Testimony of

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My name is J. Mark Robinson and I'm Director of the Office of Energy Projects (OEP) at the Federal Energy Regulatory Commission (FERC or Commission). I am here as a staff witness and do not speak on behalf of any Commissioner. Our office is responsible for non-federal hydroelectric licensing, administration, and safety; siting of electric transmission lines; certification of interstate natural gas pipelines and storage facilities; and, more significantly for today's session, authorization and oversight over the construction, operation, and safety of on-shore and near-shore Liquefied Natural Gas (LNG) terminals. We also share security responsibilities for these facilities with the U.S. Coast Guard (Coast Guard), which has primary responsibility under the Maritime Transportation Security Act of 2002.

I want to thank you for this opportunity to speak today and to specifically address how we ensure the safety and security of LNG import facilities and the related LNG shipping. Overall, the safety record of the industry is commendable. LNG terminals in the United States have never had an LNG safety-related incident that harmed the public or the environment. Similarly, no shipping incidents have occurred worldwide that resulted in a significant loss of cargo during the almost 50 years of LNG transport. I will first describe the measures we use to provide for safe and secure LNG import terminal siting, construction and operation. Next, I will briefly address the measures taken to ensure the continuing safe history of LNG shipping. And finally, I will comment on the GAO report.

Safety, Security and Siting of LNG Import Terminals

Be assured that consideration of public safety is our highest priority when fulfilling our Congressional mandate under the Natural Gas Act to regulate facilities for the importation of natural gas. The Commission has been proactive in addressing safety concerns and rigorously applies high safety standards to these projects. When projects meet our safety standards and are found to be in the public interest, the Commission will approve them. If a proposed project falls short of these standards, the Commission will reject it, as was done with the proposed Keyspan LNG Terminal Project in Providence, Rhode Island.

The excellent safety record of the LNG import facilities in the U.S. extends over the past 35 years. The siting and oversight of LNG facilities is governed by a comprehensive scheme of federal regulation that guarantees that the FERC and other federal agencies work together to ensure public safety. The FERC's LNG project review process works to address all siting and operational issues with the full participation of the federal and state agencies, and the public, and, only after that comprehensive review, attempts to ensure the timely development of necessary energy infrastructure. Once in operation, FERC oversight and inspection is an on-going process for the life of the facility.

Every aspect of our engineering and siting review, and our coordination with the Coast Guard and the U.S. Department of Transportation (DOT), is geared

toward assuring that a facility will operate safely and securely. This review may be broken into three distinct phases: pre-authorization review; pre-construction review; and pre-operation review.

Pre-Authorization Review -- During the pre-authorization phase, Commission staff addresses the safety and security of an LNG import terminal by reviewing facility designs and ensuring that the proposal includes a number of design and operational features. FERC regulations require that from the early stages of project development, potential applicants meet with FERC staff to describe the proposal and solicit guidance on required design features. At this point, we make sure that DOT and the Coast Guard are aware of new projects or proposed expansions. These meetings provide the opportunity for FERC staff to offer suggestions related to the environmental, engineering and safety features of the proposal and review conceptual designs. These activities occur over at least a six month time span during the mandatory pre-filing period required by the Energy Policy Act of 2005 and are detailed in the FERC's regulations under Title 18 of the Code of Federal Regulations (CFR), § 157.21.

Based on this input from FERC staff, the project sponsors continue to develop the front-end-engineering-design (FEED) to be filed as part of the formal application for the proposed LNG facility. The design information, which must be contained in the formal application, is extensive and is specified by 18 CFR § 380.12 (m) and (o). In order to ensure that the filings are complete, FERC publicly issued "Draft Guidance For Filing Resource Reports 11 (Reliability and Safety) & 13 (Engineering and Design) For LNG Facility Applications" in December 2005. This document clarified the level of detail required for the engineering submittal so FERC staff can adequately assess the safety, operability, and reliability of the proposed design. Areas for specific guidance and clarification include:

- the level of detail, including a requirement for a hazard design review, necessary for the FEED submitted to the FERC;
- LNG spill containment sizing and design criteria for impoundments, sumps, sub-dikes, troughs or trenches;
- design spills to be used in the calculation of thermal and flammable vapor exclusion zones; and
- use of the Coast Guard's Navigation and Vessel Inspection Circular 05-05 and the waterway suitability assessment process.

The level of detail required to be submitted in the proposed design will require the project sponsor to perform substantial front-end engineering of the complete facility. The design information is required to be site-specific and developed to the extent that further detailed design will not result in changes to the siting considerations, basis of design, operating conditions, major equipment selections, equipment design conditions, or safety system designs considered by the FERC during the review process. The required information must include all

features necessary for commissioning, start-up, operation and maintenance of the facility, including details of the utility, safety, fire protection and security systems. Novel designs require additional detail for proof of concept.

