# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company Profile</td>
<td>2</td>
</tr>
<tr>
<td>Practice Areas and Industries</td>
<td>3</td>
</tr>
<tr>
<td>Liquefied Natural Gas Services</td>
<td>4</td>
</tr>
<tr>
<td>LNG Releases, Vapor Dispersion, and Consequence Analysis</td>
<td>5</td>
</tr>
<tr>
<td>LNG Marine Terminal and LNG Shipping Operations</td>
<td>6</td>
</tr>
<tr>
<td>Risk Management and Reliability</td>
<td>7</td>
</tr>
<tr>
<td>Mechanical, Materials, and Corrosion Engineering</td>
<td>8</td>
</tr>
<tr>
<td>Structural, Civil, and Construction Management</td>
<td>8</td>
</tr>
<tr>
<td>Air and Water Emissions &amp; Environmental Sciences</td>
<td>9</td>
</tr>
<tr>
<td>Selected Project Experience</td>
<td>10</td>
</tr>
<tr>
<td>LNG Publications and Presentations</td>
<td>12</td>
</tr>
<tr>
<td>Professionals</td>
<td>15</td>
</tr>
<tr>
<td>Office Locations</td>
<td>29</td>
</tr>
</tbody>
</table>
Company Profile

Exponent is a science and engineering consulting firm that solves complex technical problems. The Exponent name is widely recognized for integrity, objectivity, independence, and professionalism. Our core values drive a commitment to client service that enables us to deliver consistently high-quality work to clients worldwide. For nearly 50 years, we have provided engineering, scientific, environmental, and health consulting services to corporations, insurance carriers, government agencies, law firms, and individuals, assisting clients with their most important challenges and guiding them through their most dire disasters. We have investigated many of the most high-profile incidents over the last half-century including the grounding of the Exxon Valdez, the Phillips Petroleum Explosion in Pasadena, Texas, the attack on the World Trade Center, and the Buncefield Fuel Depot explosion. While Exponent is best known for analyzing accidents and failures in order to determine their causes, we are also active in assisting clients with human health, environmental, engineering, and regulatory issues associated with new products or processes to proactively help prevent future problems.
Practice Areas and Industries

Exponent’s multidisciplinary organization of over 900 scientists, physicians, engineers, and regulatory consultants combines more than 90 technical disciplines to address complicated issues facing industry and government today. Our integrated practices offer a multifaceted perspective that leads to innovative solutions that produce bottom line results. Our network of U.S. and international office locations provides broad expertise and capabilities:

**Engineering**
- Biomechanics
- Biomedical Engineering
- Buildings & Structures
- Civil Engineering
- Construction Consulting
- Electrical Engineering & Computer Science
- Engineering Management Consulting
- Human Factors & Industrial Engineering
- Industrial Structures
- Marine Engineering, Naval Architecture & Nautical Science
- Materials & Corrosion Engineering
- Mechanical Engineering
- Polymer Science & Materials Chemistry
- Statistical & Data Sciences
- Thermal Sciences
- Vehicle Engineering

**Industries**
- Chemical
- Construction & Infrastructure
- Consumer Electronics
- Consumer Products
- Defense
- Electronics, Security & Information Technology
- Food & Beverage
- Life Sciences & Healthcare
- Manufacturing Technology & Industrial Equipment
- Marine and Shipping
- Oil & Gas
- LNG
- Transportation
- Utilities

**Health & Environmental Sciences**
- Chemical Regulation & Food Safety
- Ecological & Biological Sciences
- Environmental & Earth Sciences
- Health Sciences
Liquefied Natural Gas Services

Exponent has broad experience with the liquefied natural gas (LNG) industry and assists with failure analysis, engineering design reviews, third-party technology evaluation, research and development, and process hazards and risk assessments associated with LNG facilities and operations. Our engineering and scientific expertise includes investigating and modeling the failures and potential hazards and risks posed by natural gas, LNG, and all associated streams or equipment (pumps, valves, flares, etc.) from production through the liquefaction process, storage, transportation, and use.

Throughout our history, we have provided consulting services to most of the major international oil and gas companies, in all aspects of their operations. Exponent has also developed particular expertise in the LNG industry over the last 15 years by working with owners and operators on the development of import and export facilities and of small scale LNG applications. With our experience analyzing complex projects and evaluating thousands of failures, Exponent is a leader in loss investigation and failure analysis, with investigations ranging from small incidents to high-loss disasters for major exploration and production companies. Because of this knowledge, we are able to assist proactively with design assessments, health studies, environmental evaluation, and regulatory compliance. The value Exponent brings to its LNG, oil, and gas clients includes:

- Proven experience on high-profile projects—often in a dispute resolution setting.
- Deep, functional knowledge of fundamental engineering disciplines, including mechanical, structural, metallurgical, materials, chemical, electrical, and others.
- Scientific depth in environmental and health perspectives.
- Convergence of our skills in risk, reliability, and vulnerability analyses.

Exponent engineers and scientists have unique insights into various risk and reliability, environmental impact, and health assessments that help clients improve safety practices and procedures for their personnel, processes, and facilities while minimizing operational disruptions and property loss. Additionally, our expertise in risk assessment, release characterization, dispersion modeling, vapor-cloud explosion analysis, industrial hygiene, toxicology, and epidemiology allows us to comprehensively examine the consequences of both hypothetical and actual releases of toxic and flammable substances. Our expertise in site investigation, environmental fate and transport, modeling, and remediation allows us to provide groundwater and soil remediation support as needed.

Exponent’s LNG services in the following areas are further described in the subsequent sections:

- LNG Release, Vapor Dispersion, and Consequence Analysis
- LNG Marine Terminal and LNG Operations
- LNG Shipping
- Risk Management and Reliability
- Fires, Explosions, and Incident Investigations
- Mechanical, Materials, and Corrosion
- Structural, Civil, and Construction Management
- Environmental, Atmospheric, and Health Sciences
LNG Releases, Vapor Dispersion, and Consequence Analysis

Liquefaction processes typically contain large inventories of cryogenic and/or pressurized liquid flammable refrigerants. More so than natural gas, flammable refrigerants may pose vapor cloud explosion overpressure hazards to onsite and offsite populations. Therefore, safe land-use planning for LNG facilities requires quantifying thermal radiation, vapor dispersion, and vapor cloud explosion hazard exclusion zones and demonstrating acceptable risk to people or property outside the plant. Exponent has considerable expertise in:

- Reviewing the hydraulic design of trenches, troughs, and containment basins.
- Characterizing the behavior of pressurized liquid/vapor flashing jets and liquid rainout.
- Using integral model-based vapor dispersion for screening studies and conservative analyses.
- Vapor dispersion modeling in complex terrains and environments using computational fluid dynamics (CFD).
- Quantifying the effect of mitigation strategies on vapor dispersion.
- Estimating the thermal radiation from pool fires and jet fires.
- Analyzing vapor cloud flash fire and quantifying the resulting explosion overpressure.

