



DOE/Sandia National Laboratories Coordinated Approach for LNG Safety and Security Research

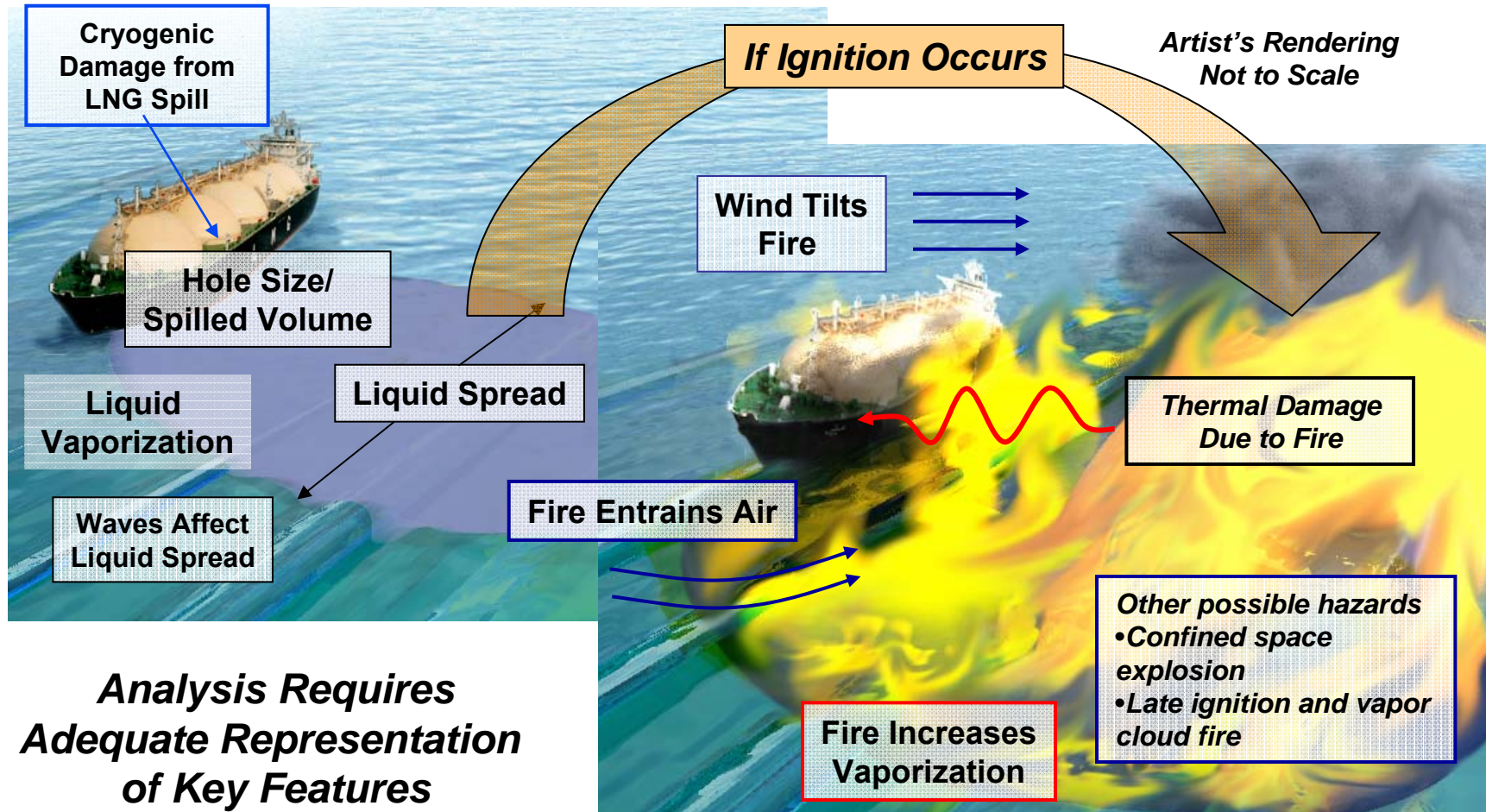
Committee on Gas, NARUC Summer Committee Meetings, Portland, OR
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Key Features of LNG Spills Over Water



Sandia LNG Activities



- **December 2004, DOE "Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill over Water", SAND2004-6258**
- **Classified Vulnerability Analysis & Breach Research(2004-2007)**
- **USCG, Deepwater Ports**
 - **Cabrillo (California), January 2006, US Coast Guard "Review of the Independent Risk Assessment of the Proposed Cabrillo Liquefied Natural Gas Deepwater Port Project", SAND2005-7739**
 - **New England, (Massachusetts) April 2006, US Coast Guard "Independent Risk Assessment for Neptune and Northeast Gateway Deepwater Ports", report by Acutech Consulting Group for USCG**
 - **Calypso Deepwater Port (Florida)**
 - **Others in progress**
- **Large Scale Spill and Fire Research – 2006-present**
- **Cascading Failure Research - 2008**