A complete FEED submittal will include up-to-date piping and instrumentation diagrams (P&IDs). Information on these drawings allows FERC staff to begin assessing the feasibility of the proposed design. Adequate P&IDs will include:

- equipment duty, capacity and design conditions;
- piping class specifications;
- vent, drain, cooldown and recycle piping;
- isolation flanges, blinds and insulating flanges;
- control valves and operator types (indicating valve fail position);
- control loops including software connections;
- alarm and shutdown set points;
- shutdown interlocks;
- relief valve set points; and
- relief valve inlet and outlet piping size.

Once an application is formally made to the Commission, FERC staff performs a detailed review of the information supporting the proposed LNG facility design. Since the enactment of the Energy Policy Act of 2005, no later than 30 days after the application filing, the agency designated by the Governor of the state where the terminal is proposed may file an advisory report on state and local safety considerations. Before issuing an order authorizing an applicant to site, construct, expand, or operate an LNG terminal, the Commission shall review and respond specifically to the issues raised.

During the analysis of the application, FERC staff compiles pertinent technical information to assess the design of the LNG facility. Although operability and reliability of the proposed design are considered, our primary focus is on the safety features that must be built into the system. This review is performed prior to any Commission approval and evaluates the safety of:

- the LNG transfer systems;
- storage tanks and process vessels;
- pumps and vaporizers;
- pressure relief, vent and disposal systems;
- instrumentation and controls;
- spill containment systems;
- hazard detection and control systems; and
- emergency shutdown systems.

Each LNG import terminal must have an extensive array of hazard detection devices to provide an early warning for the presence of combustible gases, fires, or spills of LNG and activate emergency shut-down systems. Using the submitted design, FERC staff assesses the conceptual hazard detection system,

which typically consists of combustible-gas detectors, fire detectors, heat detectors, smoke or combustion product detectors, and low temperature detectors. Typically, each facility will have over 100 of these types of detectors.

Use of these active systems to automatically shutdown equipment, and other passive safety protections, such as impoundments, are reviewed to ensure that appropriate safety provisions are incorporated in the plant design. A detailed layout of the passive spill containment system showing the location of impoundments, sumps, sub-dikes, channels, and water removal systems is evaluated to allow FERC staff to assess the feasibility of the location, design configuration, dimensions, capacity and materials of construction for this system. In accordance with Title 49 of the Code of Federal Regulations, § 193.2181, these spill containment systems must accommodate 110 percent of an LNG tank's maximum liquid capacity.

Active hazard control systems consisting of strategically placed dry chemical extinguishers; carbon dioxide or nitrogen snuffing equipment; high expansion foam systems; and fire-water systems throughout the terminal are evaluated in accordance with Federal regulations and good engineering practices. A detailed layout of the fire water system showing the location of fire water pumps, piping, hydrants, hose reels, and auxiliary or appurtenant service facilities is reviewed for adequacy.

In addition, each storage or process area containing LNG must be surrounded by an impoundment structure to contain and limit potential spills associated with that equipment. Based on the size and location of these impoundments, the project sponsor must establish exclusion zones around the facility so that the effects from potential LNG pool fires and flammable vapors from an unignited LNG spill do not pose a hazard to the public. In accordance with Title 49 CFR § 193.2057 and 193.2059, and in conjunction with the National Fire Protection Association 59A LNG Standards, thermal radiation and vapor dispersion exclusion zones are calculated by FERC staff based on spill scenarios and heat flux levels. The operator must be able to legally control land uses within any portion of these zones extending beyond the terminal site to prevent damaging effects of an LNG pool fire or a flammable vapor mixture from impacting public safety.

Further, during the pre-authorization phase and beyond the cryogenic design review, each application for an LNG facility is subject to a detailed review by the FERC staff of numerous other studies and reports that the applicants are required to complete. These include:

- seismic analyses;
- fire protection evaluations;
- threat and vulnerability assessments; and
- Operation and Maintenance manuals.

The information used for the pre-authorization review is gathered from the application, data requests, and a *Cryogenic Design Technical Conference* held

with the applicant's design team. This meeting allows FERC staff and company engineers to discuss specific engineering-related issues. Representatives from the Coast Guard and DOT, as well as state and local fire marshals, are invited to attend. Although the Coast Guard is generally in attendance to address facility issues, the issues specifically related to LNG vessel transit are dealt with during the Coast Guard's separate waterway suitability assessment (WSA) process.

