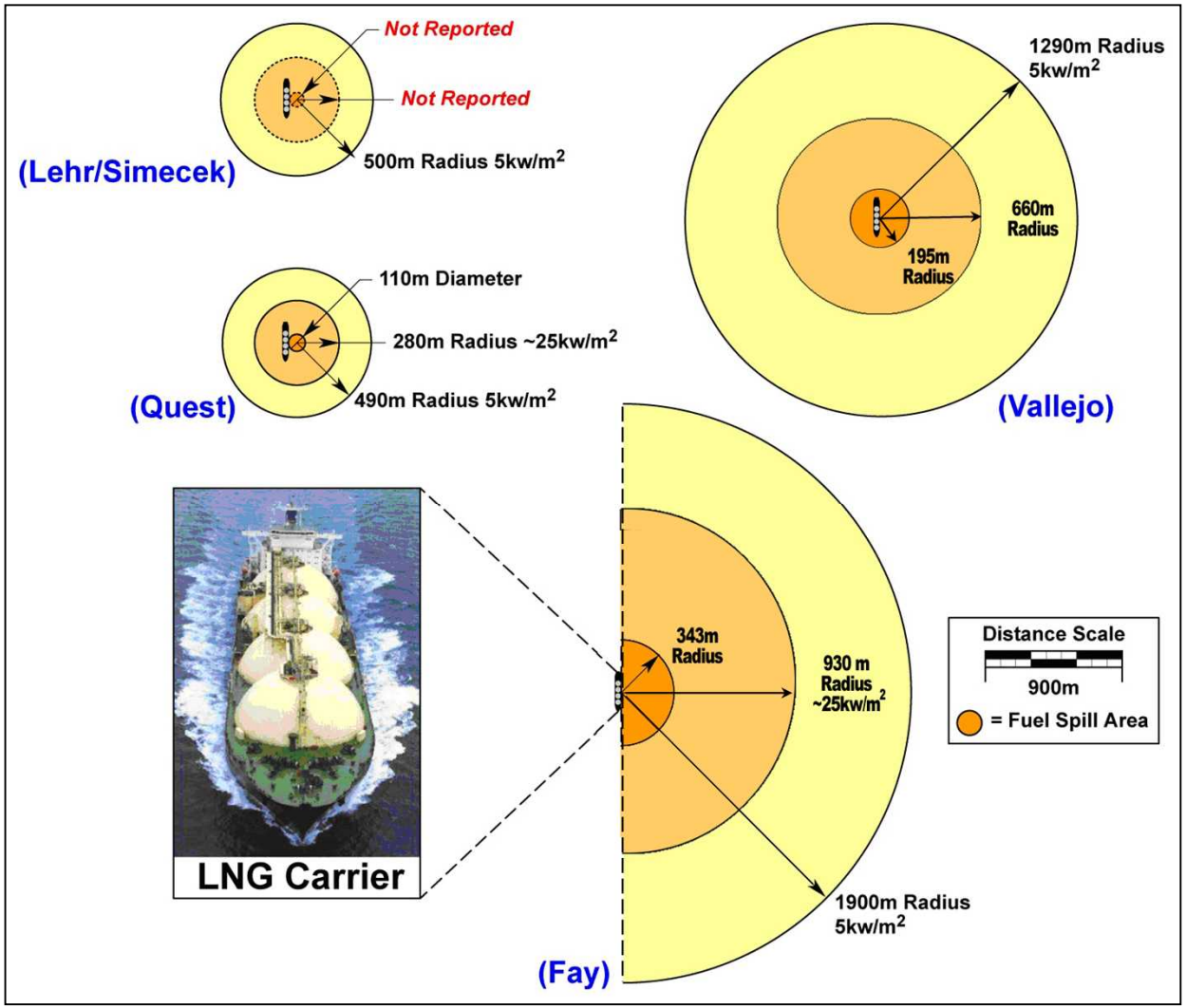
Extent of Thermal Hazards Predicted in Four Recent LNG Carrier Spill Studies



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LNG Spill Safety Analysis and Risk Management Guidance

- Provide direction on hazards analysis
- Identify “scale” of hazards from intentional events
- Provide direction on use of risk management to improve public safety
- Provide process for site-specific evaluations