Exponent is active in LNG safety-related research and scholarly activities, authoring many technical papers for industry over the last several years. As a part of an industry-sponsored project, Exponent developed an experimental facility to perform controlled and repeatable experiments to study the behavior of LNG spills on water. Exponent has developed quantitative data and improved physical models for these factors.

Exponent has also performed numerical simulations and published research on LNG propagation in trenches and impoundments and studied the effects of substrate thermal properties on the evaporation rate of LNG. As part of this work, Exponent developed an in-house liquid propagation model validated with CFD calculations. This research provides guidance to LNG facilities on the proper design of LNG spill conveyance systems. In addition, Exponent has researched the effect of vapor fencing as a passive mitigation strategy to limit the extent of a flammable vapor cloud resulting from a loss of containment. Exponent’s models have assisted clients in applying passive mitigation strategies like this to their facility designs. Because of our extensive knowledge of the processes involved in vapor dispersion, Exponent is the author of the vapor dispersion book chapter in the latest edition of the Society of Fire Protection Engineers (SFPE) handbook, which is the leading reference for fire protection engineers.

Exponent has leveraged its experience with the LNG physical models and experimental results, combining this experience with mathematical models to effectively bound the potential consequences as a result of a worst-case release scenario during the design stages for LNG facilities of multiple scales. Exponent routinely optimizes parametric studies using CFD and other mathematical model tools to aid clients in the economical design of LNG facilities. Parametric studies have been guided by Exponent’s experience and knowledge of local regulatory criteria, e.g., those posed by PHMSA, FERC, CFR, CRE, ASEA, and SEMARNAT.
LNG Marine Terminal and LNG Shipping Operations

Safe and cost-effective transportation of LNG by sea, including safe loading and unloading of LNG cargoes is fundamental to the LNG value chain.

Exponent’s Marine Team comprises Master Mariner, Marine Engineers and Naval Architect, based in London, delivering hands on marine operational, marine engineering and naval architecture expertise with experience of LNG Marine terminal operations, LNG ship operations and maintenance, LNG ship design and build and LNG terminal development projects. Our expertise also encompasses LPG shipping and transportation.

Our Marine Team provides in depth practical knowledge of port operations, including pilotage, escort, support craft and safety or exclusion zones; ship/shore interface, including mooring and mooring analysis; cargo measurement and custody transfer; loading and discharge of LNG cargo; contingency planning and emergency response; and ship to ship (STS) LNG cargo transfer operations.

With our engineering knowledge and experience we can consider the practical and theoretical aspects of all types of machinery, electrical, control and systems failures, including cargo handling and conditioning as well as malfunctions and the actions of the Master, crew, terminal staff, ship managers, ship owners and other relevant stakeholders. The Marine Team’s knowledge and experience also encompasses more general types of shipping incidents including groundings, collisions, allisions, fires and explosions and personal injury. We are also able to advise on damage repair costs and methodology for ships and marine facilities.

The Marine Team’s skillsets include newbuilding, design, classification and approval for ships and their systems including, for example, firefighting and safety systems.

With nautical, marine engineering and ship construction proficiency in addition to well-developed investigative skills, the Marine Team can determine the causes of failures, incidents or accidents in LNG marine terminals, on LNG ships and support craft or during port approach and maneuvering. Experience of major LNG projects enables the ability to offer review of Front End Engineering Design (FEED) or outline proposals from a shipping and marine operations perspective to assist in the determination of risk or feasibility of plans and suggested mitigations or improvements. Naval Architecture, marine engineering, ship construction and ship classification expertise together with marine and marine terminal operational experience enable the team to assist with all facets of LNG transportation by sea.

As part of Exponent’s multidisciplinary organization, the Marine Team enhances the considerable LNG expertise available within Exponent such that all parts of the LNG value chain are effectively addressed.
Risk Management and Reliability

Effective risk management addresses business, technical, and safety issues in the LNG, oil, and gas industries. With experience in analyzing thousands of failures, Exponent provides unique, advanced services in performing risk and reliability assessments. The primary focus of our scientists and engineers is minimizing bottom-line losses in a client’s business or operation. Accidents, unanticipated events, and system failures are the primary causes of production interruptions and may lead to property damage or chemical releases as well as personal injury or loss of life.

Our staff uses traditional and innovative situation-specific methods and tools to identify risk scenarios and their causes, consequences, and likelihood. Client need dictates methodology, which may include:

- Process hazards analysis (HAZID, What If, HAZOP)
- Layer of Protection Analysis (LOPA)
- Fault Tree or Event Tree Analysis (FTA, ETA)
- Failure Mode and Effects Analysis (FMEA)
- Quantitative Risk Analysis (QRA)
- Transportation Risk Analysis
- Consequence modeling
- Mechanical integrity assessment
- Thermal stress analysis
- Heat transfer analysis
- Blast overpressures and structural assessments
- Fire and explosion analysis
- Facility siting
- Human factors analysis
- Failure/accident investigation
- Offshore platform hazards analysis

Fires, Explosions, and Incident Investigations

Our staff has combined experience on thousands of projects investigating failures involving petrochemical, chemical, and oil and gas installations and fire protection systems as well as the origin and cause of structural, wildland, vehicle, and industrial fires and explosions. Such investigations are a core competency of Exponent and often involve testing and sophisticated computer analyses using computational fluid dynamics (CFD) or process simulation tools.

Our personnel are often called upon to ensure that facilities, buildings, processes, and equipment are compliant with chemical, fire, and explosion safety requirements and accepted codes, standards, practices, and guidelines. Our proactive work includes fire protection engineering for new buildings and structures, asset integrity management in the oil and gas industry, chemical process safety and risk analysis consulting, and regulatory and engineering consulting for the LNG Industry. Exponent’s team also consults on combustion systems such as boilers, heaters, furnaces, and turbomachinery (gas turbines, compressors, expanders), as well as HVAC equipment. Our consultants also address thermal management issues related to batteries and energy storage technology.