The staff's conclusions and recommendations on the proposed design, including all safety measures, are presented in the Safety section of the publicly-released FERC environmental assessment or environmental impact statement (EIS). Ultimately, these recommendations have appeared as conditions in Commission Order approving the project. In addition to design considerations, the Order may also contain other LNG-specific standard conditions that pertain to the safe operation and security of the facility. If the Commission decides that a project would be safe, is in the public interest, and authorizes it, continued review would occur during the pre-construction phase.

Pre-Construction Review -- If a project sponsor receives a Commission Order and decides to pursue the project, it will engage the services of an Engineering, Procurement, and Construction (EPC) firm to commence detailed engineering of the facility. This process results in a "final design" that usually contains further development or minor refinements to the approved FEED on file with the FERC. For these modifications, the FERC Order requires the project sponsor to request approval for the change, justify it relative to site-specific conditions, explain how that modification provides an equal or greater level of protection than the original measure; and receive approval from the Director of OEP before implementing that modification. For more significant changes, the project sponsor would be required to file an amendment or a new application, initiating another extensive review at the Commission.

The final design will typically include hundreds of pages of detailed engineering drawings and specifications for every area and piece of equipment in the facility including the marine platform, transfer lines, tanks, sumps, pumps, compressors, vaporizers, and blowers. Only after FERC staff has reviewed the final design for a particular facility component to ensure it complies with all the safety conditions of the Order and that it conforms to the approved design on file, will authorization to construct that component be granted. We review large scale issues such as the facility's final plot plan and location of equipment, tanks, and impoundments to verify that all exclusion zones remain in compliance with siting regulations. These final review checks will also confirm that the number, location, type, and size of hazard detection and hazard control equipment match or improve upon the approved design and that redundancy, fault detection, and fault alarm monitoring exist in all potentially hazardous areas and enclosures.

Prior to entering the detailed design phase, project sponsors perform a hazard and operability study of the initial design. This study is intended to

identify potential process deviations that could occur during operation and lead to personnel injury or equipment damage. The analysis proceeds by systematically identifying possible causes for operational deviations and the consequences of these deviations at numerous locations in the regasification process. Areas of concern typically include equipment failures, human failure, external events, siting issues, previous incidents, and safeguard or control failures. These causes and consequences are in turn used to evaluate the inherent safeguards in the design and to identify suitable design modifications as required. Examples of the additional safeguards that are required are: detection systems, prevention systems, procedural safeguards, active and passive safety equipment, emergency response procedures, and secondary containment.

During the pre-construction phase, FERC staff will review this study as well as review all piping and instrumentation diagrams, including every valve and thermocouple, to make sure that the overall safety of the final design provides an equal or greater level of protection as the original design approved by the FERC.

Furthermore, the design of some facility components such as the foundation of the LNG tanks will be reviewed by geotechnical experts who determine if the foundation structure is capable of safely supporting the load of a full LNG tank, even during seismic events.

In accordance with the Energy Policy Act of 2005, Commission Orders authorizing an LNG import terminal require the project sponsor to develop an Emergency Response Plan (ERP) in consultation with the U.S. Coast Guard and state and local agencies. Prior to any construction at the facility, this plan, which must also include cost-sharing provisions for safety and security, must be approved by the Commission. The ERP must include written procedures for responding to: emergencies within the LNG terminal; emergencies that could affect the public adjacent to an LNG terminal; and emergencies that could affect the public along the LNG vessel transit route. The ERP must be prepared in consultation with the Coast Guard and state and local agencies, and it must be approved by the Commission prior to any final approval to begin construction at the terminal site.

Commission engineering staff reviews each ERP to ensure that the appropriate state and local agencies have been involved in preparing the plan, that the local Coast Guard Marine Safety Office has been consulted and concurs, and that the following topics are completely addressed:

- Structure of the incident management organization of the LNG terminal; and name, title, organization, and phone number of all required agency contacts;
- Procedures for responding to emergencies within the LNG Terminal - identification of the types and locations of specific emergency incidents that may reasonably be expected to occur at the LNG terminal due to operating malfunctions, structural collapse, personnel error, forces of nature and activities adjacent to the terminal;

- Procedures for emergency evacuation adjacent to the LNG Terminal and along LNG vessel transit route; detailed procedures for recognizing an uncontrollable emergency and taking action to minimize harm to terminal personnel and the public; procedures for the prompt notification of appropriate officials and emergency response agencies based on the level and severity of potential incidents; and the sequence of such notifications;
- Plans for initial and continuing training of plant operators and local responders; and provisions for annual emergency response drills by terminal emergency personnel, first responders, and appropriate federal, state and local officials and emergency response agencies; and
- Documentation that the required consultation with the Coast Guard and state and local agencies has been completed through correspondence with consulting agencies, and minutes or notes of coordination meetings.

