



ALFRED M. PETTINGER, Ph.D., P.E.

PRINCIPAL

VICE PRESIDENT

ampettinger@engsys.com

Dr. Alfred Pettinger is a Principal and Vice President. His areas of expertise include mechanical behavior of materials, structural engineering, design, reliability, durability, operation, and maintainability. Dr. Pettinger has conducted design reviews, risk assessments, failure investigations, safety investigations, regulatory compliance reviews, cost estimates, and damage tolerance evaluations of offshore and onshore pipelines, metal and composite aircraft, machinery and mechanical equipment, vehicle components and industrial machinery, such as, pumps, actuators, hydraulic systems, gears, engines, bolts, fans, turbines, conveyors, and other processing equipment. He has also provided consulting services on patent validity for a variety of mechanical apparatuses and assisted manufacturers of consumer and commercial products with product recall decisions.

He has evaluated soil-pipe interactions, pipe vibration, pipe integrity, and pipe performance of pipelines, and piping systems for buildings and nuclear power plants. He has also been asked to evaluate personal injury accidents involving heavy machinery and equipment. He is also known for his work on insurance claims related to the transport of machinery and heavy equipment.

Dr. Pettinger's aerospace work focuses on structural engineering, damage tolerance, and failure analysis. He has worked on the fuselage and wing structure of commercial aircraft and business jets. He worked for the European aerospace industry on the design and analysis of various components, with a specialization in glass and carbon fiber reinforced composite components (GFRP, CFRP).

Dr. Pettinger has been recognized as an expert in various courts of the United States of America, submitted reports, and provided oral testimony. He has testified and participated in several arbitrations for complex matters. His practice focuses on large complex multidisciplinary investigations for a variety of stakeholders.

Areas of Specialization

Mechanical Engineering

Energy & Power

Oil & Gas

Structural Engineering

Product Design

Root Cause Investigations

Aviation

Reliability

Machinery Design

Transport

Pipelines

Safety & Maintenance

Product Recalls

Operation & Maintainability

Composite Materials

Repairability

September 2023



Education

- Ph.D. Mechanical Engineering/Applied Mechanics, Massachusetts Institute of Technology (MIT), MA, 1998
- M.S. Mechanical Engineering, Worcester Polytechnic Institute (WPI), MA, 1993
- Dipl. Ing. Aerospace & Vehicle Engineering, Fachhochschule München (FHM), (Nowadays known as the University of Applied Sciences), Germany, 1991

Licensed Professional Engineer (P.E.)

State of CaliforniaLicense No. M32075

State of TexasLicense No. 101701

Professional Affiliations

American Society of Mechanical Engineers (ASME)

Member

Member of the Power Train and Gear Committee

Former Vice-Chair of the Special Committee on Engineering Licensure

ASM International

Past Member

ASTM International

Past Member

Past Member of the E58 Committee on Forensic Engineering

Languages

Fluent in German and Spanish

Conversation level Italian

Professional Training and Education

“Airframe Stress Analysis and Sizing,” UCLA Extension, 2006

“Practical Piping Vibration,” Becht Engineering Company, 2005

“Structural Integrity of New and Aging Metallic Aircraft,” UCLA Extension, 2004

“HALT, HASS and ESS – Fundamentals and Practice,” Equipment Reliability Institute, 2001

Positions Held

Engineering Systems Inc., Irvine, CA

Principal & Vice President, January 2022 – present
Principal & Senior Director, January 2021 – December 2021
Principal, Senior Managing Consultant and Director of Mechanics, January 2011 – December 2020

Exponent, Irvine, CA

Senior Managing Engineer, Managing Engineer in the Mechanics & Metallurgy Practice, February 2001 – December 2010

Exponent, Menlo Park, CA

Senior Engineer & Engineer in the Mechanics & Metallurgy Practice, July 1998 – January 2001

Teaching Experience

Dr. Pettinger was an Instructor at MIT from 1997 to 1998
Mechanics & Materials I (Undergraduate Course 2.001)

Dr. Pettinger was a Teaching Assistant at MIT from 1996 to 1997
Mechanics & Materials I (Undergraduate Course 2.001)
Dynamics (Graduate Course 2.032)

Dr. Pettinger was a Teaching Assistant at WPI from 1992 to 1993
Stress Analysis
Thermodynamics
Conceptual Design of Aircrafts (Part Time Instructor)

Peer Reviewer

Journal of Applied Mechanics, ASME
Journal of Testing and Evaluation, ASTM International
Journal of Failure Analysis and Prevention, ASM International

Technical Conference Organization

ASME International Design Engineering Technical Conference/IDETC/CIE 2023
Technical Papers Review Coordinator, Paper Reviewer
ASME International Design Engineering Technical Conference/IDETC/CIE 2019
Technical Papers Review Coordinator, Paper Reviewer, Session Organizer
ASME International Design Engineering Technical Conference/IDETC/CIE 2017
Paper Reviewer