Our fire and explosion investigation team comprises a diverse group of professionals with backgrounds in mechanical engineering, chemical engineering, and fire protection engineering. Most of our consultants are registered professional engineers and accredited fire investigators who are nationally and internationally recognized leaders in the development and implementation of innovative approaches in safety and regulatory compliance and major accident investigation and
prevention. Many serve on code-making standards committees for national and international organizations, including the NFPA, ASTM, UL, and ASME.

Mechanical, Materials, and Corrosion Engineering

Exponent’s mechanical engineering staff analyzes how failures occur in mechanical systems, processes, and equipment and why they may occur in the future. Exponent’s materials & corrosion engineering staff is uniquely suited to investigate and understand issues facing the LNG industry. Because our staff combines the deep expertise of our mechanical, civil/structural, electrical, and chemical engineers with statisticians, chemists, and polymer scientists, we can provide a comprehensive, integrated approach to complex challenges. Our broad perspective on materials issues across industries and applications provides value to our clients through our ability to solve complicated problems quickly and accurately.

Exponent’s materials & corrosion engineering staff hold professional licenses in metallurgical, mechanical, electrical, corrosion, and chemical engineering. Collectively, our metallurgists, polymer and corrosion scientists, electrochemists, and ceramists have many years of experience in the prevention and analysis of material failures. As a result of this close familiarity with all types of materials, our scientists and engineers have a unique ability to provide advice on how to avoid problems early in the design cycle when materials are being selected.

Structural, Civil, and Construction Management

Industrial structures such as those involved in the LNG industry constitute the infrastructure of our energy, petrochemical, agriculture, and manufacturing sectors. These structures differ from the general building stock, because their form and function are integral. Their function is often to support and contain industrial processes that would constitute extreme loads for common buildings, be it thermal extremes, intense pressure, or highly corrosive/toxic materials. Because of this, gaining a thorough understanding of the performance of industrial structures requires a multi-disciplinary, holistic approach that incorporates the expertise of structural, chemical, and mechanical engineers, as well as materials scientists.

Some services Exponent provides in these areas include identification of construction defects; damage assessment due to hurricanes, earthquakes, and other disasters; building envelope studies; evaluation of material performance; structural health monitoring; and cause and origin analyses. We often arrive onsite to investigate construction accidents within hours of the incident. Our cause and origin evaluation involves determining the failure’s technical cause(s) and contributing factors and often includes evaluating the roles and responsibilities of architects, engineers, and other parties involved in the design and construction process. We also conduct peer reviews for complex structures. Exponent guides clients throughout the entire project lifecycle: risk management, project planning and oversight, management oversight, and dispute resolution. We apply this expertise proactively to anticipate potential problems and propose remedial actions. We also apply expertise retrospectively to identify project impacts and analyze the resulting schedule and cost implications.
Air and Water Emissions & Environmental Sciences

Our environmental scientists and engineers perform cost-effective, scientifically defensible assessments of complex situations and provide realistic solutions to multifaceted problems. We offer technical, regulatory and litigation support to industries that include oil and gas, mining and minerals, chemicals, forest products, railroads, and aerospace, as well as trade associations and municipal and government clients. Our consultants specialize in environmental fate and transport, environmental chemistry and forensics, hydrogeology, air toxics, modeling and monitoring, water quality and water supply, data analytics, remediation consulting, environmental engineering and waste management, climate impacts, and evaluation of environmental and social risks. Our work often involves complex and high-visibility environmental issues, often the focus of environmental or toxic tort claims, where evaluation of contamination and historical reconstruction of events, releases, and doses, as well as water resource concerns are central to problem resolution. We provide strategic and advisory consulting on risk mitigation, planning, and regulatory issues.

Exponent also provides unparalleled, interdisciplinary expertise to evaluate the full range of environmental, occupational, and public health issues that face our nation and the world. These issues include potential health effects associated with environmental agents, chemicals, consumer products, food, and pharmaceutical products. Members of our staff are leaders in developing essential risk assessment methodologies to address the complexities of these health issues. Our national and international clients rely on us for incisive and objective assessments that address physical, chemical, and biological phenomena to arrive at reliable solutions for making important decisions.

The Center for Health Sciences is organized into the following specialties:

- Atmospheric Sciences
- Epidemiology & Computational Biology
- Occupational & Environmental Health Risk Assessment
- Toxicology & Mechanistic Biology

By working with members of a variety of technical disciplines throughout the firm, including both environmental scientists and engineers, we are able to leverage Exponent's unparalleled range of expertise to meet our client's needs most effectively. Whatever your resource needs, Exponent can augment your regulatory, legal, and scientific team and provide flexible, strategic consulting, while maintaining our adherence to the highest scientific and ethical standards of performance.
Selected Project Experience

Exponent has assisted numerous LNG clients in their development, facility siting, process safety management, and risk analyses regarding LNG projects. Projects have focused on small liquefaction facilities, risk analysis of LNG use as a rail transportation fuel, over the road and rail transportation of LNG, and large scale import and export facilities. Below is a list of some of the more significant import and export facilities that Exponent has assisted. Additional project examples can be provided upon request.

**Energía Costa Azul LNG Terminal, Ensenada, Baja California, Mexico**
Provided engineering analysis and modeling of flammable refrigerants and LNG vapor dispersion, cryogenic liquid conveyance, explosion overpressure, and risk analysis.

**Port Arthur LNG Terminal, Port Arthur, TX**
Provided engineering analysis and modeling of flammable refrigerants and LNG vapor dispersion, cryogenic liquid conveyance, and explosion overpressure.

**Cameron LNG Terminal, Hackberry, LA**
Provided engineering analysis and modeling of flammable refrigerants and LNG vapor dispersion, cryogenic liquid conveyance, explosion overpressure, and cool-down procedures.

**Freeport LNG Terminal, Quintana Island, TX**
Provided engineering analysis and modeling of LNG vapor dispersion and expected overpressures during explosion scenario.

**EcoEléctrica LNG Terminal, Peñuelas, PR**
Provided engineering analysis and modeling of LNG vapor dispersion.

**Downeast LNG Terminal, Passamaquoddy Bay, ME**
Provided engineering analysis and modeling of LNG vapor dispersion.

**Sound Energy Solutions Long Beach LNG Terminal, Long Beach, CA**
Provided engineering and technical support for the site permit application process.