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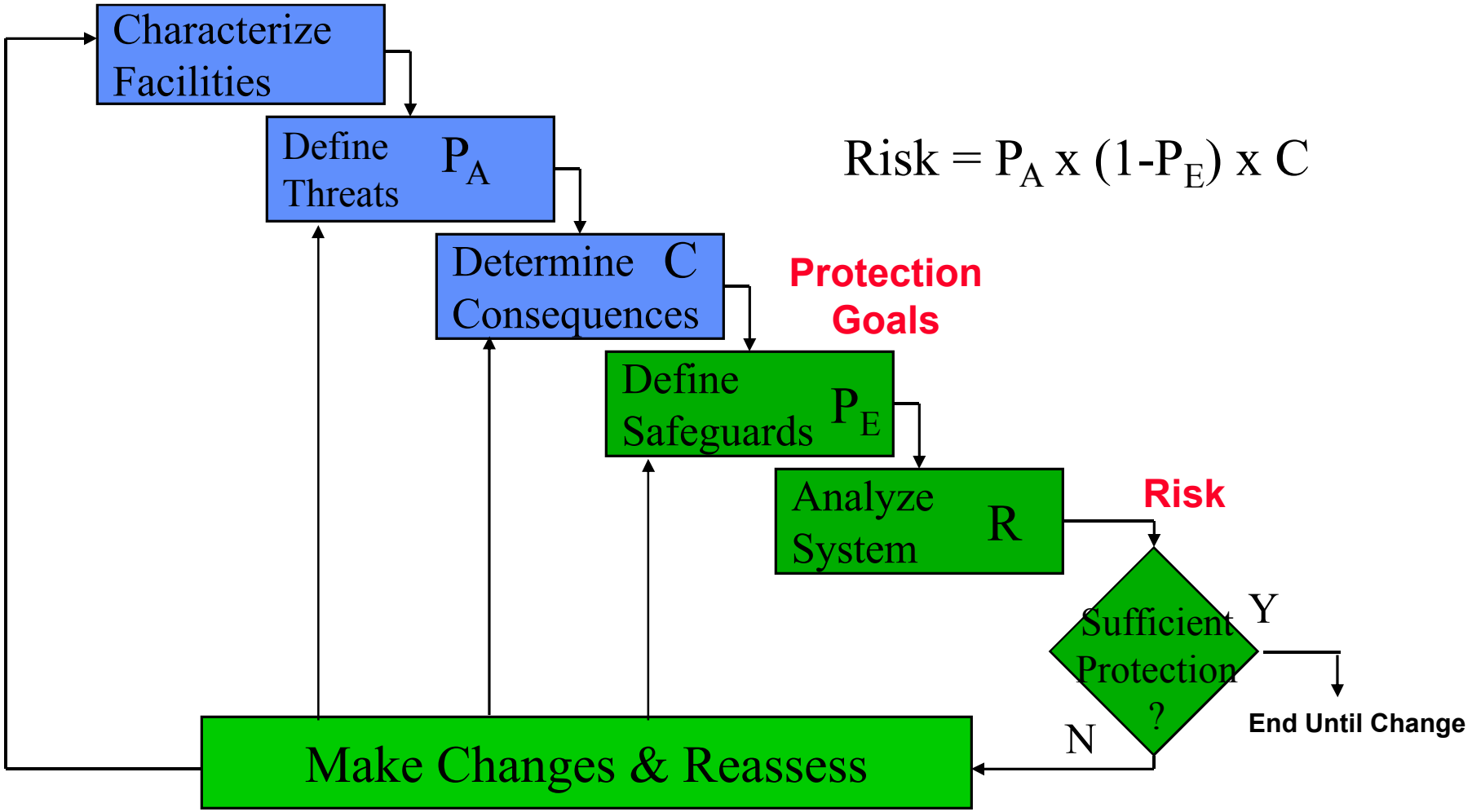
Performance-based Risk Assessment Approach for LNG Spills



$$Risk = P_A \times (1-P_E) \times C$$

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Potential Thermal Hazards for Spills from Common LNG Vessels