- ASME International Design Engineering Technical Conference/IDETC/CIE 2015
Technical Papers Review Coordinator, Paper Reviewer, Session Chair
- ASME International Design Engineering Technical Conference/IDETC/CIE 2013
Technical Papers Review Coordinator, Paper Reviewer, Session Chair
- ASME International Design Engineering Technical Conference/IDETC/CIE 2011
Technical Papers Review Coordinator, Paper Reviewer, Session Chair
- National Renewable Energy Laboratory (NREL) and the Department of Energy (DOE)
Advanced Drive Train Workshop, Participant by Invitation of NREL, Denver, CO,
June 2010
- ASME International Design Engineering Technical Conferences & Computers and
Information in Engineering Conference/ IDETC 2010, Paper Reviewer
- ASME International Design Engineering Technical Conference/ IDETC/CIE 2009
Technical Papers Review Coordinator, Paper Reviewer, Session Chair
- ASME International Design Engineering Technical Conferences, Paper Reviewer,
Long Beach, CA, 2005

Publications/Presentations

- L. Ginsberg., J. Hassebrock, J. Wagner, H. Iwand, **A. Pettinger** "Fatigue Crack Growth and Relief of Preload in Bent, Threaded Fasteners (U-bolts)," presented at the Society of Experimental Mechanics Annual Meeting, Orlando, FL, June 7, 2023.
- Pettinger A.**, Solomon E.L., Babcock J.R., Sanders S.A., McDougall J.L., "Corrosion of Sulfur Removal Tanks Used in the Processing of Landfill Gas," Journal of Failure Analysis and Prevention, February 2021.
- Pettinger A.**, Shireen S., "Thermal Analysis of Buried Insulated Pipes," Journal of Failure Analysis and Prevention, 18, 1554-1561 (2018), October 2018.
- Pettinger A.**, Mitolo M., "Interactions between Cathodically Protected Pipelines and Grounding Systems," IEEE Transactions on Industry Applications Vol. 52, No. 5; Sep/Oct 2016. Pages: 3694-3698. ISSN: 0093-9994; DOI: 10.1109/TIA.2016.2593809.
- Pettinger A.**, Cameron K., "The Effect of Low Sulfur Content on the Weldability of Linepipe Steel," Proceedings, 9th International Pipeline Conference, September 2012.
- Pettinger A.**, Sykora D., "Landslide Risk Assessment for Pipelines Crossing Mountainous Regions," Journal of Pipeline Engineering, September 2011.
- Pettinger A.**, Montgomery R., "Project Management Considerations of Pipelines Crossing the Andes," Proceedings, 8th International Pipeline Conference, October 2010.
- Pettinger A.**, Cameron C., "Effectiveness of Hydrostatic Testing for High Strength Pipe Material," Proceedings, 8th International Pipeline Conference, October 2010.

- Pettinger A.**, Montgomery R., Mathieson E., “Design, Construction and Operation of South American Pipelines Crossing the Andes,” Touch Briefings – Hydrocarbon World 2010; 5(1).
- Pettinger A.**, Cameron K., “Axial Loads from Soil Movement Challenge Pipeline Integrity,” Pipeline Gas Technology, November/December 2009.
- Pettinger A.**, Cameron K., “Assessing Pipeline Integrity Using Fracture Mechanics and Currently Available Inspection Tools,” Journal of Pipeline Engineering, October 2009.
- Pettinger A.**, Montgomery R., “Hazards and Benefits of Pipelines Crossing the South American Andes,” Pipeline & Gas Journal, August 2009; 236(8).
- Pettinger A.**, Rakow J., “Failure Analysis of Composites: Sandwich Structures,” Advanced Materials & Process, August 2009; 167(8).
- Pettinger A.**, Rakow J., “Failure Analysis of Composites: Laminate behavior,” Advanced Materials & Process, July 2009; 167(7).
- Pettinger A.**, Cameron K., “Assessing Pipeline Integrity Using Fracture Mechanics and Currently Available Inspection Tools,” The 2008 European Conference on Evaluation and Rehabilitation of Pipelines, Prague, Czech Republic, October 2008.
- Pettinger A.**, Rakow J., “Failure Analysis of Composite Structures in Aircraft Accidents,” Annual Conference of the International Society of Air Safety Investigators, Cancun, Mexico, September 2006.
- Pettinger A.**, Moore D., “Supplemental Type Certificates: Understanding and Assessment,” Journal of Air Law and Commerce, 40th Annual SMU Air Law Symposium, February 2006.
- Pettinger A.**, Abeyaratne R., “On the Nucleation and Propagation of Thermoelastic Phase Transformations in Anti-Plane Shear. Part 1 Couple-Stress Theory,” Computational Mechanics, 2000; 26, Springer Verlag.
- Pettinger A.**, Abeyaratne R., “On the Nucleation and Propagation of Thermoelastic Phase Transformations in Anti-Plane Shear. Part 2 Problems,” Computational Mechanics, 2000; 26, Springer Verlag.
- Pettinger A.**, “A Regularized Couple Stress Theory and Its Implications on Nucleation and Kinetics of Phase Transformations in Anti-Plane Shear,” Ph.D. dissertation, Massachusetts Institute of Technology, May 1998.
- Pettinger A.**, “Optimal Focusing of the Heat Flux by an Anisotropic Medium,” M.S. thesis, Worcester Polytechnic Institute, July 1993.
- Pettinger A.**, “Überarbeitung und Optimierung der Seastar Höhenleitwerksflosse: Vergleich einer GFK- und CFK Struktur (Design and Optimization of the Seastar’s Horizontal Stabilizer: A Comparison Between GFRP and CFRP),” Diplomarbeit, Fachhochschule München, July 1991.

