Develop a Risk-Based Approach and Criteria for Hazard Detection Layouts at LNG Facilities

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Public Presentation

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  - Distrigas of Massachusetts, a division of Exelon Generation
  - Southern Company Gas
- **Technical Advisory Panel (TAP)**
  - Chau Tran – DOT-PHMSA (Technical Task Inspector)
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  - Dave Opheim – MSA
  - Simon Pate – Det-Tronics

Project Background

- NFPA 59A requires LNG facilities to have the equipment necessary for the detection and control fires, leaks, and spills of hazardous materials, yet provides no guidance or requirements for the locations of hazard detection devices.
- Publicly available literature gives factors to consider in placing detectors, but uses generic and non-quantifiable terminology such as "quick and reliable".
- No consistent approach to developing hazard detection layouts and there is no systematic method for regulators to evaluate these designs.
- For PHMSA siting studies, applicants may use a 10-minute spill duration if the process design includes acceptable detection, isolation and shutdown
- Applicants are also permitted to evaluate a release duration shorter than 10 minutes based on demonstrable surveillance, shutdown isolation design1
- Research Project #852 established to develop a performance-based methodology to evaluate hazard detection layouts.

[1] https://www.phmsa.dot.gov/pipeline/liquified-natural-gas/lng-plant-requirements-frequently-asked-questions#ds8

Performance-Based Design Approach

- NFPA 59A requires hazard detection systems to be installed in accordance with NFPA 72

- In the absence of prescriptive methods for locating flame and gas detectors, a performance-based design approach is required
  - Document performance objectives
  - Identify applicable scenarios
  - Provide technical justification

- ISA TR 84.00.07 Guidance on the Evaluation of Fire, Combustible Gas, and Toxic Gas System Effectiveness
  - Outlines a performance-based design process
  - Methods to quantify detector coverage
  - Sample performance targets

- **While risk tolerance, harm criteria, and performance targets had to be specified in order to run the demonstratives included in the report, these values should not be interpreted as requirements of PHMSA nor as acceptable to them.**

Project Tasks

- **Task 1:** Project Initiation
- **Task 2:** Literature Review
- **Task 3:** Establish Performance Targets
- **Task 4:** Identify Hazard Scenarios
- **Task 5:** Consequence Modeling
- **Task 6:** Case Study 1 – Large Scale LNG Facility
- **Task 6b:** Case Study 2 – Small Scale LNG Facility
- **Task 7:** Final Report
- **Task 8:** Project Management
- Total Project funding for all tasks = $388,180 ($310,544 by PHMSA)

Task 1: Project Initiation

- Regulators (in addition to PHMSA)
  - Federal Energy Regulatory Commission
- Industry Committees
  - NFPA 59A Technical Committee (3 members)
  - ISA 84 Working Group on Fire and Gas
- Detector Manufacturers
  - MSA
  - Det-Tronics
- Owner/Operators from across the industry
  - Distrigas of Massachusetts, division of Exelon Generation
  - Southern Company Gas
  - Baltimore Gas & Electric, an Exelon Company
  - Tellurian Inc.
  - Penn LNG
  - Dominion Energy
  - National Grid

Task 2: Literature Review

- US Standards
  - NFPA 15 Standard for Water Spray Fixed Systems for Fire Protection
  - NFPA 59A Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)
  - NFPA 72 National Fire Alarm and Signaling Code

- European Standards
  - BS 1473 Installation and equipment for liquefied natural gas – Design of onshore installations
  - BS 50073 Guide for selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen
  - BS 60050 Explosive and toxic atmospheres: Hazard detection mapping – Guidance on the placement of permanently installed flame and gas detection devices using software tools and other techniques
  - NORSOK Standard S-001 Technical Safety

