

LNG STORAGE AND TRANSIT IN BOSTON

BY

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THIS REPORT WILL ADDRESS THE FOLLOWING QUESTIONS:

- **HOW BIG WILL THE INITIAL FIRE BE?**
- **WILL INITIAL FIRE CAUSE FURTHER DAMAGE?**
- **HOW LONG WILL THE FIRE LAST?**
- **WHAT ARE DANGEROUS LEVELS OF RADIANT HEAT (HEAT FLUX)?**
- **CAN THE INFORMATION IN ITEMS 1-4 BFD BE USED TO DEVELOP RESPONSE GUIDELINES?**
- **ARE THERE OTHER AREAS IN NEED OF CLARIFICATION?**
- **WHY WAS THERE UNCERTAINTY REGARDING THESE ISSUES? - WHO HAS JURISDICTION?**
- **CAN THE APPLICABLE REGULATIONS BE IMPROVED?**

GOVERNMENT/INDUSTRY ESTIMATES OF THE INITIAL FIRE

- **THE LLOYD’S REPORT**

- *“The Lloyd’s Report, commissioned by Tractabel LNG North America LLC, the company that runs the Everett LNG terminal, instead concluded that, at worst, an attack on a tanker would “create a slow moving relatively confined fire.””* - Boston Globe 10/13/01.
- This Report is important because, *“The Lloyd’s Report was used by the Coast Guard in approving a safety plan for the Everett site.”* - Providence Journal, 01/04/04.

- **THE QUEST REPORT**

- *“J. Robinson, of FERC, said Quest would continue to use the Quest Report, That study with a relatively mild assessment of the dangers posed by federal officials to suggest that an accident involving one of the tankers would only impact a small area.”* - Mobile Register, 11/25/03.

EST. OF HEAT - 1M² HOLE

	7,000 BTU per hr-ft ²	4,800 BTU per hr-ft ²	4,000 BTU per hr-ft ²	1,500 BTU per hr-ft ²
FAY 1m ² Hole	1,280 ft.	Approx. 1,750 ft.	1,598 ft.	2,417 ft.
QUEST 1m ² Hole	835 ft.	Approx. 900 ft.	1020 ft.	1,420 ft.
LLOYD'S 1m ² Hole (20m pool)		175 ft.		
LLOYD'S 1m ² Hole (50m pool)		300 ft.		

***Note: Fay estimates are approximately 50% higher than Quest's.
Fay's estimates are 3 or more times greater than Lloyd's.***

A 1m² hole fire should last approximately 30 minutes.

EST. OF HEAT FLUX - 5M² HOLE

	10,000 BTU per Hr-ft ²	7,000 BTU per hr-ft ²	6,000 BTU per hr-ft ²	4,000 BTU per hr-ft ²	1,500 BTU per hr-ft ²
KOOPMAN 5m² Hole	1,850 ft.		2,600 ft.		4,200 ft.
FAY 10m² Hole	1,834 ft.	2,045 ft.		2,477 ft.	3,622 ft.
QUEST 5m² Hole* (Inner Harbor)		>1,020 ft.		>1,260 ft.	>1,770 ft.
QUEST 5m² Hole (Outer Harbor)		1,020 ft		1,260 ft.	1,770 ft.

** Quest' distances for the inner harbor would most likely be larger than numbers for the outer harbor. (later slide will explain.)*

Note: Fay & Koopman's estimates are approximately double Quest's "outer harbor" estimates.

A 5-10m² hole fire should last approximately 5 minutes.

WHY ARE ESTIMATES SO DIFFERENT?

- **Originally Quest stated**
 - ***“The calculations (of the 10/10 Report) would address a national security concern with the Boston LNG Terminal following the 9/11/03 attacks.”*** – Mobile Register 10/19/03.
- **Later, in 11/03, Quest stated in a letter to DOE.**
 - That Quest modeled a ship collision in the outer harbor as the. ***“most credible worst case event”***.
 - This assumption allowed Quest to take into account “wave action”, which caused pool size to be smaller. Quest also wrote, ***“It is important to note that the model developed by Quest is flexible in the sense that other locations with different site-specific conditions may yield significantly different results””***.
- **However, in a 07/02 e-mail D. Juckett of the DOE wrote,**
 - ***“To put together the original scenario DOE coordinated: State Officials, DOT, USCG, industry , and others. - Did this group agree to “outer harbor accident” scenario? BFD was not included in discussions.”***

WILL FURTHER FAILURE OCCUR?