Selected Reports

- Pettinger A.**, Investigative Report: "Rheem Manufacturing Water Heater Investigation", ESi Expert Report, June 2021.
- Pettinger A.**, "PCC, et al. v. Schulz, et al.," ESi Expert Rebuttal Report", March 2020.
- Pettinger A.**, Investigative Report: "Champ Landfill & Ameren", ESi Expert Report, September 2019.
- Pettinger A.**, Investigative Report: "PCC, et al. v. Schulz, et al.," ESi Expert Report, August 2019.
- Pettinger A.**, Edwards J., Investigative Report: "Value and Damage Evaluation of a Trent 800 Aircraft Engine Subjected to Impact Loads", ESi Report, July 2019.
- Pettinger A.**, Iwand H., Investigative Report: "Invenergy Buckeye Gearbox Failure Analysis", ESi Report, May 2019.
- Pettinger A.**, Investigative Report: "BNSF Logistics Transformer Investigation", ESi Report, August 2018.
- Pettinger A.**, Investigative Report: "Splitter Gearbox of Littoral Combat Ship", ESi Report, April 2017.
- Pettinger A.**, Investigative Report: "Orbital Taurus XL Payload Fairing Investigation, Phase 1", ESi Report, May 2017.
- Pettinger A.**, Investigative Report: "Orbital Taurus XL Payload Fairing Investigation, Phase 2", ESi Report, December 2017.
- Pettinger A.**, Investigative Report: "CNRL, et al. v. Shawcor, et al.," ESi Expert Rebuttal Report, January 2016.
- Pettinger A.**, Investigative Report: "APLNG GE Turbine Investigation," ESi Report, March 2015.
- Pettinger A.**, Investigative Report: "Preliminary Investigative Report on Sundyne Compressor Investigation," ESi Report, April 2014.
- Pettinger A.**, Cameron K., Investigative Report: "Investigation of NGL Pipeline Rupture," ESi Report, April 2014.
- Pettinger A.**, Kenney R., Investigative Report: "Mine Subsidence and Pipelines in the Matter of Emerald Coal Resources v Texas Eastern Transmission," ESi Expert Report, July 2013.
- Pettinger A.**, Investigative Report: "Investigation of the Standard of Care for the Gas Transmission Pipeline of Northwest Pipeline Company in the Matter of Northwest Pipeline Company v. Chevron Company," ESI Report, December 2012.
- Pettinger A.**, Kenney R., Investigative Report: "McCorkle/Dixie Pipeline Incident," ESi Expert Report, November 2011.
- Pettinger A.**, Arruda J., "Tractor Gear Box Evaluation on the Matter of Armando Orozco Juarez v. Pacific Vineyard Company," Exponent, Failure Analysis Associates, Inc. Report, submitted to the State Compensation Insurance Fund of the State of California, May 2009.