LNG Spill Safety Analysis and Risk Management Guidance SAND2004-6258



- **Significant increase in LNG tanker deliveries to U.S. ports and increased public safety concerns from accidental or intentional spills**
- **Provide direction on hazards analysis for current class of LNG ships**
- **Identify “scale” of hazards from intentional events**
- **Provide direction on use of risk management to improve public safety**
- **Provide process for site-specific evaluations**
- **Soon to be released report on analyses conducted for larger class of LNG ships**



Study used many resources: experts from academia, government and industry on LNG vessel design and operations, explosion and fire modeling, terrorism, and risk management



A Coordinated Plan for LNG Safety and Security Research



1. LNG Fire Physics – **In progress**
 - Objective: Determine thermal hazard distances for large-scale LNG pool fires
 - Testing to commence Fall, 2008
 - Viewing of tests to be coordinated through DOE
2. Cascading Failure - **In progress**
 - Objective: Determine if cryogenic or fire-induced damage to the ship leads to cascading (multi-tank) structural failures and catastrophic release of LNG
 - Develop time scale for cargo release
 - Testing to commence Fall, 2008
3. Mitigation – Start after task 1 and 2
 - Objective: Develop mitigation options to reduce the risk to ships at land-based and deep water ports.



DOE/SNL Large Scale LNG Spill Fire Experiments Purpose and Approach



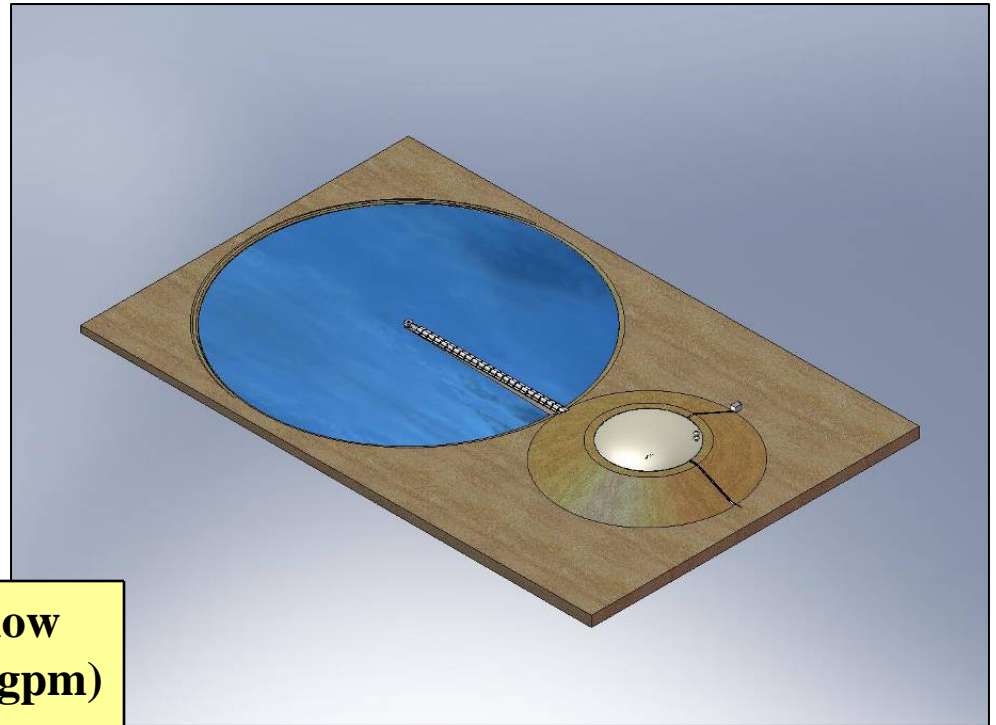
- Existing experimental data is much smaller in size and scale than postulated large accidental and intentional spills
- Large scale experimental data is needed to develop and validate fire models to address current spill and hazard assessment deficiencies
- DOE and SNL will perform LNG spill fire experiments (on water) at intermediate to large scale (~40 m up to 100 m diameters)



Large LNG Pool Fire Experiment Description



- Concrete-lined soil-bermed reservoir
- LNG gravity released onto a 120-m diameter water pool
- Reservoir, pool, and perimeter instrumentation to measure burn rate, flame height, and heat flux (smoke shielding)



Fire Diameter (m)	LNG volume (gallons)	LNG flow rate (gpm)
40	51,000	10,000
70	154,000	31,000
100	310,000	62,000



DOE/SNL Large Scale LNG Spill Fire Experiments



Anticipated Benefit, Historical Analogue

UNCERTAINTY IN UNVALIDATED MODELS NECESSITATES EXPERIMENTS

Dispersion Model Comparison for 25,000 m³ LNG spill on water from 1980 Report* (BEFORE Burro experiments, 1982)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Length of flammable cloud	28 km	18 km	26 km	40 km	1.2 km	8.3 km

Distance is around 3 km based upon validated computational fluid dynamics (CFD) simulations

Burro (LLNL), LNG dispersion experiment



*Safety Aspects of Liquefied Natural Gas in the Marine Environment, National Materials Advisory Board



DOE/SNL Large Scale LNG Spill Fire Experiments Anticipated Benefit



- LLNL Dispersion Experiments greatly enhanced understanding of LNG dispersion and allowed data for validation
- SNL Pool Fire Experiments are anticipated to be the analogue to the LLNL Dispersion Experiments
- Will facilitate progress in siting LNG terminals by allowing federal and state agencies to make informed decisions



Cascading Failure Due to Cryogenic Damage



Experimental verification of cryogenically-induced failures in naval ship materials and components.