**Suez LNG Neptune Deepwater Port, Offshore of Boston, MA**
Provided third-party safety and security reviews of fire and vapor dispersion analyses.

**Excelerate Energy Northeast Gateway Energy Bridge Deepwater Port, Offshore of Boston, MA**
Provided third-party safety and security reviews for fire and vapor dispersion analyses.

**Cheniere Energy Sabine Pass LNG Terminal, Cameron Parish, LA**
Provided engineering support and dense-cloud dispersion modeling.
The Center for Liquefied Natural Gas
Assessed the actual impact of open-rack vaporizers on marine life in the Gulf of Mexico (mainly fish eggs and larvae) and concluded that the impacts will be even less than the minimal impacts predicted in the environmental impact statement (see complete report at http://www.lngfacts.org/newsroom/Eval-OLV.pdf)

Port Acres-Keith Lake Transmission Line
Provided modeling of electric and magnetic fields and other assistance for permitting a transmission line to support a proposed LNG site.

Skikda, Algeria, Explosion
A team of Exponent engineers investigated the natural gas liquefaction facility accident that occurred on January 19, 2004, in Skikda, Algeria. The accident incapacitated three LNG lines, affected approximately 2% of the world’s liquefaction capacity, and resulted in 27 fatalities.

Tangguh LNG Projects and Plant, Indonesia
Performed a consequence analysis for large LNG storage facilities. Also conducted fire and explosion analysis for the LNG plant. Performed a QRA to support the sanction process for the TANGGUH LNG project under development by a consortium led by British Petroleum.

Pyongtaek LNG Terminal
Korea Gas Corporation Pyongtaek LNG Terminal, Pyongtaek, Republic of Korea—Exponent staff performed a hazard analysis and QRA for this LNG receiving terminal and regasification operation.

Inchon LNG Terminal
Korea Gas Corporation Inchon LNG Terminal, Inchon, Republic of Korea—Exponent staff performed a hazard analysis and QRA for this LNG receiving terminal and regasification operation. Terminal is situated on reclaimed land. Risk analysis included a proposed liquefied petroleum gas facility proposed near the terminal.

Probabilistic Safety Assessment, Major Gas Company, South Korea
Exponent staff performed a preliminary hazards analysis (PrHA), followed by a probabilistic safety assessment, of a major gas company in South Korea. The scope of the safety assessment involves a marine terminal, associated pipelines, and numerous valve stations (both aboveground and underground). Subsequent to the PrHA, a detailed QRA was done on selected scenarios using fault-tree/event-tree analysis and dispersion modeling to assess the frequencies and consequences of potential natural gas releases and subsequent fires and explosions.

MEGA Project
Exponent staff performed Phase I and II QRA and HAZOP studies for a natural gas liquid recovery and separation plant constructed in Loma La Lata and Bahia Blanca, Argentina, and connecting NGL pipeline (600 km).
LNG Publications and Presentations

Exponent staff is actively engaged in the LNG industry and associated oil, gas, and chemical industries through industry-related technical standards committees, technical conference leadership, and technical publications and presentations. The following list represents many of Exponent’s technical contributions relevant to the LNG industry.


Morrison DR. *Identifying and managing the risks of LNG in rail*. 3rd Annual Natural Gas for Off-Road Applications USA 2015, Houston, TX, June 2-3, 2015.


Ponchaut NF, Kytömaa HK, DesAutels C, Kaganoi S, Becu O, Cardiff G. **Modeling of ground flare pits.** AIChE Spring Meeting, 12th Topical Conference on Gas Utilization, Houston, TX, April 2012.

Ponchaut NF, Ibarreta AF, Kytömaa HK. **Modeling of LNG spills into trenches and troughs.** AIChE Spring Meeting, 12th Topical Conference on Gas Utilization, Houston, TX, April 2012.


Ponchaut NF, Kytömaa HK, Morrison DR, Chernovsky MK. **Modeling the vapor source term associated with the spill of LNG into a sump or impoundment area.** Journal of Loss Prevention in the Process Industries; November 2011; 24(5):870–878.

Ponchaut NF, Kytömaa HK, Ibarreta AF. **Modeling the vapor source associated with spills of LNG into troughs and trenches.** AIChE Spring National Meeting, 11th Topical Conference on Gas Utilization, Chicago, IL, March 2011.

Ponchaut NF, Kytömaa HK, Morrison DR, Chernovsky MK. **Modeling the vapor source associated with the spill of LNG into a sump or an impoundment area.** Mary Kay O’Connor Process Safety Center. 2010 International Symposium, College Station, TX, October 2010.

Ponchaut NF, Kytömaa HK. **Cooldown of large pipes during the commissioning phase of cryogenic facilities.** AIChE Spring Meeting, 10th Topical Conference on Natural Gas Utilization, San Antonio, TX, March 2010.


Ponchaut NF, Kytömaa HK. **Transient spreading of LNG on water.** Mary Kay O’Connor Process Safety Center. 2009 International Symposium, College Station, TX, October 2009.

Ponchaut NF, Chernovsky M, Gavelli F, Kytömää HK. **Modeling the spreading of large LNG spills on water.** AIChE Spring Meeting, 9th Topical Conference on Natural Gas Utilization, Tampa, FL, April 2009.


Kytömaa H, Gavelli F. **Studies of LNG spills over water point up need for improvement.** Oil Gas J 2005; May 9.
Dr. Kytömaa is the leader of Exponent’s LNG Services Team. Dr. Kytömaa's LNG project experience includes thermal stress analyses, LNG spill dynamics, and flammable vapor dispersion. He specializes in mechanical engineering and the analysis of thermal and flow processes. He applies his expertise to the investigation and prevention of failures in mechanical systems. He also investigates fires and explosions and their origin and cause. He consults in the utilities, oil and gas, and chemical industries.

Dr. Kytömaa has decades of experience in the area of dynamics and thermal hydraulics of piping systems, valves and pipelines. He has developed flow modeling tools for such systems and their components and has applied these to drilling and downhole applications. He pioneered the modeling of the acoustics of drilling fluid piping systems for acoustic telemetry and Measurement-While-Drilling (MWD), which was one of the enabling technologies for directional drilling. Dr. Kytömaa has also developed ultrasonic techniques for both medical and engineering applications, including instrumentation for flow measurement and the characterization of dense suspensions.