- **“There is a possibility of escalating failure of the ship structure due to embrittlement, followed by an internal explosion caused by either a rapid phase transition, or by a gas air mixture being ignited.”**
 - *(From page 90 Overall Conclusions - Lloyd’s Report).*
- **“Fires on the ship or adjacent to the ship may lead to high temperatures on the hull, the tank walls, insulation, and tank support structures which further can lead to failure of the cargo containment system and release of cargo.”**
 - *(T. K. Authen, in a paper titled, Gas Carriers – Effects of Fire on the Cargo Containment System. - Gastech Conference proceedings)*
- **“A pool fire caused by LNG release from one tank may threaten the integrity of adjacent tanks.”**
 - *(Solberg et al in a paper titled, Assessment of Consequences from Accidental release of Liquefied Gases - Gastech Conference proceedings)*

EFFECT OF HEAT ON STEEL

- **“The heat flux exposure for all locations on the deck will be approximately 100Kw/m²“. This is equivalent to 32, 700 BTU/hr/ft². (Solberg et al in a paper titled, Assessment of Consequences from Accidental release of Liquefied Gases - Gastech Conference Proceedings)**
- **“A heat flux of 7,000 Btu/hr/ft² will weaken structural steel after prolonged exposure”. (Statement made by Quest in the 11/17/03 letter to the DOE)**
- **Perhaps that is why - “Most predictions suggest that even the largest LNG tankers (typically more than 900 feet in length) might be completely enveloped in a pool fire following a complete spill of a single 6.5 million gallon tank. This raises questions about the vulnerability of the ship and the potential for additional releases.” (Haven, “Terrorism: Ready to Blow.”)**

**DESPITE THIS EVIDENCE, QUEST DID NOT
CONSIDER CASCADING FAILURE OF TANKS.**

WHAT ARE DANGEROUS LEVELS OF RADIANT HEAT?

- **NATIONAL FIRE PROTECTION ASSOCIATION'S GUIDELINES - (59A, LNG STANDARD, 2006 EDITION)**
 - Adopted through reference by federal and state governments, including Massachusetts
 - *Provisions shall be made to prevent thermal radiation flux from a fire from exceeding the following limits :*
 - *1600 Btu/hr/ft² (5000 w/m²) at the nearest point located outside the owner's property in existence at siting and used for outdoor assembly.*
 - *3000 Btu/hr/ft² (9000 W/m²) at the nearest point of the building outside the owner's property line in existence at time of siting and used for assembly, educational, health care, detention or residential,*
 - *10,000 Btu/hr/ft² (30,000 W/m²) at a property line that can be built upon for a fire over an impounding area.*
- *These are not just technical decisions. They involve "value judgments".*

WHAT DO THESE "ACCEPTABLE" LEVELS MEAN?

- **1600 Btu/hr/ft² - The NFPA Committee members consider this level of radiation acceptable for an outside assembly location.**
 - This level of heat flux will cause 2nd degree burns in 30 seconds.
 - This level of heat flux will cause extreme pain in 15-20 seconds.
 - Fatal to 1% of the affected population in 60 seconds. (According to a Quest Report)
 - Educational occupancies often have playgrounds but the level for educational occupancies is 3,000 BTU/hr/ft²
 - This might not sound acceptable to everyone.
 - The Society of Fire Protection Engineers Handbook recommends 750 Btu/hr/ft² (1/2 of the NFPA's acceptable level) as a recommended maximum to allow for people to safely evacuate.

WHAT DO THESE "ACCEPTABLE" LEVELS MEAN?