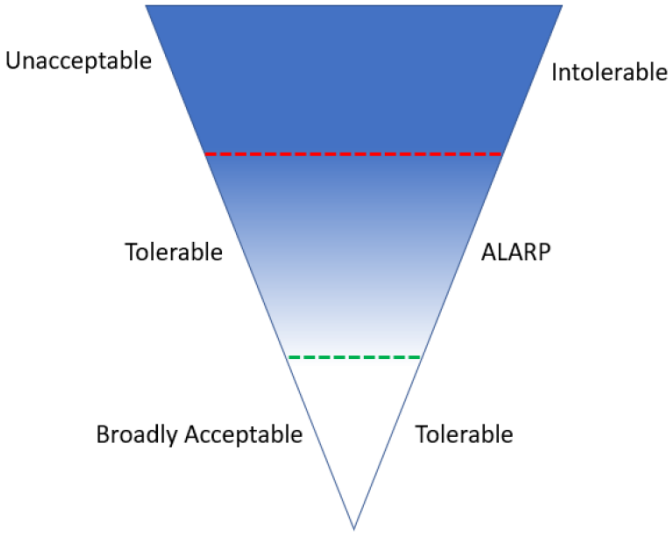
- Various Guidance Documents
  - International Society of Automation (ISA)
  - Health & Safety Executive (HSE)
  - Center for Chemical Process Safety (CCPS of the AIChE)

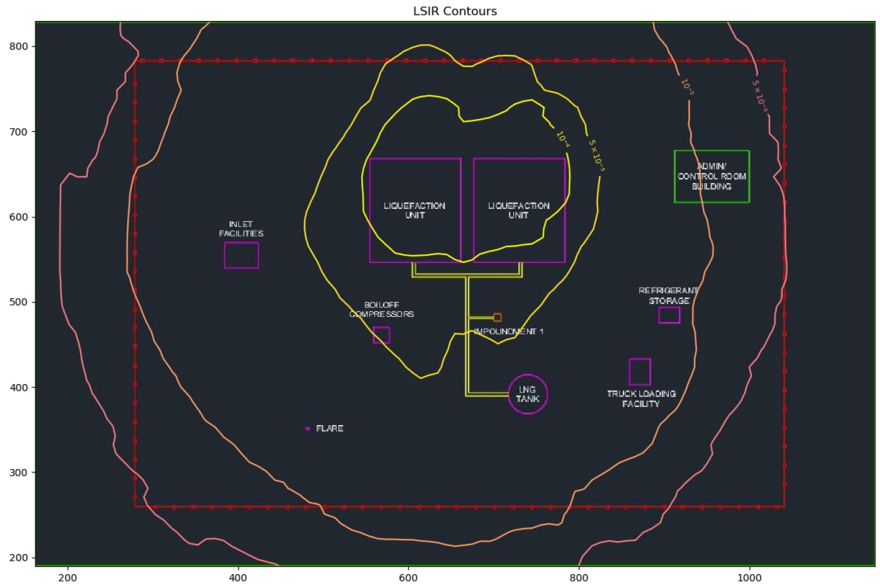
Task 3: Performance Targets

- Detector Coverage Approaches
  - Geographic Coverage
  - Scenario Coverage

- Successful detection is based on two leading parameters
  - Detector coverage criteria (%)
  - Detector voting criteria (1oo**N**, 2oo**N**)

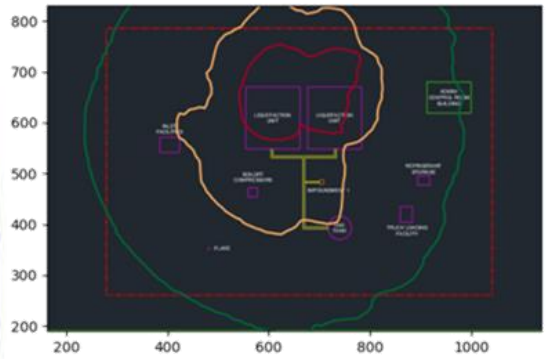
Risk Classification	Minimum Detector Coverage
High	90%
Normal	80%
Low	60%



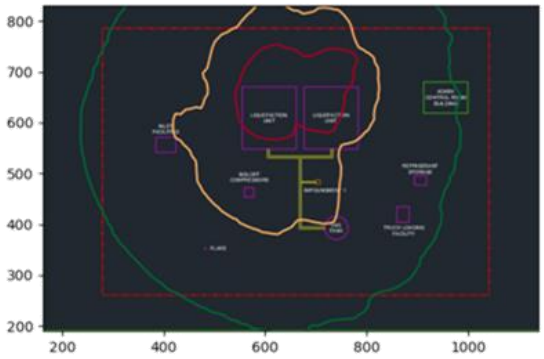


Task 4: Identify Scenarios

- A risk-based approach requires developing an appropriate list of potential hazard scenarios that should be used to assess detector coverage
  - Specify risk criteria
  - Define isolatable inventories
  - Determine failure rates
  - Set criteria for ignition probability
  - Calculate the consequences associated with a full range of release categories
  - Calculate and plot LSIR contours
  - Perform hole size sensitivity to determine which release categories are driving the facility risk profile