Dr. Kytömaa was Assistant Professor and Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology, where he was head of the Fluid Mechanics Laboratory. He has also held positions as Visiting Professor at the Helsinki University of Technology and at the DOE Pacific Northwest Laboratory in Washington, and served as Lecturer at the Worcester Polytechnic Institute. Dr. Kytömaa consulted for Teleco Oil Field Services, Inc., developing MWD technology and other downhole applications.
Dr. Morrison's practice areas encompass chemical engineering, process engineering, and process safety management through hazard and risk analysis, failure analysis, and post-incident investigation. He specializes in evaluations of origin, cause, and engineering issues related to catastrophic incidents involving fires, explosions, and chemical process technology. His project experience includes analyzing the effects of chemical process design, plant operator actions, control system response, and process unit response during upset situations and operations that may lead to a hazardous loss of containment.

As part of Dr. Morrison's proactive safety consulting services, he leads hazard and risk assessments using industry-accepted process hazard analysis (PHA) methods such as HAZOP studies, What-If studies, and LOPA studies, combined with analytical techniques such as Fault Tree Analysis, Event Tree Analysis, Root Cause Analysis, Consequence Analysis, and Quantitative Risk Assessment. He routinely applies this expertise to risk analysis for natural gas, LNG, propane, and other gas processing facilities.

Dr. Morrison is an active professional in the chemical process safety community. In addition to his technical committee memberships, international presentations, and publications, he serves in leadership roles in the field of chemical process safety through process safety conferences sponsored by the American Institute of Chemical Engineers in North America and in Latin America. Dr. Morrison has chaired many industry conferences including the 45th AIChE Loss Prevention Symposium in 2011, the 8th Global Congress on Process Safety in 2012, the 5th Process Safety Management Mentoring Forum in 2016, and the 7th Latin American Conference on Process Safety in 2016. The objectives of these activities are to aid in the prevention of major loss incidents that involve fires, explosions, runaway reactions, and hazardous material releases in the chemical, petrochemical, and related industries.
Dr. Paulsen has 24 years of experience with projects involving hydrodynamics, aquatic chemistry, and the environmental fate of a range of constituents. She has provided expert testimony on matters involving the Clean Water Act and state water quality regulations, and she also provides scientific and strategic consultation on matters involving Superfund (CERCLA) and Natural Resources Damages (NRD). She has expertise designing and implementing field and modeling studies of dilution and analyzing the fate and transport of organic and inorganic pollutants, including DDT, PCBs, PAHs, copper, lead, and selenium, in surface and groundwater and in sediments.

Dr. Paulsen has designed and implemented field studies in reservoir, river, estuarine, and ocean environments using dye and elemental tracers to evaluate the impact of pollutant releases and treated wastewater, thermal, and agricultural discharges on receiving waters and drinking-water intakes. Dr. Paulsen has designed and managed modeling studies to evaluate transport and mixing, including the siting and design of diffusers, and has evaluated water quality impacts of stormwater runoff, irrigation, wastewater and industrial process water treatment facilities, and desalination brines. Dr. Paulsen has extensive knowledge of California water supply issues, including expertise in California's Bay-Delta estuary, the development of alternative water supplies, and integration of groundwater basins into supply and storage projects.

Dr. Paulsen has designed studies using one-dimensional hydrodynamic models (including DSM2 and DYRESM), three-dimensional CFD modeling, longitudinal dispersion modeling, and Monte Carlo analysis. Dr. Paulsen has participated in multi-disciplinary studies of the fate and transport of organic and inorganic pollutants, including DDT, PCBs, PAHs, copper, lead, selenium, and indicator bacteria in surface waters, groundwaters, and/or sediments. She has worked on matters involving both CERCLA and NRDA, including several involving the fate and transport of legacy pollutants, and she has evaluated the impacts of oil-field operations on drinking-water aquifers.

Dr. Paulsen has broad expertise with water quality regulation through the Clean Water Act and state regulations in California, Washington, Hawaii, and other states, and has worked on temperature compliance models, NPDES permitting, permit compliance and appeals, third-party citizens' suits, and TMDL development. She has evaluated the importance of background and natural sources on stormwater and receiving-water quality and the development of numeric limits for storm flows and process-water discharges. Dr. Paulsen is the author of multiple reports describing the history and development of water quality regulations and has provided testimony on regulatory issues, water quality, and water rights.
Dr. Schulman is a Certified Consulting Meteorologist with over 40 years of experience in the development, evaluation, and application of air quality models. He co-developed the building downwash algorithm currently recommended by the U.S. EPA for regulatory use. He has conducted air quality analyses for a wide range of sources and industries including power plants, oil refineries, chemical plants, offshore platforms, smelters, asphalt plants, landfills, incinerators, natural gas pipelines, and paper mills and involving emissions such as toxic chemicals, odors, and dense gases. Other work has involved the design and siting of data measurement systems and forensic meteorological studies.

Dr. Schulman was also a co-developer of the Buoyant Line and Point Source model for aluminum reduction plants and managed the development of the Offshore and Coastal Dispersion model, which is applied to pollutant releases over water. These models have also been recommended by the EPA for regulatory use.

As part of his interest in micro-scale and urban-scale air flow, Dr. Schulman has been involved in applying the computational fluid dynamics models FLUENT, STAR-CCM+, OpenFOAM, and FLOW-3D. These numerical models were used to simulate the effect of wakes near structures. Some of the applications have included wind forces on buildings during a hurricane, design of wind fences to mitigate wind-blown fugitive dust, two-phase accidental releases of dense gases from railcars or vents, fogging and recirculation of exhausts from mechanical draft cooling towers, plume rise from air-cooled condensers, the effect of structures on wind turbines, and the contamination of fresh-air intakes by rooftop vent emissions.
Mr. Ritti is the Director of Exponent's Construction Consulting practice. He advises construction clients on a range of topics including risk management, project governance, project controls, change management, project scheduling, contract review and assessments, process improvement, change order negotiations, dispute avoidance, and the development or defense of construction claims. His experience with construction disputes includes the development, analysis and defense of construction claims related to scheduling, inefficiencies, and cost overruns. He has analyzed owner, contractor, and designer performance and allocated responsibility for project impacts on a wide variety of projects. He has developed as-planned schedules, prepared and analyzed as-built schedules, and utilized numerous schedule analysis techniques to quantify delay.