In addition, both the Energy Policy Act of 2005 and Commission Orders authorizing LNG terminals require that the ERP include a Cost-Sharing Plan identifying the mechanisms for funding all project-specific security costs and safety/emergency management costs that would be imposed on state and local agencies. The cost-sharing plan must specify what the LNG terminal operator will provide to cover the cost of the state and local resources required to manage the security of the LNG terminal and LNG vessel, and the state and local resources required for safety and emergency management, including:

- Direct reimbursement for any per-transit security and/or emergency management costs (for example, overtime for police or fire department personnel);
- Capital costs associated with security/emergency management equipment and personnel base (for example, patrol boats, fire fighting equipment); and
- Annual costs for providing specialized training for local fire departments, mutual aid departments, and emergency response personnel; and for conducting exercises.

The cost-sharing plan must include the LNG terminal operator's letter of commitment with agency acknowledgement for each state and local agency designated to receive resources.

FERC and other federal agencies work with state and local entities, as well as the general public, to ensure that all public interest considerations are carefully studied and weighed before a facility is permitted and allowed to begin construction and operate, and that public safety and the environment are given high priority. No construction may commence until the Director of OEP finds that all safety requirements have been met.

Pre-Operation Review -- Once construction of the project has been authorized to begin, Commission staff inspects each site at least once every eight

weeks to ensure that project construction is consistent with the designs approved during the pre-authorization and pre-construction review phases.

During these inspections, Commission staff physically examines the entire site to verify the ongoing construction activities in each area. Staff confirms that the locations of individual process equipment under construction are in accordance with the approved site design, ensuring that the safe distances required between property lines, equipment, and facilities are being maintained. Staff verifies that all site activity and equipment under construction comply with the conditions of the Order that are applicable for that phase of the project. Commission engineers also meet with the owner's project design engineers to discuss any modifications or design refinements that may result from the detailed design phase of development - for example, adjustments considered necessary as a result of equipment vendor specifications or other insights realized during construction.

In addition, staff reviews both the owner's and the EPC firm's quality assurance plans to verify that rigorous and stringent quality control inspections are being conducted by both parties during all phases of the construction process. Inspections must apply to equipment and components being fabricated at manufacturing sites, material and equipment received at the construction site, specific assembly or fabrication methods employed during construction, and also the continuous verification of the precision and quality of all structural work carried out during the construction process.

Staff reviews all of the non-conformance reports generated by the project's quality control inspectors and how these incidents have been satisfactorily resolved. These deviations from the intended quality of work are evaluated by FERC staff to ensure that the final quality of the work will meet or exceed design requirements. Problems of significant magnitude are required to be reported to the Commission within 24 hours.

During the later stages of the typical three-year construction period, FERC staff monitors the EPC contractors' efforts to commission (*i.e.*, test and start-up) the various process systems and equipment throughout the terminal in preparation for the commencement of commercial operations. Commission staff is actively involved in the commissioning phase to verify that the final, constructed facility complies with the design authorized by the Commission Order, and that the project sponsor has complied with all conditions. This review includes verification that all of the cryogenic design recommendations in the Order applicable to the facility's pre-construction and construction phases have been fulfilled. Multiple on-site inspections are performed to confirm the construction and location of all plant equipment, process systems, and safety systems, including:

- Verifying LNG spill containment structures for completion of walls, piping, correct slope, size, materials used, sump pumps, and instrumentation for cold detection shutoff, and confirmation that proper materials have been used to complete containment;

- Checking critical instrumentation against the P&IDs with the actual piping, valves, and controls; and the instrument readouts, controls, and alarm/shutdown functions in the plant control room;
- Confirming that all required hazard detection devices (combustible gas, fire, smoke, low temperature) have been installed, including an examination of the cause and effect diagrams and instrument locations for appropriate redundancy and "alarm" and "shutdown" conditions. The physical inspection also evaluates detector location and orientation for blind spots that may require additional hazard detection devices;
- Confirming that all dry chemical, carbon dioxide, or other fire extinguishing units/bottles have been installed. The devices are checked to confirm proper weight and areas have been covered;
- Confirming that all critical pressure relief valves have been installed, have proper discharge orientation, and vent collection systems are operable;
- Confirming that the entire firewater system is in place, including monitors, hydrants, pumps, screens, deluge and water supply, and has been tested for operation;
- Checking each LNG storage tank's equipment including elevation bench marks, rotational devices, liquid level gauges, pressure and vacuum relief valves, and discretionary relief valves for proper installation and confirming that all permanent covers have been installed. After cool-down, the fill lines and tank penetrations are inspected for presence of excessive low temperature conditions;
- Checking critical, required alarms and shutdowns, including set points (*e.g.*, tank foundation temperatures, send-out temperature shutdown set points) within the plant's Control Room and satellite control centers;
- Confirming that all temporary construction structures have been removed and the facility complies with National Electrical Code Division requirements; and
- Confirming that the plant's Emergency Shutdown System has been tested and is fully operational, including that all required systems have been tied into it.