- Pettinger A.**, “Integrity Analysis of the Camisea Transportation System, Peru, S.A,” Exponent, Failure Analysis Associates, Inc. Report, submitted to the Inter-American Development Bank (IADB), June 2007.
- Pettinger A.**, Moore C.D., “Engineering Analysis of Pemco B737-300 Quick Change Modification,” Exponent, Failure Analysis Associates, Inc., Rule 26B Report, May 2005.
- Pettinger A.**, “Stress Analysis of the Sunrise Mountain Landfill Pipeline,” Exponent, Failure Analysis Associates, Inc. Report, submitted to the EPA, December 2003.
- Pettinger A.**, Hamilton D, Lyle J., “Expanded Pipeline Investigation Report, Sunrise Mountain Landfill Clark County, Nevada,” Exponent, Failure Analysis Associates, Inc. Report, submitted to the EPA, August 2003.
- Pettinger A.**, “06CW4 - Failed Item Analysis Report, Contractor AST,” Prepared for Project Manager Soldier System (U.S. Army). Exponent, Failure Analysis Associates, Inc., Report, March 2003.
- Pettinger A.**, “06CW5 - Failed Item Analysis Report for DT,” Prepared for Project Manager Soldier System (U.S. Army). Exponent, Failure Analysis Associates, Inc. Report, March 2003.
- Pettinger A.**, “06CW - Failed Item Analysis Report, Final Contractor HALT Test,” Prepared for Project Manager Soldier System (U.S. Army). Exponent, Failure Analysis Associates, Inc. Report, February 2003.
- Pettinger A.**, “06CW1 - Failed Item Analysis Report,” Prepared for Project Manager Soldier System (U.S. Army). Exponent Failure Analysis Associates, Inc. Report, February 2003.
- Pettinger A.**, “06CW3 - Failed Item Analysis Report for EOE (EFA),” prepared for Project Manager Soldier System/U.S. Army. Exponent, Failure Analysis Associates, Inc. Report, February 2003.
- Pettinger A.**, Fessler J, Shekerlian S, Medhekar S., “Recommendations for the Design, Manufacture, Installation, Operation and Maintenance of the Cement-Lined Pipe for Well IID-16,” Exponent, Failure Analysis Associates, Inc. Report, June 2002.
- Pettinger A.**, “Follow-up Survey of Invensys MA-200 Series Actuators,” for submittal to the U.S. Consumer Product Safety Commission. Exponent, Failure Analysis Associates, Inc. Report, April 2002.
- Pettinger A.**, Du Y., “Failure Investigation of Challenger Bus Lifts, Valley Transportation Authority, CA,” Exponent, Failure Analysis Associates, Inc., Report, September 2000.
- Pettinger A.**, Medhekar S., Pye J., “SSD Design Risk Assessment,” Prepared for Space Systems LORAL, Exponent, Failure Analysis Associates, Inc., Report, June 2000.
- Pettinger A.**, Wu M., Jewett C., Emery J., Foulds J., Kalinowski A., James B., “Finite Element Analysis and Fatigue Life Evaluation of TALENT Endoluminal NiTi Spring Stent Graft System,” Exponent, Failure Analysis Associates, Inc. Report, April 2000.

Technical Reports

Pettinger A., Rakow J., "Failure Analysis of Composites: A Manual for Aircraft Accident Investigators," First Edition, International Society of Air Safety Investigators, 2007.

Book Chapters

Pettinger A., Rakow J, Chapter 9. Structures Investigation: Composite Materials. Manual of Aircraft Accident and Incident Investigation, Part III, International Civil Aviation Organization, Doc 9756-AN/965.

Invited Speaking Engagements

Pettinger A., "Engineering Investigations in the Court of Law: An Engineer's Perspective," Bar approved MCLE, presented to various legal and insurance audiences in California since 2013.

Pettinger A., "Composite Forensics: Differences between Metals and Composites," Presented at Society of Naval Architecture and Marine Engineers Southwest Section, San Diego California, September 2012.

Pettinger A., "Failure Analysis," Professional Development Course Hosted by ASME District C – Nebraska Section (Eight Continuing Education Hours Course for Professional Engineers), Omaha Nebraska, March 2012.

Pettinger A., "Updated Pipeline Integrity Analysis of the Camisea Transportation System," Presented at 6th public conference on the Camisea Project by the Inter-American Development Bank, Lima, Peru, November 2007.

Pettinger A., "Pipeline Integrity Analysis of the Camisea Transportation System," Presented at 5th public conference on the Camisea Project by the Inter-American Development Bank, Washington D.C., June 2007.

Pettinger A., "Safety Investigation Elements: Design, Materials, Usage and Manufacture," Presented at Center for Occupational and Environmental Health of the University of California, Irvine, October 2005.

Various presentations for the London Insurance Market between 2012 and 2023 on pipeline engineering, construction, operation and maintenance, the Oil & Gas industry, the Energy Transition, and Aircraft Design.

Selected Project Experience

Energy, Power, and Pipelines

- Performed an evaluation of a gas pipeline explosion that ruptured due to a landslide in the United States of America. ESi was asked to evaluate the impact the design, the construction and the used mitigation measures for erosion and sedimentation control had upon the direct and indirect causes for the pipeline rupture.
- Assisted in the evaluation of an offshore pipeline leak and the development of the needed mitigation measures to enhance the system's resilience and increase operational proficiency to mitigate further oil leaks along California's coast.
- Assisted in the evaluation of an onshore pipeline leak with discharge into the Pacific Ocean.
- Performed an evaluation of a recall decision to replace seamless nickel alloy pipe of a gas processing facility for the transport of hazardous sour gas downstream of the "Christmas tree" in the Middle East. The investigation entailed a detailed review and analysis of the pipe processing records, a metallurgical pipe analysis, and the development of additional testing and analysis to evaluate the pipe recall decision. During the investigation ESi visually and ultrasonically inspected pipe, destructively tested removed pipe, established causation for the pipe material's failure to adhere to the technical specifications and substantiated the need to recall pipe material.
- Dr. Pettinger was asked to evaluate the technical aspects related to Force Majeure claims and the means and efforts a party undertook to mitigate its inability to perform the agreed upon services of consuming landfill gas at a renewable power plant. The equipment of interest were stainless steel tanks, piping, heat exchangers, and turbines.
- Reviewed the design of high temperature sour gas flow lines to address issues of upheaval buckling and pipe integrity.
- Performed several investigations in the Energy, Oil and Gas industry to address issues on the validity and scope of claims on grounds of technical requirements and regulatory compliance. These investigations were typically conducted for insurance claims disputes arising from the Merger & Acquisition of larger assets like pipelines, terminals, tank farms, and power plants.
- Evaluated the cathodic protection of pipeline systems from electric interference on various U.S. based pipeline systems. Analysis included technical evaluation of stray current and interference as well as regulatory compliance questions.
- Performed a failure analysis investigation of two separate pipeline ruptures of a heavy crude oil pipeline in Ecuador. The investigation included a metallurgical field investigation, site inspection, geotechnical evaluation, and review of the operational data to determine the root cause of this pipeline failure. In both cases landslide activity caused the pipeline to rupture. In one instance the pipeline was aligned parallel to the slope and the second instance the pipeline was downslope. In the second case Dr. Pettinger also evaluated the operator's emergency response and repair procedures for the London reinsurance market.