Mr. Ritti has provided risk analysis services to large construction owners and contractors including contract risk assessments, probabilistic scheduling, Monte Carlo simulations, and schedule and cost assessments. He has provided project management oversight and construction management services, structured project control systems, conducted construction audits, and developed project status reviews.

Mr. Ritti's construction project experience includes casinos, vertical construction, commercial structures, residential structures, power plants, offshore and onshore oil and gas facilities, pipelines, wastewater treatment facilities, highways and bridges, tunneling and light rail. Mr. Ritti's clients have included corporate entities, public agencies, contractors and subcontractors, architectural and engineering firms, insurance carriers, and attorneys.

Mr. Ritti has participated in the successful negotiation of numerous disputes, and has testified on construction schedule and cost issues in mediation, dispute resolution board hearings, arbitration and trial.

Prior to joining Exponent, Mr. Ritti worked in the Construction Risk and Dispute Resolution practice for PriceWaterhouseCoopers, LLP, the Capital Project Consulting practice for KPMG, LLP, and the Litigation Consulting practice for FTI Consulting, Inc. Additionally, Mr. Ritti developed a professional services offering for a technology firm in the construction industry and worked for a general contractor on commercial and residential projects.
Dr. Bailey is a licensed Professional Engineer and Fellow of the American Society of Civil Engineers. For over 30 years, Dr. Bailey has served as a technical consultant, project manager, and researcher for private industry, universities, and government. As a Senior Managing Engineer in Exponent’s Building & Structures practice, he brings specialized expertise to areas related to wind engineering, construction materials, solid mechanics, dynamics, numerical analysis, structural analysis and design, and materials testing.

Dr. Bailey’s primary area of expertise is determining the risk exposure of residential, commercial, and industrial properties to hazards associated with hurricanes, tornadoes, and flooding. He has conducted hurricane risk assessments and developed mitigation programs for various types of health, industrial, educational, and offshore energy facilities. Over the past 15 years he has conducted field surveys to document storm damage in the aftermath of hurricanes Irene (1999), Charley (2004), Katrina (2005), Rita (2005), Wilma (2005), Ike (2008), and Sandy (2012), Tropical Storm Allison (2001), the Oklahoma City Tornado (1999), and the April-May 2011 Tornado Outbreak.

Dr. Bailey’s past work at ExxonMobil included estimating wind loads on drilling structures, developing conceptual designs of gravity-based structures for arctic offshore environments, and conducting research and teaching classes on well cementing. He also has extensive experience working with FEMA under the Public Assistance Program following Tropical Storm Allison (2001-2004), Hurricane Katrina in Louisiana (2005), and Hurricane Rita in Texas (2005-2006).

Dr. Bailey recently conducted an analysis of the storm surge risk posed to the South Texas Project Electric Generating Station using advanced hydrodynamic modeling techniques, and subsequently presented the results to the NRC.

Dr. Bailey has served as a lecturer in the private sector and at the university level on subjects related to wind and petroleum engineering. He also has been responsible for the design of test facilities and the development of test programs related to construction and energy. Dr. Bailey is currently the Presiding Officer of a five member expert panel, appointed by the Texas Department of Insurance in 2013, whose purpose is to develop ways of determining whether a loss to TWIA-insured property was caused by wind, waves, or tidal surges. He is also a member of the ASCE 7-16 Wind Load Subcommittee. He is past Chair of the ASCE Petrochemical Wind Load Task Committee, and served on an API 4F sub-committee assigned to revise specifications and guidelines for determining wind loads on onshore and offshore drilling structures.
Dr. Medhekar's practice focuses on addressing risk and reliability issues. Dr. Medhekar specializes in evaluating technologies and manufacturing operations, and reviewing process/product designs for the purpose of proactive reduction of failures and hazards. He conducts FMEA, PHA, HAZOP, MTBF, reliability, root cause, fault tree, event tree, and uncertainty analyses.

Over the last 10 years, Dr. Medhekar has provided risk assessment and management consulting services to various Automotive OEM's and Tier 1 suppliers, Semiconductor, Medical and Biomedical, Chemical/Petrochemical, Nuclear Power, and various other Manufacturing facilities. He has authored or coauthored more than 50 technical publications/reports and presented a number of papers and short courses with topics ranging from performing complex reliability investigations, identifying and managing risks under PSM/OSHA Act, practical FMEAs for product design, performing risk and reliability assessments for automotive, semiconductor, biomedical, and process industries, pipeline risk assessments, fault tree analysis, source term modeling, and Bayesian uncertainty analysis.

Dr. Medhekar also uses his expertise as a chemical engineer in the investigation and prevention of accidents, with particular emphasis on safety and risk. He provides consulting services to the chemical and petrochemical process (LNG/NG and Refinery sector) industries, specializing in the safety/risk-based evaluation/investigation of process failures, such as process upsets/explosion/fire incidents, at chemical processing and petroleum refining facilities. Dr. Medhekar's projects have involved a wide range of equipment including chemical reactors and separation systems; pressure vessels, piping, pumps and compressors; furnaces and heat exchangers; railcars and tanker trucks; and pressure relief valves and emergency relief systems.

Prior to joining Exponent, Dr. Medhekar held a variety of consulting and engineering positions with companies that include PLG, Inc. in Newport Beach, California; the Center for Risk Studies and Safety in Santa Barbara, California; Indian Oil Refinery in Baroda, India; and Union Carbide in Thane, India.
Dr. Johns specializes in the transport and fate of environmental pollutants, remediation, and cost allocation and apportionment. He has been the principal investigator on numerous remedial investigations and feasibility studies and has an extensive background in site remediation and cleanup. Dr. Johns has over 30 years of experience in the fields of geology, groundwater, and geological oceanography. He has been responsible for the technical direction of several large CERCLA-, TSCA-, and RCRA-related environmental studies pertaining to heavy metals, dioxins, PCBs, hydrocarbons, and chlorinated solvents. These studies have involved mine sites, petrochemical facilities, refineries, pipelines, and manufacturing sites throughout the U.S., South America, Australia, Europe, and the Middle East.

Dr. Johns has assisted clients with evaluations of remedial approaches and costs and the influence of various site conditions. He has developed and applied innovative cost analysis tools using Monte Carlo uncertainty simulations to evaluate a range of probabilities and sensitivities involved in decision analysis, risk, and business planning purposes (i.e., litigation and insurance coverage).