HOLE SIZE (m^2)	TANKS BREACHED	DISCHARGE COEFFICIENT	BURN RATE (m/s)	SURFACE EMISSIVE POWER (kW/m^2)	POOL DIAMETER (m)	BURN TIME (min)	DISTANCE TO 37.5 kW/m^2 (m)	DISTANCE TO 5 kW/m^2 (m
ACCIDENTAL EVENTS								
1	1	.6	$3X10^{-4}$	220	148	40	177	554
2	1	.6	$3X10^{-4}$	220	209	20	250	784
INTENTIONAL EVENTS								
5	3	.6	3×10^{-4}	220	572	8.1	630	2118
5*	1	.6	3×10^{-4}	220	330	8.1	391	1305
5	1	.9	3×10^{-4}	220	405	5.4	478	1579
5	1	.6	8×10^{-4}	220	202	8.1	253	810
12	1	.6	3×10^{-4}	220	512	3.4	602	1920

*Nominal case: Expected outcomes of a potential breach and thermal hazards based on credible threats, best available experimental data, and nominal environmental conditions for a common LNG vessel

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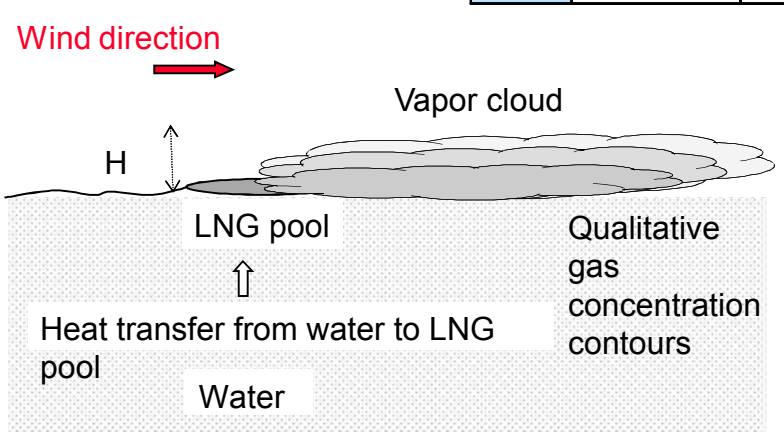
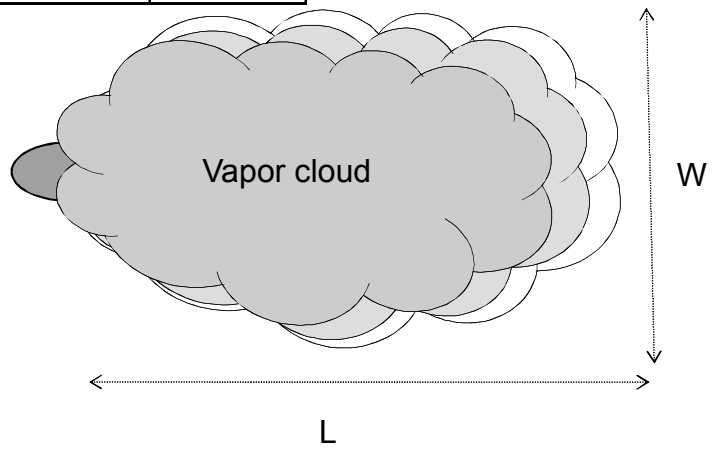
Potential Dispersion Hazards for Spills from Common LNG Vessels

HOLE SIZE (m^2)	TANKS BREACHED	POOL DIAMETER (m)	SPILL DURATION (min)	DISTANCE TO LFL (m)
Accidental Events				
1	1	181	40	1536
2	1	256	20	1710
Intentional Events				
5	1	405	8.1	2450
5	3	701	8.1	3614