Prior to operation, each LNG tank is hydrostatically tested to gauge the tank's ability to handle expected loads. During the hydrostatic test, the FERC Order will require the project sponsor to include a reliable measurement system to monitor any deflections in the tank foundation or structure during the hydraulic test. At a minimum, this system must include as many monitoring points as is necessary so that sag, warping, tilt, and settlements can be monitored. Tolerances for sag, tilt, and shell warping must meet or exceed the limits specified by the tank manufacturer. In this manner, the strength of the tank is thoroughly examined under loads similar to what will be experienced in actual operation. The final

design review will ensure that adequate plans for such testing are in place for all facility components.

As part of the pre-commission inspection, FERC staff also reviews the Start-up Manual, Safety Plan Manual, and Operations and Maintenance Manuals applicable to the installation. This review includes verifying that the terminal staff has received the necessary training to operate the plant or new systems, if an existing plant is being expanded. We confirm that the plant has employed the required staffing with a level and function appropriate for the facility.

FERC staff confirms that all plant security systems are in place (personnel, cameras, and other equipment), and that the Facility Security Plan is current. This review also includes confirming that all spare equipment that was authorized is on site and properly installed.

FERC staff also checks the entire facility site to ensure that all recommended environmental mitigation measures including erosion and sediment controls are in place, are being properly maintained, and that the company is making prudent steps to ensure that the site is properly stabilized for the operational life of the facility (*e.g.*, installation of shore line stabilization mats and rip rap).

Prior to operation, FERC staff also reviews the facility security to ensure compliance with the authorized design. Principal concerns are compliance with the DOT regulations, as well as sufficient levels of security provided by surveillance cameras; intrusion detection systems; security fencing; and on-site access control plans.

Only after all of the above-identified inspections and reviews have been successfully completed would FERC staff recommend that the terminal is ready for operations. The Director of OEP must issue a letter to the company that authorizes commencement of service from the facility.

Prior to operation, the terminal must also satisfy other federal agency requirements. For example, the facility must have a Facility Security Plan approved by the Coast Guard and a Vessel Transit Management Plan prepared by the Coast Guard and port stakeholders.

FERC oversight continues after an LNG import terminal project commences commercial operations. In fact, the Office of Energy Projects was reorganized to specifically create a Branch that is dedicated to ensuring that all FERC requirements, including safety and security measures, are complied with throughout the life of the project. Each LNG facility under FERC jurisdiction is required to file semi-annual reports to summarize plant operations, maintenance activity and abnormal events for the previous six months. LNG facilities are also required to report significant, non-scheduled events, including safety-related incidents (*e.g.*, LNG or natural gas vapor releases, fires, explosions, mechanical failures, unusual over-pressurization, major injuries) and security-related incidents (*e.g.*, attempts to enter site, suspicious activities near the plant site or around the marine terminal), as soon as possible but no later than within 24 hours. In

addition, FERC staff conducts annual on-site inspections and technical reviews of each import terminal throughout its entire operational life. The inspection reviews the integrity of all plant equipment, operation and maintenance activities, safety and security systems, any unusual operational incidents, and non-routine maintenance activities during the previous year. Ultimately, the Director of the Office of Energy Projects has the authority to take whatever measures are necessary to protect life, health, property or the environment.

We are proud of our track record working with DOT, the Coast Guard, states agencies, and with all interested stakeholders on these projects, and we are committed to continuing LNG's outstanding operational performance.

The Safe History of LNG Shipping

In addition to ensuring safe and secure terminal sites, FERC coordinates closely with the Coast Guard to ensure the safety and security of the LNG vessel transit to the import facility. Under our pre-filing regulations, applicants are required to prepare a WSA, which is reviewed by the Coast Guard and members of the local Area Maritime Security Committee. The Coast Guard convenes a working group consisting of members of the local Area Maritime Security Committee, federal agencies, state and local law enforcement, state and local firefighters, maritime and security professionals, and key port stakeholders throughout the port area.