Baseline



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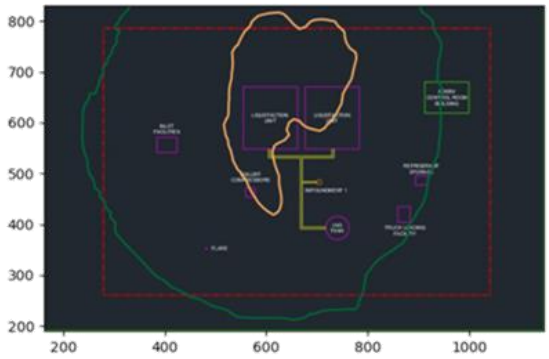
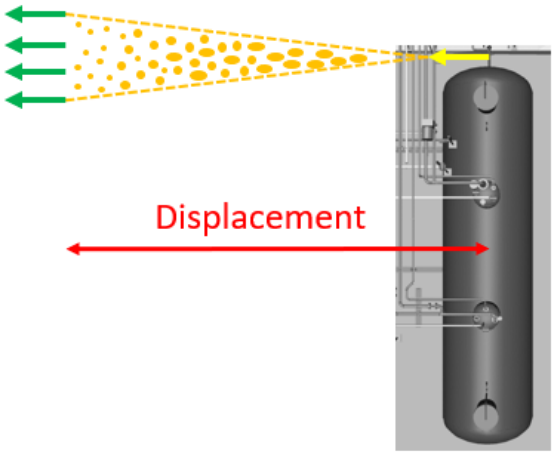
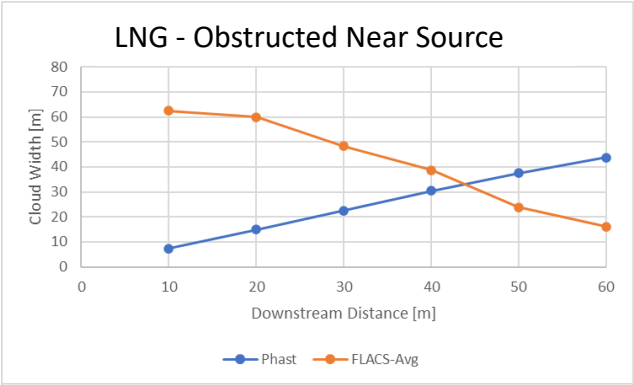


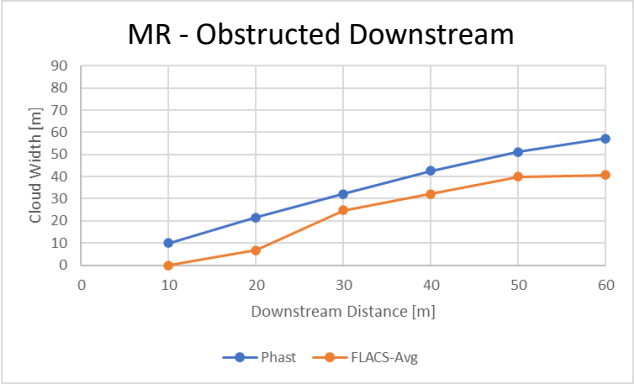
6” and larger

Task 5: Consequence Modeling

- Evaluating a flame detector layout by geographic-based coverage does not require hazard modeling
- Compare results of vapor dispersion models and evaluate the impact on scenario-based coverage of a gas detector layout
  - Use models currently approved by PHMSA (Phast and FLACS)
  - Not a model validation effort