As an expert witness in environmental transport and fate, Dr. Johns has provided expert testimony, reports, and declarations on the origin, fate, and transport of pollutants and the appropriateness of remedial cleanup and associated costs in soils, sediments, surface water, and groundwater. He has also provided expert assistance in evaluating compliance with the Clean Water Act (CWA), National Contingency Plan (NCP), and the allocation and appropriateness of remediation costs at a variety of sites.
Mr. Harling specializes in structural engineering with an emphasis on failure investigations and maintenance activities (inspection, acceptance) of antenna carriers. His experience includes investigations related to the flaws and failures of a variety of antenna carriers, concrete towers (large TV-towers / radio towers), pre-stressed centrifugally concrete masts, and steel masts (lattice and tube). He is also an expert in the area of special requirements of the extension of existing tower structures (chimneys, wind power stations) with antennas.

His background is basing on numerous static calculations, design reviews and assessment of structural behaviour of tower structures using nonlinear static and dynamic analysis techniques.

Mr. Harling is doing his doctorate about "Design of centrifugally concrete masts – Close to reality limitation of cracking and deformation" at the University of Dortmund, Germany. He is also a state-registered expert for antenna carrier structures (publicly appointed and sworn by the "Ingenieurkammer Bau NRW," March 2009).
Dr. James specializes in failure analysis, failure prevention, and integrity assessment of engineering structures and components. His specific expertise includes metallurgy, materials science, fracture, fatigue, material degradation, corrosion, life prediction, and design.

In his many years of engineering experience, Dr. James has conducted hundreds of failure analysis investigations on widely varying engineering structures, ranging from miniscule medical devices to power-plant components. Dr. James also helps clients from various industries prevent failures, assess the integrity of their designs or equipment, as well as interact with governmental agencies. Dr. James has special interest in fractography, fracture mechanics, wear, corrosion, embrittlement phenomena, microstructural development, heat treatment, material selection, and welding and joining. The common thread in each of Dr. James’ investigations is the application of metallurgical, materials science, and engineering mechanics fundamentals to help understand and solve complex problems.

Dr. James has taught several graduate-level fracture mechanics and failure analysis courses at Stanford and Santa Clara Universities. He has also taught several courses for The American Society for Materials (ASM International) involving failure analysis, design, and life prediction/validation of medical devices, and has been a Visiting Lecturer at San Jose State University. Prior to joining Exponent, Dr. James was employed as a Research Engineer, Materials Performance Division, at the Babcock and Wilcox R&D Center.
Mr. Dyson is a Marine Engineer with a Combined First Class Certificate of Competency. He has applied his seagoing experience to consulting by providing high level independent technical advice, predominantly concerning litigious disputes and major incidents, on a worldwide basis, with a primary focus on the London market.

Mr. Dyson has investigated a wide range of problems, incidents, and deficiencies in the areas of marine surveying and consulting since 1998. He has considerable experience of slow speed engines, medium-speed diesel, and diesel electric propulsion, as well as steam turbines and all associated plant. He has carried out surveys and provided opinions on matters including those related to machinery performance and failure, cranes (ship and shore), MARPOL, new building, pre-purchase, fuel quality, major structural damage, flooding, grounding, fire and technical management.

He has also managed and overseen a multitude of complex technical cases and investigations. In addition, he has assisted ship owners and managers by means of feeding back his knowledge and experience, in a pro-active manner, concerning issues such as environmental compliance, technical management, and holistic maintenance strategies.

As a marine consultant and surveyor, Mr. Dyson has provided his opinion and expert evidence in London Arbitrations, American, French, and Greek Courts, an International Arbitration held in Switzerland, and given oral evidence under Deposition in the United States.

Prior to joining Exponent, Mr. Dyson was a partner and business unit leader for a renowned marine consultancy in the UK. He was at sea over a period of thirteen years serving on LPG, LNG, crude, and product tankers, standing by the new building of a large diesel electric passenger vessel and sailing on board during, and subsequent to, commissioning.

He joined CIMAC (The International Council on Combustion Engines) in 2016 and became a member of the working group for Marine Lubricants.
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Dr. Ibarreta applies thermodynamics, fluid dynamics, and heat transfer principles to the study of combustion processes in fires, explosions, and a variety of combustion devices. He is a Certified Fire and Explosion Investigator and has investigated fires and explosions involving consumer products, residential and commercial buildings, and industrial facilities.

Dr. Ibarreta has evaluated the compliance of industrial facilities with NFPA standards, as well as state and federal codes for the prevention and mitigation of gas explosions. He has participated in Process Hazard Analyses (PHAs) and performed consequence modeling of flammable liquid / gas releases during the permitting and planning stages of LNG terminals and other oil & gas facilities. Dr. Ibarreta has employed Computational Fluid Dynamic (CFD) models, including FLACS, to calculate the consequences of flammable liquid/vapor releases, vented deflagrations, and unconfined vapor cloud explosions.

Dr. Ibarreta is a principal member of the NFPA's Technical Committee on Explosion Protection Systems. This committee is responsible for NFPA documents related to explosion protection systems for buildings and equipment, including NFPA 67 Guide on Explosion Protection for Gaseous Mixtures in Pipe Systems, NFPA 68 Standard on Explosion Protection by Deflagration Venting, and NFPA 69 Standard on Explosion Prevention Systems. Dr. Ibarreta is also the mechanical engineering representative at the Massachusetts Board of Fire Prevention Regulations. This board is responsible for amending and promulgating the comprehensive fire safety code (527 CMR) for the Commonwealth of Massachusetts.

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Dr. Colella specializes in the areas of fluid-mechanics, heat transfer, thermodynamics, fire dynamics and combustion. Application areas include fire and explosion investigations, failure analysis of industrial equipment, and flammable vapor dispersion. He has broad experience in the use and development of numerical codes for analyzing fluid dynamics and heat transfer problems applied to a large variety of fields including tunnel ventilation flows and fires, flammable releases and atmospheric dispersion, battery thermal management, wildland fires, enclosure fire dynamics, and a wide range of energy systems.

Dr. Colella also has significant experience in performance based fire protection engineering and in hands-on experimental investigations applied to tunnel ventilation, tunnel fires, car parks, and large industrial premises. Dr. Colella is currently principal member of the NFPA 502 committee (Standard for Road Tunnels, Bridges, and other Limited Access Highways) and also a member of NFPA 1700 committee (Guide for Structural Fire Fighting).