- Evaluated the inspection and testing requirements of a large gas pipeline in Australia. The investigation included the review of prior evaluations by the operator, various consulting firms and Universities. Provided an independent assessment for the operator's In-line inspection (ILI) results and mitigation options.
- Assisted the Inter-American Development Bank (IADB) with a pipeline integrity study of the Camisea transportation system in Peru, after the pipeline experienced 5 spill incidents in 19 months of operation. The IADB retained us to perform a failure analysis, conduct a design audit and risk assessment, and to provide the operator with recommendations to reduce future operational risks in the areas of seismicity, river scour, geotechnical stability, and mechanical pipe integrity. The design audit included a review of the applicable regulations, and standards promulgated by the American Society of Mechanical Engineers (ASME) and the American Petroleum Institute (API). In addition, we reviewed the adequacy of the pipe material, girth welds, and the subsequently performed hydrostatic testing. The failure analysis investigation integrated geotechnical site investigations, metallurgical investigations, in-line inspection (ILI) data, and external pipe inspection data with a detailed fracture mechanics analysis of the girth welds, to determine the root cause of the spill incidents.
- Assisted the IADB as an independent engineer with overseeing the development and implementation of a pipeline integrity management program for a pipeline system in South America.
- Evaluated the operations and maintenance practices for a liquefied petroleum gas (LPG) pipeline in the USA. One of the issues was maintenance of cover depth and the design of a pond over a preexisting pipeline. Third party damage (TPD) risk and requirements of the "call before you dig" system was evaluated.
- Evaluated the effect of mine subsidence on several pipelines due to long wall coal mining. Reviewed the maintenance and integrity management procedures for pipelines.
- Provided construction and maintenance cost estimates for pipeline systems and analyzed the FERC submitted cost estimates for pipeline construction.
- Evaluated regulatory requirements and engineering considerations for various pipeline crossings of other linear structures like roads, railroads, rivers, channels, and other utilities. Evaluated various design solutions for cased and uncased crossings. Evaluated issues relating to corrosion protection and cathodic protection system.
- Evaluated the design, construction and operation of an insulated oil pipeline system installed in the Boreal forests of Canada that suffered a severe failure of its multilayered insulation system. The analysis included the determination of the pipe soil interaction behavior and load transfer of the polyurethane based insulation, integration of the cathodic protection system, coating of the pipeline, construction methods, and operation conditions.
- Investigated the operation and maintenance procedures of a natural gas pipeline that was located in close proximity to a coalmine in the USA. Hazard identification, regulatory compliance, and standard of care in the pipeline industry were evaluated. Specifically,

possible risk mitigation techniques for pipelines subjected to geotechnical hazards in proximity to a coalmine were evaluated. The investigation also addressed issues related to the route selection for a pipeline expansion project and compliance with reporting requirements of the Federal Energy Regulatory Commission (FERC).

- Assisted a U.S. gas pipeline operator in characterizing the impacts of a large-scale natural gas explosion and fire in a populated area that resulted in several fatalities, injuries, and substantial loss of property. Reviewed issues related to the dynamic interaction of the pressurized gas, crack propagation, and ground deformation in the ensuing explosion.
- Assisted a U.S. gas pipeline operator on a natural gas explosion related to third party damage.
- Assisted in the evaluation of a hazardous liquid pipeline that leaked gasoline into the ground. Evaluation centered on the weld integrity of pipe joints for ERW pipelines and the use of in-line inspection tools. The analysis included an evaluation of the pipeline operator's operation and maintenance procedures.
- Analyzed gas leak rates for various pipeline systems through small crack like features.
- Reviewed the pipeline integrity management program of a large natural gas operator.
- Assisted in the investigation of pipe soil interactions occurring during hydrostatic testing of pipelines and the evaluation of pipeline ruptures and leaks at welded joints. Evaluated the welding of circumferential welds.
- Assisted in the analysis of a pipeline transporting hazardous liquids that ruptured due to ground movement. The investigation included a design and construction review of subject pipeline.
- Evaluated a spill incident at an oil terminal in Panama. The investigation included the inspection of the oil terminal, operation procedures, and maintenance records to determine the causal links that led to the spill incident. The investigation included a detailed inspection and technical evaluation of valves.
- Performed a feasibility and due diligence study for a pipeline expansion project in Africa and an oil terminal in Costa Rica.
- Performed a failure analysis of an insulated steel pipe. The investigations determined that the polyurethane foam of this buried hot water distribution system suffered excessive creep deformation, causing the separation of the foam from the steel pipe.
- Performed a root cause investigation into the failure of a pipe component during the "fracking" operation. It was determined that the plug valve had a preexisting crack that grew over time. The fracking fluid escaped under high pressure severely eroding the fracture surface. The back-flowing gas ignited and caused significant damages.
- Assisted the general contractor of a nuclear power plant where a large pipe of the primary circuit was vibrating excessively, significantly reducing the allowable power production. The assignment included the technical support of the general contractor's engineering staff on fluid