Under Coast Guard supervision, this group, through a series of focused meetings, brings together its viewpoints to form a consensus on appropriate measures and mitigation needed to manage responsibly the safety and security risks posed by LNG marine traffic. At these meetings, FERC staff serves as the LNG technical advisor to the working group, provides insight from our participation in other waterways, and assists in identifying credible hazard scenarios. The group's detailed recommendations from the meetings are presented to the Coast Guard to assist in the Captain of the Port's review of the applicant's WSA. Based on its review, the Captain of the Port will make a preliminary determination on the suitability of the waterway. This determination will be presented to the FERC in the Coast Guard's Waterway Suitability Report.

The Waterway Suitability Report, filed with the Commission, preliminarily determines whether the waterway is suitable for LNG vessel transits, from both a safety and security perspective, and identifies additional resources that may be required. The results of this analysis are incorporated into the draft EIS and released for public comment. The 45-day comment period usually includes a public meeting near the proposed facility and along the pipeline route. In this manner, after public comment has been received and the final EIS is published, the Commission has a complete record on the suitability of the waterway and potential resource requirements prior to deciding whether to approve a particular LNG import terminal.

Since the beginning of commercial operations in 1959, LNG carriers have made over 46,000 voyages worldwide without a significant release of cargo or a major accident involving an LNG carrier. In no instance has an LNG cargo tank been breached either by an accidental or intentional event.

Any LNG carriers used to import LNG to the United States must be constructed and operated in accordance with the International Maritime Organization's (IMO) *Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*, the *International Convention for the Safety of Life at Sea*, as well as 46 CFR Part 154, which contain the United States safety standards for vessels carrying bulk liquefied natural gas. Foreign flag LNG carriers are required to possess a valid IMO Certificate of Fitness and a Coast Guard Certificate of Compliance.

LNG carriers are well-built, robust vessels employing double-hull construction, with the inner and outer hulls separated by about 10 feet. The LNG cargo tanks are further separated from the inner hull by a layer of insulation approximately one-foot thick. As required by the IMO conventions and design standards, hold spaces and insulation areas on an LNG carrier are equipped with gas detection and low temperature alarms. These devices monitor for leaks of LNG into the insulation between primary and secondary LNG cargo tank barriers. In addition, hazard detection systems are also provided to monitor the hull structure adjacent to the cargo tank, compressor rooms, motor rooms, cargo control rooms, enclosed spaces in the cargo area, specific ventilation hoods and gas ducts, and air locks.

Even in the few instances worldwide where there have been incidents, the integrity of LNG vessel construction and safety systems has been demonstrated. One of the more significant incidents involved the *El Paso Paul Kayser* which grounded on a rock in the Strait of Gibraltar during a loaded voyage from Algeria to the United States in June 1979. Extensive bottom damage to the outer hull and the ballast tanks resulted; however, the cargo tanks were not damaged, and no cargo was released.

There have been a few other instances where LNG ships have grounded. In 1980, the *LNG Taurus* grounded near the entrance to Taboata Harbor, Japan. The grounding resulted in extensive bottom damage, but the cargo tanks were not affected and no cargo was released. The ship was refloated and the cargo was unloaded. In 2004, the *Tenaga Lima* was grounded on rocks, due to a strong current while proceeding to open sea East of Mopko, South Korea. The ship's shell plating was torn open and fractured over an approximate area of 20- by 80-feet. Internal breaches allowed water to enter the insulation space between the primary and secondary membranes. However, the ship was refloated, repaired, and returned to service. Although damage was incurred when these LNG ships were grounded, their cargo tanks were never penetrated and no LNG was released.

In another incident, the *Norman Lady* was struck by the nuclear submarine *USS Oklahoma City* while the submarine was rising to periscope depth near the

Strait of Gibraltar in November 2002. The LNG carrier sustained only minor damage to the outer layer of its double hull but no damage to its cargo tanks.

More recently, the *Khannur* had a cargo tank overfill into the ship's vapor handling system during unloading at Everett, Massachusetts, in 2001. Approximately 100 gallons of LNG were vented onto the protective decking over the cargo tank dome resulting in several cracks. After inspection by the Coast Guard, the *Khannur* was allowed to discharge its cargo. In 2002, the *Mostaefa Ben Boulaid* had LNG spill onto its deck during loading operations in Algeria. The spill, which was believed to be caused by overflow, caused brittle fracturing of the carbon steelwork. The ship was required to discharge its cargo and proceed to dock for repairs. Although all these incidents resulted in an LNG release, there were no injuries in any of these incidents.

The most recent incident occurred in 2006 when the *Golar Freeze* moved away from its docking berth during unloading in Savannah, Georgia. The powered emergency release couplings on the unloading arms activated as designed, and transfer operations were shut down, preventing release of significant amounts of LNG or any structural or environmental damage. After inspection and onsite clearance by FERC staff and the Coast Guard, the arms were reactivated and transfer operations resumed without incident.