- **3000 Btu/hr/ft² - The NFPA Committee members consider a this level of radiation acceptable for buildings containing educational and healthcare occupancies.**
 - This level of heat flux will cause 2nd degree burns in 15 seconds.
 - Fatal to 50% of the affected population in 60 seconds. (According to a Quest Report.)
- **This exceeds the level suggested as a maximum for wildland firefighting, 2,200 BTU/hr/ft² (7 KW/m²).**
- **Why is it "acceptable" to potentially expose school children to these types of heat flux?**
- **What about bedridden hospital patients exposed to radiation passing through glass windows?**

BFD GUIDELINES FOR HEAT FLUX (RADIATION) EXPOSURE

10,000 (BTU/hr-ft²)	Assume concrete structures will fail. No rescue or fire fighting activity possible.
7,000 (BTU/hr-ft²)	Assume steel structures will fail. Assume buildings will ignite after a short duration No rescue or fire fighting activity possible.
4,000 (BTU/hr-ft²)	Assume buildings will ignite after more than 30 mins. No fire fighting activity except for life safety. FFs exposure should be limited to a few minutes.
2,500 – 4,000 (BTU/hr-ft²)	Buildings should not burn at this level, from pool fire but may eventually burn due to adjacent building fires Evacuate civilians using as much shielding as possible.)
1,500 – 2,500 (BTU/hr-ft²)	Buildings should not burn, so defend in place. Firefighters should be able to operate reasonable safely in this zone with proper bunker gear.
500 – 1500 (BTU/hr-ft²)	Buildings should not burn, so defend in place. Non –firefighters should be able to operate reasonable safely, for short periods to assist in evacuation.

USDA Forest Service estimates max exposure, for 90 seconds, for FF, with head and neck protection, to be 7.0 KW/m² (2,200 BTU/hr/ft²).

BFD EST. OF HAZARD DISTANCES - 2002 (APPROX AVE OF FAY AND QUEST)

	BFD ESTIMATED DIST TO HEAT FLUX		QUEST	SANDIA
	1M ² HOLE	5M ² HOLE	5M ² HOLE	"INTENTIONAL"
12,000 BTU/hr/ft ²				1,465 ft
7,000 BTU/hr/ft ²	1,100 ft	1,500 ft	1,020 ft	
4,000 BTU/hr/ft ²	1,300 feet	1,900 feet	1,280 ft	Est. > 2,000 ft
2,500 BTU/hr/ft ²	1,600 feet	2,250 feet*		
1,500 BTU/hr/ft ²	1,800 feet	2,700 feet		4,800 ft

Original 2002 BFD estimate of hazard distances, for 5m² hole, was much closer to Sandia's 12/04 estimate than the estimate by QUEST used by DOE and USCG.

WHO HAS VESSEL JURISDICTION?

- **BFD Assumed that the agency that authorize the hazard analysis, e.g. the Quest Study, was the agency that had jurisdiction.**
- **The “State”?**
 - **USCG informed BFD it was the State. (05/02)**
 - **The Exec Office of Public Safety denied involvement. (06/02)**
 - **Juckett, from the DOE identified, M. Bolden, Under Sect. of Public Safety as making request for a study to DOE. (07/03)**
- **The DOE?**
 - **Junkett stated in an e-mail that DOE, *“was able to task Quest using existing government funds”*.(07/03)**
 - **DOE Press Officer, Drew Malcolmb later stated, *“DOE was not involved with the study in any way”*.(– Mobile Register 10/19/03)**
- **FERC (Federal Energy Regulatory Commission)?**
 - **J, Robinson of FERC stated, *“FERC does not set exclusion zones around tankers.” But he also stated, “FERC had used and would continue to use the Quest Study”*. (Mobile Register, 11/25/03.**

WHY THERE IS A NEED FOR AN "INDEPENDENT REVIEW"

- ***Surveys of almost 1,500 members of...professional societies (e.g. environmental economics, epidemiology, exposure assessment, industrial hygiene, toxicology) found that 3 in 10 respondents had observed a biased research design, 2 in 10 had observed plagiarism, and 1 in 10 observed data fabrication or falsification. Respondents with many years in risk analysis, business consultants, and industrial hygienists reported the greatest prevalence of misconduct. These respondents perceived poor science, economic implications of the research, and lack of training in ethics as causes of misconduct. (Greenberg and Goldberg, 1994: 223) - Minding the Machines***

WHY THERE IS A NEED FOR “PUBLIC PARTICIPATION”

- ***“Controversies have politicized the issue of risk. Risk assessment is no longer seen as simply an exercise in the technical measurement of risk. Questions of risk can no longer be defined simply in technical terms; they must also be defined in political and social terms, because the real question is not how safe it is, but how safe is safe enough for individuals and society? Moreover, since technical risk assessors are no more qualified than the general public to assess value judgements ... The view that the public perception of risk is distorted by subjective biases and that only experts can define the “real” risks is overly simplistic. Experts are also subject to biases in interpreting quantitative data, especially when objective uncertainties are present. Many so-called objective assessments ultimately depend on the subjective interpretations and normative judgements of engineers and applied scientists.” - Minding the Machines***