induced pipe vibration, and the selection of the most effective mitigation methods to reinstate full power production.

- Assisted another operator of a nuclear power plant in the identification of pump and pipe related vibration problems. Identified the root cause and recommended simple structural changes to the pump's support structure to shift the critical natural frequency away from the van bypass frequency of the impeller. The operator recently implemented these recommendations to successfully curb the pumps unwanted vibration.
- Assisted a power plant operator in the evaluation of a vibration related problem of a large induced draft fan. Evaluated the proposed design changes and assisted the general contractor in identifying the problem and develop an effective solution.
- Evaluated the gas, air, and hydrogen piping system in a large powder metallurgy factory where a fatal incident occurred. Developed a rapid response program for assessing the integrity of several piping systems. Made recommendations concerning possible mitigation projects and developed acceptance criteria for inspection. Assisted in the development of the new preventive maintenance program.
- Performed a statistical analysis and review of a proposed risk-based inspection program of deep seawater flow lines.
- Performed failure analyses and design evaluations of various gas distribution systems made of polyethylene and steel pipe. These investigations included the analysis of pipe soil interactions, failure analyses of various pipe components and a performance evaluation of buried compression couplings.
- Evaluated the creep behavior and risks associated with carbon steel welds for a high temperature steel pressure vessel (e.g., hydrogen embrittlement).
- Performed a failure analysis and designed a replacement for a cement lined pipeline system at a geothermal power plant. This project included a root cause analysis, a preliminary pipe stress analysis, a development of design criteria, qualified welding procedures, construction specifications, and a startup procedure.
- Performed design and constructability studies of pipeline systems crossing landfills. These efforts included the design and design evaluation of large diameter above ground HDPE pipeline systems (soil settlement and thermally induced deflections).
- Evaluated various drainage and sewer piping systems for various parties where soil movement was identified to be a significant risk factor.
- Performed a root cause failure analysis investigation of a large diameter low-pressure air piping system. The investigation determined that the failure of the expansion joints during pressure testing was related to the design of the piping system. The design was subsequently changed.

- Assisted in the investigation of a large diameter mining tailing pipeline in Southeast Asia where the inner liner of vulcanized rubber separated from the steel spools. The investigation included the investigation of the rubber's adhesion strength and the prevalent loading conditions.
- Assisted in the evaluation of various building piping systems. These investigations included issues on vibration, control, maintenance, design, and construction.
- Conducted a performance evaluation and root cause analysis of a thermal energy storage system, including its piping, tanks, chillers, energy storage medium, and auxiliary equipment.

Machinery Design, Safety, and Maintenance

- Assisted a U.S. shipbuilder in the root cause investigation of a gearbox failure onboard a to be commissioned Navy combat vessel. Inspected the subject gear box and relevant driveline components and analyzed the drivetrain, gears, and bearings to support the stakeholders. Identified root cause and made recommendations.
- Assisted a marine engine manufacturer for Navy combat vessels in determining the root cause of a bolted joint failure. This collaborative investigation included the metallurgical analysis of exemplar bolts and the subject bolt, development of experimental techniques, fracture mechanics calculations, and bolted joint analysis. Reports were developed to assist the U.S. Navy and the engine manufacturer in the decision process.
- Assisted a contractor for Navy combat vessels in the assessment of piping systems.
- Evaluated the water injection modification to a stationary aeroderivative turbine with a focus on design and assembly of bolted connections in a high air flow field at the intake of the turbine. Investigation was precipitated by the turbine digesting a foreign object.
- Evaluated alleged steam turbine damage due to the digestion of foreign objects and related maintenance activities.
- Evaluated long and short term fatigue cycling issues and the design of steam turbine blades.
- Reviewed and evaluated the design of a proprietary machine design to manufacture highly engineered plastic films. This investigation included the evaluation of several patents that were claimed to constitute prior art and the testing and evaluation of highly engineered string reinforced plastic films. This case related to the infringement of a trade secret.
- Assisted the United States Patent and Trademark Office in the evaluation of a patent claim dispute relating to welded large diameter pipes.
- Performed a fitness of service evaluation of the mechanical equipment used in the Biosphere 2.
- Evaluated the coke removal process of a refinery.
- Evaluated vibration data by analysis and testing and the observed internal damage caused during overland transport of a large transformer for an electric substation. The investigation revealed that the "shock sensor" was not properly calibrated and over reporting vibration and

shock inputs during transport. The observed interior damage to the winding's supports was related to a design change of a bolt field that was shown to have failed below the specified allowable impact and vibration loads.