The low number of LNG tanker incidents can be attributed to the careful handling of the tankers, as well as safety and security procedures used in the ports. The transit of an LNG vessel through a waterway is strictly controlled by the Coast Guard to prevent accidental or intentional incidents that could damage the vessel or endanger the public. Entry into a port typically involves Coast Guard requirements such as:

- 96 hours advance notification of arrival and the vessel crew manifest;
- Coast Guard boarding of the LNG Vessel for an inspection of the ship safety system;
- Moving safety/security zones around the LNG vessel;
- Armed and unarmed escorts;
- Tug escort to assist with turning and mooring operations;
- Safety and security zones around the terminal dock while the vessel is berthed;
- Accompaniment by a state-licensed pilot; and
- Inspection of the dock safety systems before commencing cargo transfer.

With these operational measures, the transit of LNG carriers has been demonstrated to be safe along the waterway from the berthing area to the territorial sea.

GAO Report [No GAO-07-316]: "Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification."

I am encouraged that the GAO report reached many of the same conclusions on LNG hazards which we have published in each FERC environmental impact statement. The findings of the GAO expert panel concur with FERC staff's assessment of the potential public safety consequences of a terrorist attack on an LNG tanker regarding:

- unconfined vapor cloud explosions;
- freeze burns;
- asphyxiation; and
- rapid phase transitions (RPTs).

These phenomena do not pose a significant hazard to the on-shore public during a large-scale LNG spill. Natural gas vapors (primarily methane) can detonate if contained within a confined space, such as a building or structure, and ignited. However, unconfined methane-air mixtures have been ignited but not detonated in experiments. Although the addition of heavier hydrocarbons influences the tendency of an unconfined vapor cloud to detonate, the possibility for detonation of a large unconfined vapor cloud is unrealistic due to precise timing, necessary mixing, and required amount of initiating explosives.

Similarly, the public is not at risk from freeze burns or asphyxiation. Clouds from an LNG spill would be continuously mixing with the warmer air surrounding the spill site. Dispersion modeling estimates that the majority of the cloud would be within 25 degrees Fahrenheit of the surrounding atmospheric temperature, with colder temperatures closest to the spill source and away from the public. In addition, the majority of the cloud would be below concentrations which could result in oxygen deprivation effects, including asphyxiation, with the highest methane concentrations closest to the spill source.

The report also focused on potential impacts from RPTs. Our project-specific EISs include a discussion of this issue. While RPTs can occur during a spill on water, impacts would be limited to the area within the pool and would be unlikely to affect the public. The overpressure events observed during experimentation have been relatively small, estimated to be equivalent to several pounds of TNT. Although such an event is not expected to cause significant damage to an LNG vessel, it could increase the rate of LNG pool spreading and the LNG vaporization rate for a spill on water.

FERC staff also concur with the GAO report on the potential for a boiling liquid expanding vapor explosion (BLEVE). While it may be theoretically possible, the low storage pressure, use of insulation, and installation of relief valves on both onshore LNG storage tanks and LNG carriers render the possibility of a BLEVE unlikely for LNG as it is normally transported and stored.

The report further states that the most likely public safety impact from an LNG spill would be from heat associated with a pool fire. FERC staff has also

analyzed this issue in the course of project specific reviews and has reached that same conclusion. In its 2004 report, Sandia considered scenarios likely to breach an LNG cargo tank. Events ranged from accidental collisions, groundings, rammings, sabotage, hijackings, attacks with small missiles and rockets, and attacks with bulk explosives. These types of events which could potentially lead to a large LNG spill would likely be accompanied by a number of ignition sources. Surrounding impacts would be from an LNG pool fire, and subsequent radiant heat hazards, rather than the formation of a large unconfined vapor cloud. Each of our EISs describes those potential impacts on the local waterway.

As stated in the 2004 Sandia report, the most significant impacts to public safety and property exist within approximately 500 meters (1,640 feet) of a spill due to thermal hazards from a fire, with lower public health and safety impacts beyond 1,600 meters (approximately 1 mile). We believe the Sandia report and FERC's site-specific analysis are a reasonable and conservative basis to examine potential impacts from an LNG tanker fire.

The GAO study reports four experts thought the Sandia distance calculations were "too conservative"; four thought "not conservative enough"; seven thought "about right." Although the report characterizes this as disagreement, the majority of the panel (11 of 15) responded that the calculations were either accurate or overly conservative.