BFD REGULATORY RECOMMENDATIONS (2002)

- **Owners of LNG hazards should provide a comprehensive report which should include:**
 - Analysis of “reasonable worst case scenarios” using risk and hazard analysis (including terrorist attacks).
 - Note: risk analysis takes into account probability.
 - The consequences should be described in terms of impact on surrounding infrastructure, communities and terminals - not just heat flux estimates.
 - When analyzing consequences, use the “acceptable” criteria recommended by the BFD as opposed to NFPA’s.
 - Identification of specific required capabilities on-site, or in the local community, that are in place, or more importantly - not in place, to manage these consequences.
 - Do first responders have resources to mitigate the consequences?

“ASSESSING THE SUITABILITY OF A WATERWAY FOR LNG MARINE TRAFFIC” (USCG - NCIV 05-05)

- ***Finally, in May of 2005 USCG takes responsibility for evaluating LNG Risks on Water.***
 - ***Section 6. c - “LNG facilities in operation prior to the publication of this Circular; Current safeguards and security measures for LNG terminals, including related LNG marine traffic, that were in operation prior to the publication of this Circular should be considered appropriate. However, they are subject to case-by-case review if circumstances warrant. Modification or expansion of existing facilities may be such a circumstance.” (Essentially “grandfathers” existing facilities.)***
 - ***Section 4. b. – “The Sandia Labs Report provided foundation for USCG position on LNG and provided basis for evaluating risks.”***

BUT – ACCORDING TO SANDIA LABS (12/04) REPORT ...

- In Zone 1 – *“Incident management and emergency response measures should be carefully evaluated to ensure adequate resources (i.e. firefighting and salvage) are available for consequence and risk management.”*
- In Zone 2 – *“Strategies should include incident management and emergency response measures that ensure areas of refuge(enclosed areas, buildings) are available. The development of community warning procedures and educational programs to ensure that are aware of precautionary measures.”*

WHY NOT APPLY THESE CONCEPTS TO EXISTING SITUATIONS LIKE BOSTON HARBOR?