Prior to joining Exponent, Dr. Colella was a postdoctoral research assistant in the Energy Department at the Politecnico di Torino (Italy), and a research assistant at the BRE Centre for fire safety engineering at the University of Edinburgh (UK). For his doctoral thesis, he developed a multiscale 1D-3D CFD technique to reduce the computational time for tunnel fire safety applications. During his career, he carried out several CFD analyses of ventilation systems for various major tunnels in Europe including the Dartford tunnels (UK) and the Frejus tunnel (IT-Fr). As a consultant, Dr. Colella has been extensively involved in the design of the ventilation system of the new
Copenhagen subway system (DK) including tunnels, underground stations and caverns, as well as in the upgrade of the ventilation system in the Grand Saint Bernard tunnel (IT-SW).

**Ryan J. Hart, Ph.D., P.E.**
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Dr. Hart assists in the investigation and analyses of fires, explosions, and chemical process safety incidents. His investigations have focused on mid-scale to large-scale chemical production facilities, industrial material handling and processing facilities, power plants, refineries, and bio-fuel production facilities. The investigations have focused on fire and explosion cause analysis, origin determination, and evaluating root causes and contributory events covering the elements of process safety management. Additionally, Dr. Hart has experience in the design of high temperature and high pressure experimental techniques, chemical analysis, and analytical chemistry methodologies and interpretations.

Dr. Hart has also been trained in the use of the consequence and hazard analysis software tool PHAST. Dr. Hart has applied the PHAST tool and other consequence modeling methodologies in assisting clients with regulatory permit applications for LNG import/export terminals, assessing project risk in the pre-FEED stages of plant design, conducting facility siting studies, performing EPA Risk Management Plan (RMP) evaluations, evaluating natural gas blowdowns, and in fire and explosion investigations.

Dr. Hart is an active professional in local and national chemical process safety communities. In addition to his technical committee memberships and publications, he has served in leadership roles in the field of chemical process safety through process safety conferences sponsored by the American Institute of Chemical Engineers. Most recently, Dr. Hart chaired two sessions at the 8th Global Congress on Process Safety in 2012, which had approximately 100 domestic and international attendees from the fields of process safety and risk analysis attending both sessions. The focus of the sessions concerned the continuing development of operational discipline programs to reduce the overall risk of operating chemical process facilities.

**Patrick Lawson-Earley**
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Captain Lawson-Earley is a Master Mariner who sailed in command of crude oil tankers from AFRAMAX to VLCC. Since coming ashore, he has worked as a Marine Superintendent, Marine Consultant, Marine Advisor, Marine Manager for an LNG Shipowner and Marine Terminal Manager for LNG regasification terminals.

Captain Lawson-Earley has firsthand operational experience of refrigerated cargo ships, container ships, patrol vessels, high speed ferries, crude oil, black oil, product and gas tankers and offshore support vessels. He also has experience with LNG terminal development projects and management of LNG marine terminal operations. In addition, he is familiar with Floating Storage and Regasification Unit (FSRU), Floating Production and Storage Offshore (FPSO), oil LPG and LNG Ship to Ship transfer (STS) operations and offshore marine operations including rig moves, jacket and topsides installation, pipelaying, etc.
He has carried out surveys and audits of vessels for energy majors, including on-hire and off-hire surveys and in-service vessel inspections and is familiar with the requirements of OCIMF SIRE Program and OVID database, CDI and IMCA CMID. Captain Lawson-Earley has conducted audits and inspections of ports, marine terminals, ship owners, ship managers and ship operators for energy majors based upon OCIMF MTMSA and TMSA Programs. He is also thoroughly familiar with the requirements of PSC Inspections under various MoU's and MLC 2006.

He has conducted incident and accident investigations and follow-up on board ships, in terminals and on offshore assets to determine root cause, lessons learned, actions to prevent recurrence and confirm that recommendations are fully implemented. As Marine Manager and Marine Superintendent, Captain Lawson-Earley was the Designated Person Ashore (DPA) under International Safety Management (ISM) Code and served as Company Security Officer. He was also responsible for the development, updating and implementation of the Safety, Quality and Environmental Management Systems and is thus familiar with the requirements of the ISM Code and International Organization for Standards (ISO) safety, environmental and quality management systems such as ISO 9001, ISO 14001 and OHSAS 18001.

While working for energy majors, Captain Lawson-Earley served as a representative at OCIMF and Society of International Gas Tanker and Terminal Operators (SIGTTO) meetings and sat on committees including those responsible for drafting new recommendations for tanker manifolds and associated equipment and submissions to the IMO during development of the Polar Code.

**Morgan Reed, D.Eng.**

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Dr. Reed has extensive experience in the upstream, midstream, and downstream sectors of the oil, gas, and petrochemical industries. Within Exponent’s Thermal Sciences group, Dr. Reed specializes in analysis of fluid flow and combustion events with regards to process safety incidents. His assessment of flammable vapor and toxic gas dispersion, jet fires, pool fires, and vapor cloud explosions provides guidance to a wide variety of industrial clients for regulatory compliance and continuous improvement of their corporate process safety and risk management performance.

Dr. Reed’s primary area of expertise lies in modeling (analytical and Computational Fluid Dynamics) and development of studies including Fire Risk Assessment (FRA); Explosion Risk Assessment (ERA); Escape, Evacuation, and Rescue Assessment (EERA); and Helideck Availability. For the last several years, Dr. Reed has applied CFD analysis to a wide variety of risk problems associated with flammable vapor and toxic gas dispersion and vapor cloud explosions within enclosed modules, congested process units, and Liquefied Natural Gas (LNG) terminals.

Dr. Reed is active with local and national professional organizations including the American Chemical Society (ACS) and the American Institute of Chemical Engineers (AIChE). He has served as a technical reviewer for texts produced by the Center for Chemical Process Safety (CCPS) such as Guidelines for Process Safety Knowledge and Expertise and Guidelines for Siting and Layout of Facilities. He has also been a committee member for the development of the Evergreen LOPA/IPL Database and the text Guidelines for Inherently Safer Design. Dr. Reed is the 2016 Vice-Chair for the AIChE South Texas Section Young Professional Organization and will be the 2017 Chair.
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