Although FERC staff generally agrees with the material presented in the GAO report, further explanation of some information is necessary. For instance, the report mentions that an LNG vapor cloud is visible, but natural gas vapors are colorless. The fog-like appearance usually associated with an LNG vapor cloud results from condensation of water vapor in the air due to the lower temperatures of the cloud. However, appearance of this visible water vapor does not necessarily reflect the flammable portion of the cloud. In addition, the report states that LNG fires burn hotter when the maximum flame temperature of methane is nearly the same as other fuels. Radiant heat from a large-scale LNG pool fire is assumed to be greater than other common hydrocarbon fuels based on the results of small-scale fire measurements. However, it has not been proven that this effect would scale up to larger fires. Oxygen deprivation and smoke generation in a larger fire may lead to lower surface emissive power.

In each EIS, FERC staff includes site-specific modeling done with the methodology developed for FERC by ABS Consulting. In areas of uncertainty due to the lack of large-scale field data, the FERC model uses conservative assumptions (*i.e.*, resulting in longer hazard distances). These conservative assumptions concern: calculation of the pool spread; determination of the pool fire flame height; and use of a higher surface emissive power. Our results have been in agreement with the Sandia guidance zones of concern, and support the conservative nature of the calculations.

Cascading failure of the LNG storage tanks, addressed by Sandia in its previous examination of currently operating LNG carriers, was another topic of

disagreement among the experts. Sandia stated that the events would not likely involve more than two or three cargo tanks. As stated in the 2004 Sandia report, the nominal hole size of an intentional breaching scenario would be no more than 5- to 7-m2, which is the appropriate range we use in the FERC staff EIS for calculating potential hazards from spills. For a breach of a 7 m2 in a single tank, the fire duration would be approximately 10 minutes. Whereas smaller hole sizes could result in fires lasting over 1 hour. While the expected fire duration from cascading tank failure would increase, the overall fire hazard was not expected by Sandia to increase by more than 20 to 30 percent. GAO recommended that further study of this issue could be undertaken by Sandia. We concur that further study on cascading mechanisms may clarify if the subsequent failure of the fourth and fifth cargo tanks would occur over time with the most probable consequence of further extending the duration of the fire.

Related to cascading failure mechanisms are the effects such an event may have on a pool fire (*i.e.*, whether it would increase the duration of the event, increase the size of the pool fire, or lower the radiant heat due to increased smoke generation). Current knowledge of the physical properties associated with an LNG spill are based on small-scale (<35 meter diameter pool) tests. How the data collected from small-scale pool fires can be extrapolated to the potentially large-scale cargo releases is a subject of much debate among the modeling community. Quantifying the physical properties of large-scale LNG spill should be a priority. This will allow analysts to refine the consequence models and generate more consistent results. Sandia currently has this effort underway with the Advanced LNG Pool Fire Testing Program.

Initial experimental results are expected in a few months, and the large-scale experiments are planned to be complete by August 2008. The initial results of these experiments will determine better correlations for the flame height and mass fire behavior which could be expected during larger fires. The large-scale tests will result in better data on vapor production rates, smoke generation, and surface emissive power. In a separate effort, Sandia is also applying its threat analysis and spill probability methodology to LNG tankers larger than those previously studied. The research is designed to provide an estimation of the sizes of breaches, including hole size, spill volume, and number of tanks breached, for membrane-designed ship classes ranging from 216,000 m^3 to 267,000 m^3. These are representative of LNG ships that are currently being designed, constructed and proposed for use at LNG facilities in the United States. Presently, each Order issued by the Commission requires the applicant to prove that staff's modeling of hazards for those large tankers is accurate. They must do this and get approval from the Director of OEP prior to accepting the larger size ships.

We will use this new data to enhance our modeling capabilities for determining possible consequence areas resulting from a successful intentional attack on an LNG tanker. FERC staff has always committed to modify our

analyses, when appropriate, as new data and improved modeling technologies are developed.

I believe that this research is beneficial and necessary and will provide more exact information and technical details. Removing the uncertainty inherent in modeling phenomena will result in more accurate models. However, in current areas of uncertainty, we have made conservative assumptions. FERC staff believes the refined models will likely show smaller consequence areas. FERC, and along with it, the Coast Guard and DOT have a competent understanding of the risks and how to mitigate them effectively to ensure public safety.

In conclusion, LNG is a commodity which has been and will continue to be transported safely in the United States. The U.S. Coast Guard, the U.S. DOT and FERC are committed to ensuring that safety. As a matter of policy, the Commission is committed to continually raising the bar on energy infrastructure safety. As new safety measures, improved monitoring equipment, and enhanced safety and security protocols are developed, the Commission will ensure that LNG remains a safe and secure fuel source for the country.