- Representative key architectural features
- Development & validation of cryogenic failure models
 - Toughness-temperature transition curves
 - Linear elastic failure models



30-40 m³ LNG spill on deck results in brittle fracture

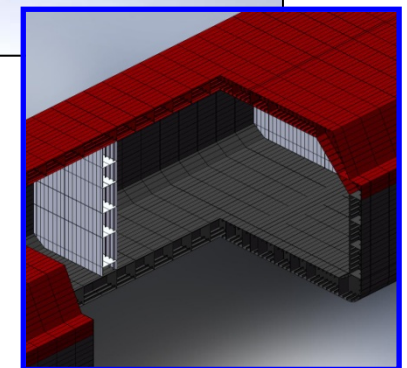
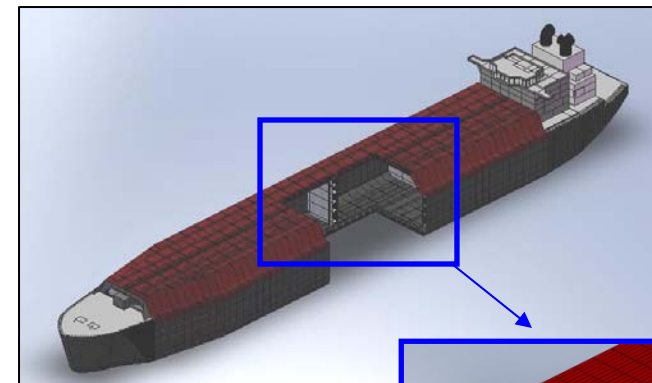
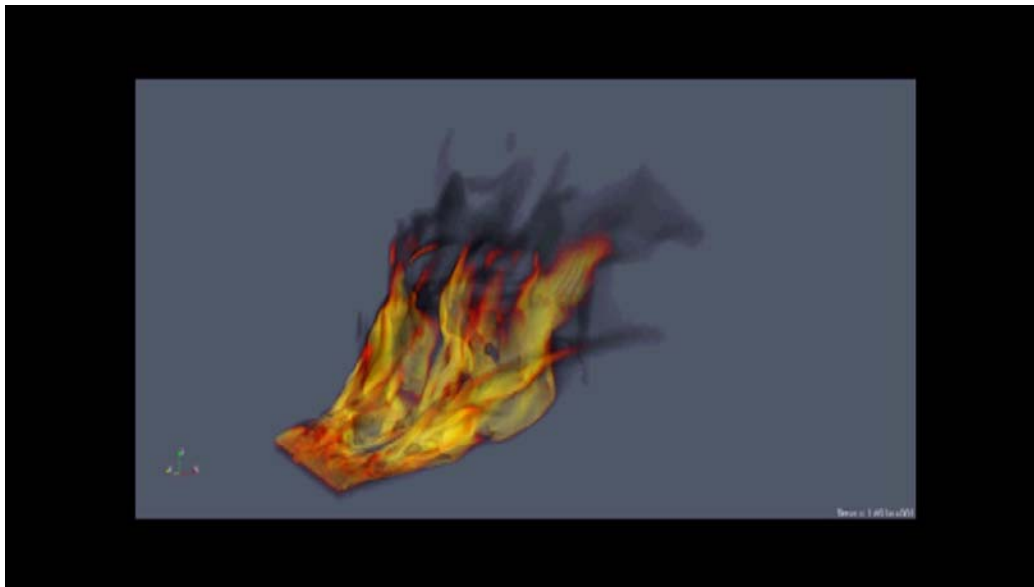
Source: A. Valudolon (2000)



Cascading Failure Due to Fire



- Large spill → large fire → thermally-induced structural failure?
- Validated large-scale pool fire simulations to determine heat flux profiles
- Failure criteria for relevant materials (steels, foam insulation, etc.)
- Coupled thermal and structural response models to predict ship response.



Fuego simulation for design of a weapons test



GAO-07-316 Maritime Security - Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification

February 2007

Conclusions

“...Understanding and resolving the uncertainties surrounding LNG spills is critical, especially in deciding on where to locate LNG facilities....

...Additional research to resolve some key areas of uncertainty could benefit federal agencies responsible for making informed decisions when approving LNG terminals and protecting existing terminals and tankers, as well as providing reliable information to citizens concerned about public safety.”



**Thank You
Questions?**