LNG TRANSIT IN HARBOR

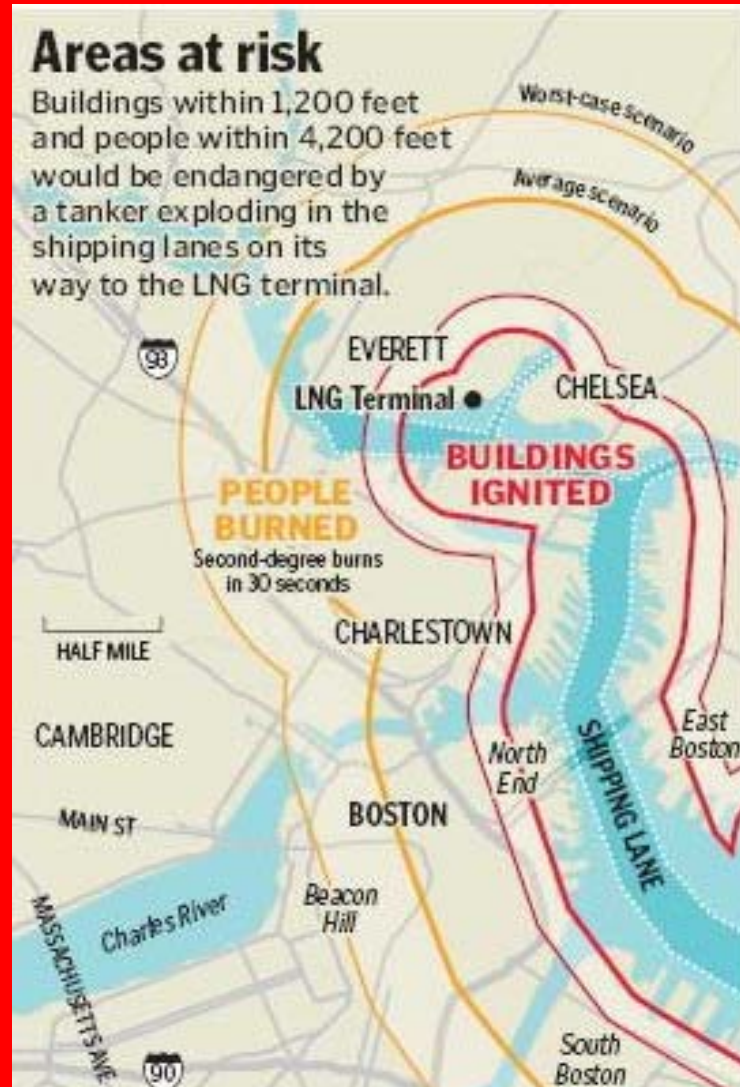


**VESSEL IS ABOUT
900 FT LONG**

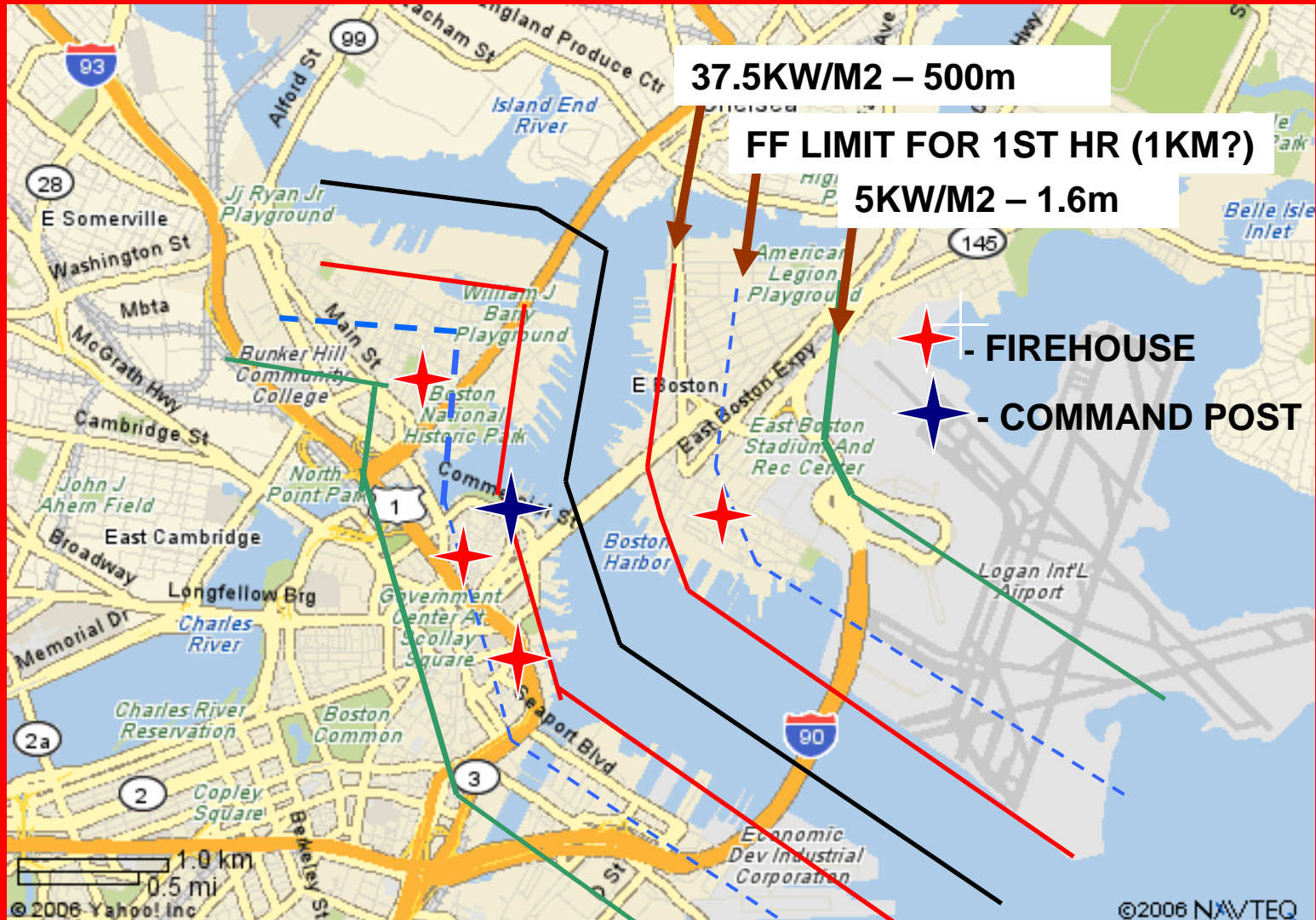


**LNG PASSING BY
CHARLESTOWN
CONDOMINIUMS**

HAZARD ZONES (LNG IN HARBOR) - BOSTON GLOBE/SANDIA



HAZARD ZONES BASED ON SANDIA ESTIMATES



COMMENTS ON HAZARD ZONES – “INTENTIONAL INCIDENT”

- **Command Post and at least 1 Firehouse potentially in Sandia’s Zone 1 – “Consequences could be significant. Thermal radiation poses