Side View **Top View**

Dispersion distances are limited by closest ignition source

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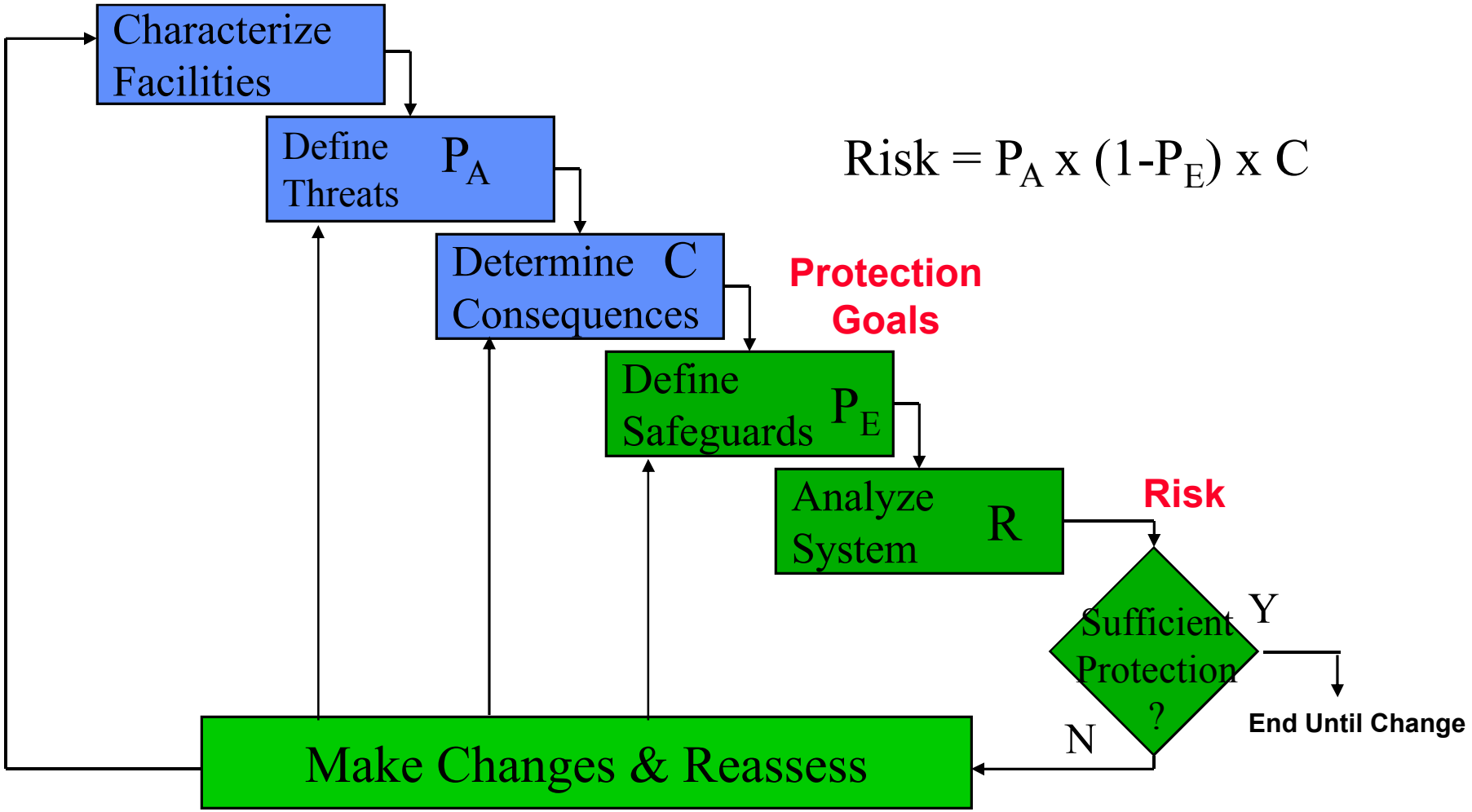
Performance-based Risk Assessment Approach for LNG Spills