- Evaluated potential shipping damage to a wide range of commercial equipment like turbines, gas compressors, sorters, filling equipment, gearboxes, processing equipment, and pumps that were allegedly caused during transport by sea and land. Developed several cost estimates for the repair of the transported industrial machinery.
- Dr. Pettinger has worked on many safety related projects. He has assisted food processing facilities such as commercial bakeries and industrial facilities with the evaluation of their safety practices and equipment. These assignments included the review of safety programs and procedures including, but not limited to the review of each facilities injury and illness prevention program, employee training program, job hazard analysis, corporate safety culture, and the control of hazardous energy sources (e.g., Lockout/Tagout). The assignments also included the inspection of several thousand pieces of equipment to evaluate the design of guards. Equipment included conveyers, mixers, dusters, furnaces, slicers, stackers, sorters, presses, printers, and humidity chambers. Machine design recommendations were provided to improve safety and ensure compliance with regulatory requirements.
- Dr. Pettinger has also investigated personal injury cases where employers were injured or fatally wounded during work at industrial and commercial facilities operating machinery, heavy construction equipment like backhoes, bulldozers, and excavators, and agricultural equipment like tractors. Many of these investigations center around the hydraulic system of the equipment.
- Performed safety analysis and guarding design on equipment used in industrial and commercial facilities.
- Evaluation of machinery and equipment used in the pharmaceutical industry.
- Performed and assisted several operators of large stationary diesel engines in determining the root cause of engine failures. These investigations included metallurgical as well as mechanical evaluations.
- Root cause analysis of wind turbine gearboxes failures, to ascertain failure modes, maintenance, and operating conditions.
- Performed a mechanical integrity investigation of various mechanical pieces of equipment that were involved in a fire. In this context, the mechanical suitability of the equipment was evaluated and determined the causality of the noted damage. Reviewed and provided advice on the refurbishment and disposition of subassemblies.
- Performed several root cause analyses on the failure of various structural components of trailers, semi-trailers, and recreational trailers. Manufacturing defects, welding quality, weld design, as well as design defects, were evaluated in this context.

- Performed several root cause analyses and dynamic analyses on the failure of various structural components on various vehicles and their components to determine causation of accidents and failures.
- Assisted in the evaluation of the cadmium plating of bolts and attachments.
- Performed many investigations on bolted joints in the aviation, marine, and general machinery industry. Load conditions would be steady or cyclic. Classical bolt joint analysis, fracture mechanics analysis as well as field inspections were performed. In some cases, tests were directed to validate analysis and gather data including the strain gaging of bolts.
- Performed an incident investigation for one of the largest bus operators in the USA. Issues involved fire causation of compressed natural gas (CNG) busses. The investigation included custom instrumentation and field-testing of buses, statistical evaluation of parts consumption data, and failure analysis of various engine components.
- Responsible for the failed item analysis and HALT/HASS of the U.S. Army's Land Warrior (LW) system (fully integrated wearable communication and situational awareness system for the soldier). This project included the system's evaluation of all components, development of test procedures, and execution of the system HALT. Moreover, the assignment included the preliminary engineering evaluation of all reported system anomalies and failures (hardware and software). Recommendations were developed for further detailed consideration and analysis by the contractor responsible for the given system component.
- Assisted in the conceptual design of a decontamination system of all assets the U.S. Marine Corps and U.S. Army deployed during Operation Iraqi Freedom. The system needed to significantly reduce the cleaning and decontamination time and provide a safe and efficient working environment for soldiers and other support personnel.
- Performed a design review and root cause analysis of a large floating dredge, which included a review of the structural design of the pontoons. Specifically, issues related to stringer and frame placement, material wall thickness, and structural welding were evaluated.
- Performed design reviews and root cause analysis of various gearboxes, gas turbines, and bearings. These investigations were performed in various countries and included root cause investigations as well as the development of design solutions. In some cases, the subject equipment failed or underperformed during operation and in other cases the equipment was damaged during transport.
- Field-tested and evaluated the gearbox of a tractor for the State Compensation Insurance Fund of the State of California. Testing determined that this tractor's gearbox suffered an intermittent failure of the gear selector, allowing the unintended movement of the tractor.
- Performed an engineering evaluation of a vehicle lift system that consists of an electric motor, a screw reduction gearbox, and a screw jack to lift busses at each wheel. The system experienced failures to hold its load at the assigned position. The investigation identified the root cause and provided design recommendations.