a severe public safety and property hazard, and can damage or disrupt critical infrastructure”.**
- **2 possibly 3 firehouse located in area where firefighting probably limited due to thermal radiation. (Approximately 7-10 KW/M²)”**
- **Dozens of buildings, some hi-rise residential, potentially within 20 KW/M² – A heat flux that will ignite buildings after a prolonged period (30-60 minutes).**

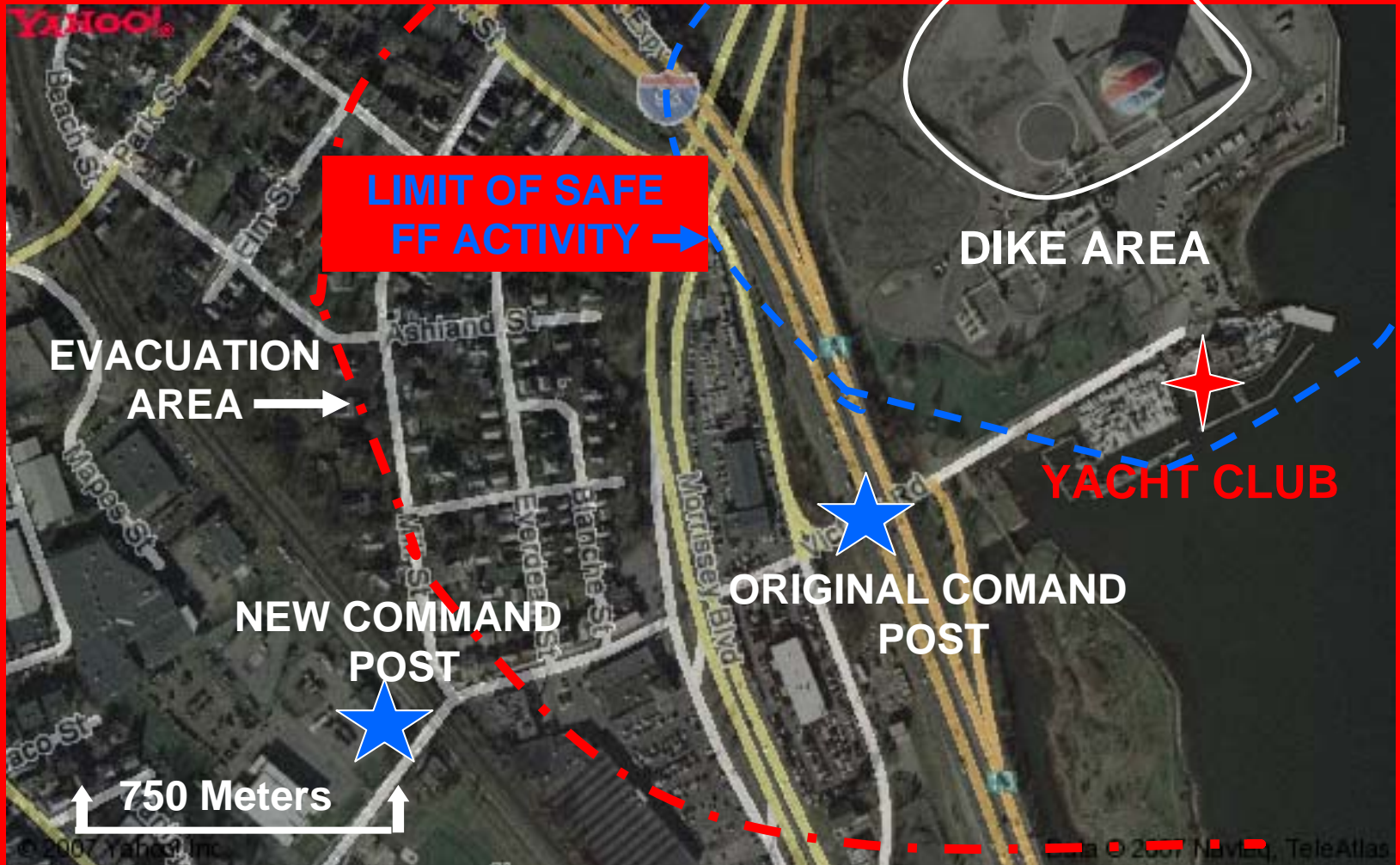
CAN FIRE BE EXTINGUISHED?