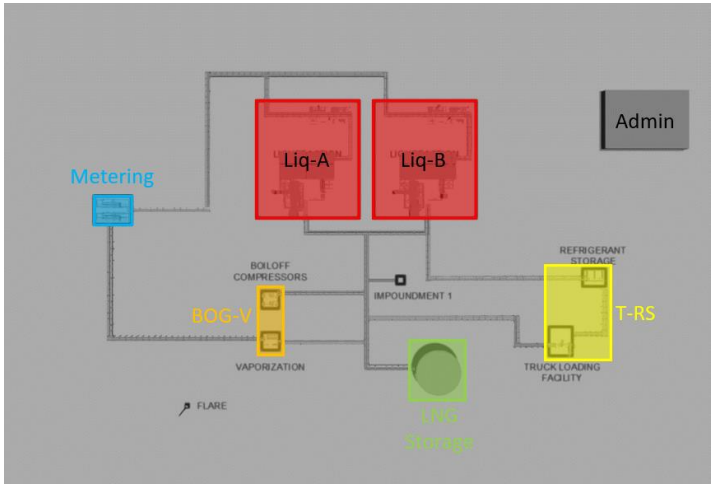


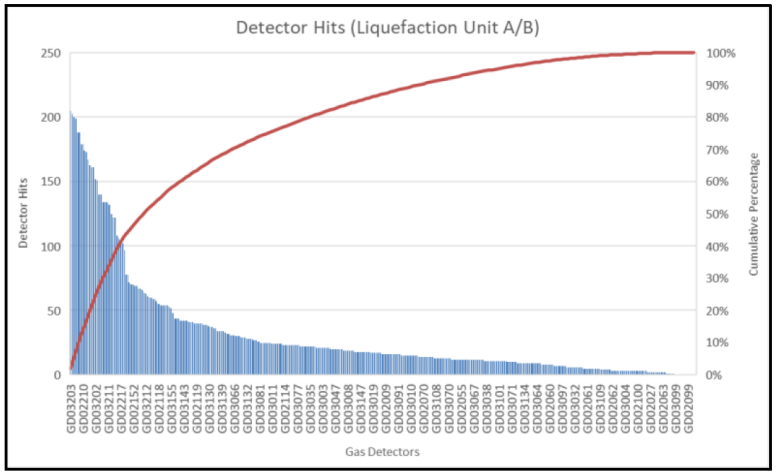




Task 6: Case Study 1 (Gas)

- Assigned detector coverage targets to each Detection Area based on LSIR contours
- Started with a 10-meter grid for the gas detector layout in each Detection Area and removed detectors until performance targets were met
- This case study demonstrates:
  - A detector layout based on uniform grid spacing is inefficient
  - A uniform detector coverage target for an entire Detection Area does not focus resources on higher risk scenarios
  - The significant increase in point gas detectors required to achieve 90% scenario-based detection compared to 80% within the liquefaction unit

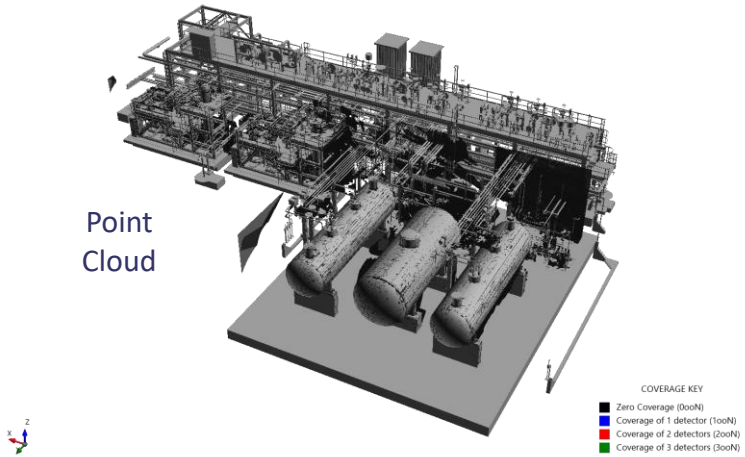


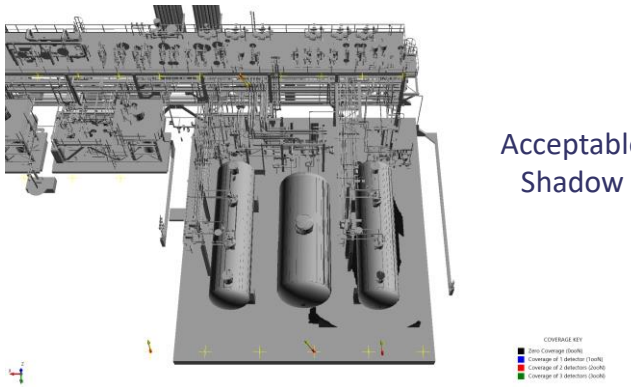


Task 6: Case Study 1 (Flame)

- Flame detector mapping using the Acceptable Shadow Approach
  - Define the size of an 'acceptable shadow' which represents a fire size that will not cause escalation, so that performance targets are not overly burdensome
  - Example mapping performed with Detect3D by InsightNumerics