$$Risk = P_A \times (1-P_E) \times C$$

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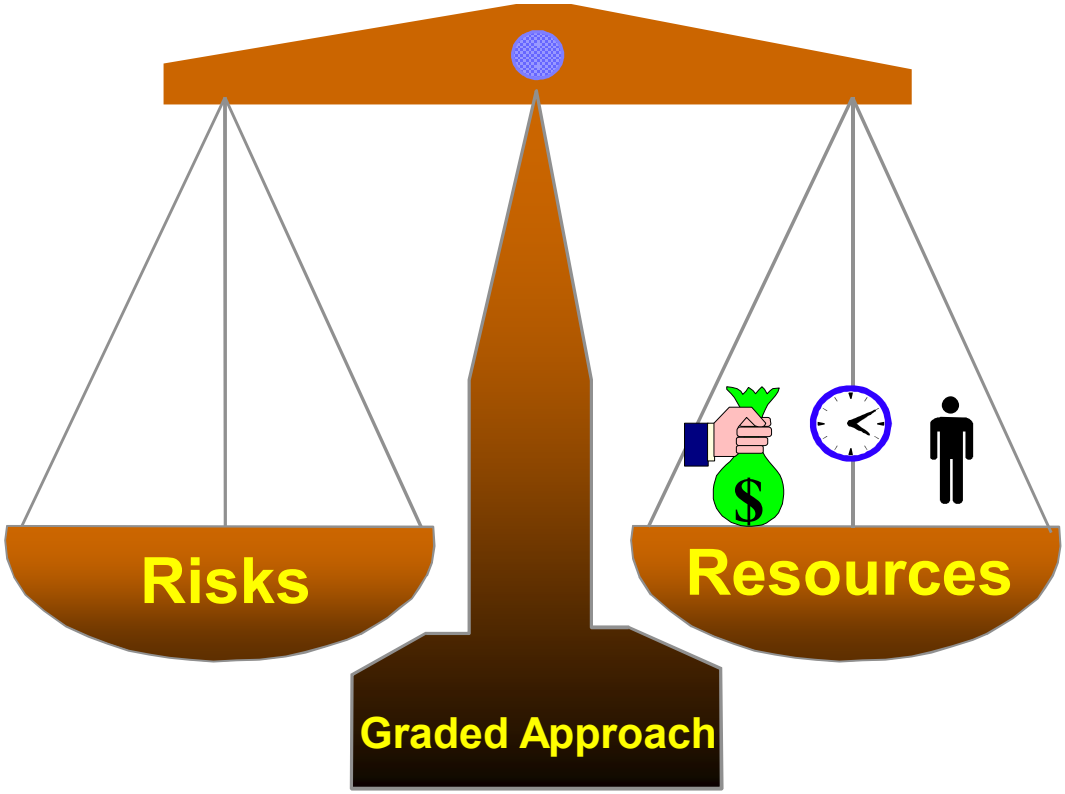
Modern Risk Management Approach



A Performance-based Process Supported by Tools

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LNG Spill Risk Management Elements

Risks can often be managed through a combination of approaches:

- **Improved risk prevention measures to reduce the likelihood of possible scenarios**
  - **Earlier ship interdiction, boardings, and searches; positive vessel control during transit; port traffic control measures; safety and security zones and surveillance; or operational changes**
- **Locating LNG terminals where risks to public safety, other infrastructures, and energy security are minimized**
- **Improved LNG transportation safety and security systems**
- **Improved hazard analysis modeling and validation**
- **Improved emergency response, evacuation, and event mitigation strategies**

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Summary of Risk Management Guidance

- Use of effective security and protection operations can be used to reduce the hazards and risks from a possible breaching event
- Risk management strategies should be based on site-specific conditions, protection goals, and the expected impact of a spill
  - Less intensive strategies can often be sufficient in areas where the impacts of a spill are low
- Where impacts to public safety and property could be high and where a spill could interact with terrain or structures – use of modern, validated Computational Fluid Dynamics models can improve hazard analyses

Risk Management Process to Help Sites Evaluate Potential LNG Spills

Chapter 6 of Sandia report provides guidance on a process for assessing and responsibly managing risks of a LNG spill:

- **Site-specific conditions to consider**
  - **location, environmental conditions, proximity to infrastructures or residential or commercial areas, ship size, and available resources**
- **Site-specific threats to evaluate**
- **Cooperating with stakeholders, public safety, and public officials to identify site-specific "protection goals"**
- **Appropriate modeling and analysis approaches for a given site, conditions, and operations**
- **System safeguards and protective measures to consider**
- **Identification of approaches to manage risks, through prevention and mitigation, enhancing energy reliability and the safety of people and property**

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