- ***“Senior Distrigas Official says even if a fire did occur, Fay’s scenario overestimates its likely impact. By throwing water on an LNG fire within seconds, the tugboat escort could reduce a fire effects. He agrees that water could not extinguish the fire.”*** – Providence Journal 01/04/04
- **However other sources disagree.**
 - *“Contact between water and pooled LNG should be avoided to prevent increased vaporization, unless vapor can be controlled.”* - NFPA Handbook.
 - *“Water is ineffective in fighting LNG fire because it provides a heat source for vaporization”.* (Which makes the fire and heat worse – my words) - Liquefied Natural Gas in California: History, Risks, and Siting
- **Any fire boat would be limited to protecting exposures several thousand feet away from large LNG pool fire.**

LNG STORAGE IN DORCHESTER



HAZARD ZONES FOR LAND BASED LNG FACILITY



COMMENTS ON HAZARD ZONES – “LAND BASED LNG”

- **Original Command Post** set up at a location on the opposite side of the expressway. It was assumed that 25 foot roadway would act as barrier for thermal radiation. – Actually, the flame height will be several hundred feet high so no protection actually existed.
- No provisions were originally made to evacuate the Yacht Club, which existed before plant was built so it was “grandfathered.” If occupants, or plant staff, do not evacuate before total area of dike filled they will be trapped in a building that will eventually burn to the ground.
- Most other occupancies in the “defend in place” zone.

CONSEQUENCE MANAGEMENT (1)

- Any plan must be able to be implemented within minutes, since pool fire will reach maximum size in that time frame.
- Initial response of emergency responders may be away from incident to a safe staging area. Once extent and location of incident known action plan can be implemented.
- Set up Command Post, with multiple staging areas outside Sandia's Zone 2 circumference. (1.6KM)
- Anticipate the need to fight conflagration on both sides of harbor.

CONSEQUENCE MANAGEMENT (2)

- Initially there will probably only be enough resources to evacuate selective populations. Area must be “triaged”.
 - Area One (0 – 0.5Km)– Heat flux ($37.5\text{kW}/\text{M}^2$) too great for FD to operate and buildings will burn due to radiant heat from pool fire. – “Occupants should be told to attempt to shelter in basements, parking garages etc.?” (Even sprinklered buildings will burn due to water supply being inadequate.) – *LOW PRIORITY*
 - Area Two (0.5Km – 1.0Km) – Heat flux dangerous for short exposures, even with bunker gear. Buildings are in danger of burning from secondary thermal radiation hazard – Attempt to evacuate population using as much shielding as possible. – *HIGH PRIORITY*
 - Area Three (1.0Km – 1.5Km)– Buildings unlikely to burn but heat flux still hazardous to humans. Bunker gear should allow short term operations. – “Shelter in place”. – *MODERATE PRIORITY*
 - Area Four (>1.5Km) – Heat Flux Low ($5\text{kW}/\text{m}^2$) Safe area, location of Command Post. - *LOW PRIORITY*
 - Distance estimates can be modified based on reports from field.
- Once pool fire burns out, in 30-60 minutes, prepare to deal with secondary exposure fires.