Point Cloud





Acceptable Shadow

Flame Detector Coverage Criteria

Risk Classification	Scenario Description	Minimum Detector Coverage
High	Equipment coverage where cascading damage hazard due to fire is identified	90% by 2ooN
Normal	Detection Areas with flammable fluid service	80% by 1ooN
Low	Detection Areas with combustible fluid service	60% by 1ooN

Task 6b: Case Study 2

- Since flame detection using geographic coverage is only based on geometry, Case Study 2 focused on gas detection only
- Assigned detector coverage targets to each flammable fluid in each Detection Area using more simplified risk ranking
- This case study demonstrates:
  - Flexibility of the proposed methodology
  - Impact of selecting release locations and orientations
  - A reduced detector count when compared to uniform grid spacing
  - A reduced detector count when compared to uniform detection targets

Gas Detector Coverage Criteria

Risk Classification	Scenario Description	Minimum Detector Coverage
High	Releases where duration less than 10 minutes is assumed based on detection	90% by 2ooN
Normal	All remaining scenarios	80% by 2ooN
Low	Releases in open areas with well-controlled ignition sources and all low reactivity gas releases	60% by 2ooN

Tasks 7 & 8

- **Task 7: Final Report**
  - Draft to TAP on June 18th
  - Draft to PHMSA on July 30th
  - Final to PHMSA on August 4th

- **Task 8: Project Management**
  - Quarterly progress reports
  - Annual Peer Review
  - Present at an LNG Conference
  - Virtually Held Dissemination Meeting
  - Project was completed on time and on budget

Project Summary

- Flame detector coverage is best evaluated using geographic coverage and does not require hazard modeling.
  - Coverage can be optimized using 3D ray tracing and the Acceptable Shadow Approach
  - A 2D evaluation is sufficient in many cases, however, coverage becomes difficult to quantify

- Gas detector coverage is best evaluated using scenario coverage and placing detectors where flammable clouds are most likely to develop rather than near potential leak sources.
  - Gas detector performance targets need to be inventory specific
  - Potential release points and directions must be carefully considered

- Both integral models and CFD models have benefits and limitations with respect to dispersion modeling for gas detection.
  - A detector study can employ both integral and CFD models, however, individual scenarios cannot be intermingled between the two models.
  - Model selection may depend on the total number of scenarios included

- Successful detection must be coupled with the appropriate action and consider the time to the end of the release, not just the time to detection.

Performance-Based Methodology

Step 1: Fire and Gas Detection Philosophy

- Set detector coverage targets (e.g., 60-80-90%)
- Set detector voting criteria (e.g., 1ooN, 2ooN)

Step 2: Designate Detection Areas

- Group areas of the facility that contain similar hazards
- Carry out Detection Area Evaluations to characterize the hazards

Step 3: Identify Hazard Scenarios

- Perform a fire and explosion risk assessment using a full range of release categories
- Perform a hole size sensitivity to determine which scenarios to include in the detector evaluation

Step 4: Assign Performance Targets

- Establish detector coverage and voting criteria for each flammable inventory in each Detection Area

Step 5: Flame Detector Evaluation

- Assess the flame detector layout using the geographic coverage approach

Step 6: Gas Detector Evaluation

- Assess the gas detector layout using the scenario coverage approach

Project Impact

- Regulators (PHSMA, FERC, local AHJs)
  - A systematic approach and sample performance targets for evaluating hazard detector layouts at LNG facilities
  - Examples showing the impact of using different performance targets/models
  - Parameters to consider when setting submission requirements

- NFPA 59A Technical Committee
  - Consider adopting/modifying the performance-based methodology, along with other important hazard detection concepts, to update code requirements and/or provide annex information related to fire and gas detection systems.

- ISA 84 Working Group 7 – Fire and Gas
  - Consider providing additional guidance for scenario selection
  - Revise terminology such as "detectors located in proximity to leak sources"
  - Differentiate application of 5-10 meter spherical clouds between offshore and onshore installations

- Operators/Consultants/Designers
  - A way to quantify hazard detector performance and optimize designs
  - Clear objectives to satisfy regulatory requirements (if adopted by AHJ)

More Information

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Project Page (Final Report and Presentation)
https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=852

Published Article
Too many or not enough? A methodology for evaluating fire and gas detector layouts at LNG facilities. *Proc Safety Prog*. 2021;e12281. https://doi.org/10.1002/prs.12281