- Performed a comparative design study of multistage planetary gearboxes. This investigation included a review of standards, engineering analysis, and stress analysis of gear components.
- Performed a detailed investigation of fire smoke dampers that were investigated by the Consumer Product Safety Commission (CPSC). Our investigation focused on the life-cycle performance of the actuator's electrical drive train and gear design. The investigation included a customer survey, field inspections, field testing, laboratory testing, and mechanical engineering analysis of the fire smoke damper and actuators. Results of this investigation were presented to the CPSC.
- Performed several large investigations on recall and warranty claims of consumer products for a large international manufacturer. These investigations included a detailed root cause investigation to isolate potential failure modes, engineering analysis to model loading and usage conditions, fracture and damage tolerance analysis, machine design reviews, manufacturing process evaluations, Failure Mode and Effect Analysis (FMEA), statistical analysis of part's consumption and warranty data, and probabilistic modeling of the likelihood of failure and the severity of consequence of the identified hazards.
- Assisted in the safety evaluation of a plastic injection molding machine that was involved in an incident. This project included an engineering assessment of the control panel's design, and an evaluation of the operator's manufacturing practices (e.g., lockout/tagout) as well as the machine's retrofitted guarding system.
- Investigation of various vehicle gates and related injuries.
- Supported colleagues and clients on several projects involving shape memory alloys. These project activities were mostly focused on nickel titanium (NiTi) alloys that exhibit the so-called super-elastic and shape memory effect. Activities ranged from developing and teaching courses to assisting in the engineering analysis and testing of medical devices.
- Investigated the failure of various stationary diesel engines by reviewing operational conditions, maintenance practices and analyzing the fracture of the failed components.
- Evaluated the hydraulic system of construction equipment, aircrafts and helicopters from a system and component's perspective.

Airplane Design, Maintenance and Composites

- Evaluated the engineering viability of repair procedures for various business jets that were damaged during operation or maintenance. Work scopes included damage to wing, tail and fuselage structures and ranged from impact damage to corrosion damage. Evaluations included the use of Structural Repair Manuals and engineering analysis tools
- Performed a review of the supplemental type certificate of a converted Boeing 737-300 for the operator. This investigation included a structural review and damage tolerance evaluation of an added upper deck main cargo door and its surround structure, with respect to compliance with the applicable Federal Aviation Regulations and generally accepted engineering practices.
- Performed a design review and accident investigation of the composite fiber reinforced plastic vertical tail of an Airbus 300-600. This vertical tail was lost in midflight and caused the aircraft to crash, resulting in more than 270 fatalities on US soil. This investigation included a technical review of the structural design of the carbon fiber reinforced plastic vertical tail, and detailed review of all proposed failure modes and scenarios. Subsequently, the control system of the vertical tail including the hydraulic actuators were evaluated with a specific focus on pilot inputs and controllers.
- Reviewed structural aspects of the supplemental type certificate of a modified Boeing 747 to evaluate the structural integrity and compliance with applicable Federal Aviation Regulations. This investigation included the structural analysis of the rear fuselage section with an added upper deck cargo door. The analysis utilized the finite element method and classical flight vehicle structural analysis techniques to compute the factor of safety of structural components of the rear fuselage and the cargo deck support structure.
- Investigated the failure to deploy the fairing of two satellite launches when reaching orbit that resulted in the total loss of both satellites within a few years. The investigation entailed a detailed review of the fairing and its frangible joints. The engineering investigation was complex as design features, the possible falsification of material certificates and limited access to flight data required an extensive engineering analysis of the relevant components. At the end, ESi was able to establish credible primary causes to assist the London insurance market in the valuation of this very large claim.
- Performed a design review and FMEA of a novel design to replace frangible joints for the release of solar panels and other auxiliary equipment of satellites in space.
- Assessment of damage to aircraft engines (turbines) during use and transport.
- Performed wreckage inspections of general aviation aircraft.
- Executed the design and analysis of two horizontal stabilizers for the Dornier Composites Seastar, which was developed in the late 80s. This assignment included the design of two horizontal stabilizers to reduce the weight of the existing design and to evaluate different design and manufacturing techniques. One design study utilized carbon fiber reinforced plastics and the other glass fiber reinforced plastics. Integral as well as sandwich designs

were evaluated during this design study using classical techniques as well the finite element method. In addition, analysis tools for composite fiber reinforced materials were developed and a complete set of manufacturing drawings of two designs were provided.

- Investigated the mechanical explosion of two Type 4 Compressed Natural Gas (CNG) tanks. Two individuals were injured when refueling the vehicle. The investigation focused on developing a root cause for the rupture of the tanks and on determining the rupture sequence. A detailed investigation of the fracture surface of the composite material of both tanks was conducted. Investigated the failure causation for several tanks and other components made of composite reinforced materials. This investigation included materials that were reinforced with short and long fibers.
- Evaluated the design of a composite carbon fiber wheel assembly for high performance motorbikes, rotor blades, and structures.
- Investigated various accidents involving airfield ground equipment.
- Evaluated the failure of the fan and vanes of a closed loop wind tunnel for an indoor skydiving facility.