RISK VS. HAZARD

- **Govt and industry officials often claim that the risk is small. What they mean is that even though the hazardous consequences of an event are catastrophic, they assume that the probability of an event is small so the resultant risk is small. Example from “Golden Pass LNG” website: “Overall, the draft EIS is very favorable. The report shows the facility would have limited impact on the environment and a low risk for accidents.”.**
- **Notice that the speaker uses the terms “*risk*” and “*accidents*”. They allow him to ignore the hazard of intentional acts while seeming to make it seem safe.**
- **The public does not understand the difference between risk and hazard. They assume that when someone says the risk is small that what they mean is that the hazard is small.**

RISK VS. HAZARD

- **Whenever someone says the risk is small, ask the following:**
 1. **Do they mean that the probability of an event is small and the hazardous consequences are small?**
 2. **Do they mean that the probability of an event is small but the hazardous consequences are big?**
 3. **Do they mean that the probability of an event is high but the hazardous consequences are small?**
- **These three different scenarios could all produce a small risk but they mean very different things to the public. In any case, how does one calculate the probability of a terrorist attack and if you cannot then how can one say the risk from a terrorist attack is small?**

INDUSTRY ATTEMPTS TO CORRECT LNG "MYTHS"

- **“Assessing risks from tankers” by Richard Grant,
President and CEO of Tractabel LNG North
America. (Editorial in Boston Globe.)**
 - ***“LNG CANNOT EXPLODE. IN FACT, IN ITS LIQUID STATE AT
MINUS 260 DEGREES, IT CANNOT EVEN BURN.”***
- **Both of these statements are true. Unfortunately
neither of them is relevant. Stating that LNG will not
explode gives the impression that it is not hazardous.
The hazard of an LNG vessel incident would derive,
not from an explosion, but from a pool fire or a vapor
cloud ignition. The original EIS for the Everett
Facility, estimated the potential fatalities from these
two incidents at 3,000 and 2,500 respectively.**

TESTIMONY FROM BOSTON CITY COUNCIL HEARING 11/06

- Chief Fleming – *“As of 11/06, there has not been a “consequence mitigation analysis” that would help BFD be prepared for LNG incident in Harbor.”*
- Industry Expert – *“Chief Fleming was wrong. There was a risk assessment, which I participated in in 1975 as part of USCG EIS report for the Distrigas Facility.”*
- Question by Councilor: *“Were there any fatality estimates, in the hundreds, as part of that risk assessment?”*
- Industry Expert: *“No, nothing like that.”*
- Truth – 1975 EIS estimates were 2,500-3,00 fatalities.

TESTIMONY FROM BOSTON CITY COUNCIL HEARING 11/06

- **Councilor:** *“Is there any report that could be used to help the BFD prepare for an event?”*
- **Industry Expert:** *“If a large spill was to occur and ignite, the total duration would be 10 minutes. This is about the same as the FD’s response to a building fire.”* (The BFD response est. is 1-2 minutes. - JMF)
- **Industry Expert:** *“Mitigation is impractical. All eggs should be put in “prevention basket”.”*
- **When discussing the Benham Gas Explosion, Houston 1992, Paul Gruhn advised the following.** *“Putting all your eggs in one basket is never a good idea. Providing adequate independent safety layers means when one system fails, which it inevitably will, another will be able to prevent the hazardous event.*

RESEARCH NEEDS - GAO 02/07

1. Large fire phenomena*
2. Cascading failure
3. Large-scale spill testing on water*
4. Large – scale fire testing*
5. Modeling: interaction of physical processes
6. Risk tolerability assessments
7. Vulnerability of containment systems (hole size)
8. Mitigation techniques
9. Effect of sea water coming in as LNG flows out
10. Impact of wind, weather, and waves

* *Only research needs funded in new DOE study.*

Most items raised as issues by BFD over 5 years ago.

FINAL THOUGHTS

- **When communicating risk information to the public, explain it in terms of consequences and probability. This makes the “risk vs. hazard” issues transparent.**
- **USCG Circular NCV05 should be applied to all LNG facilities, including existing facilities. (Similar policies should be developed for LPG, gasoline etc.)**
- **Sandia recommendations should be followed. Particularly in terms of assessing local capabilities.**
- **Heat flux guidelines should take into account thermal radiation level that prevents FF activity. (Express consequences in terms of damage to people and property not “heat flux lines”.)**
- **Any report should be peer reviewed by independent 3rd party, at the expense of facility, who answer local concerns. (Similar language in Mass Building Code.)**