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Robert Kurth, Ph.D.
Senior Research Leader
Probabilistic Mechanics

Education

B.S. Mathematics, University of Notre Dame
M.S. Nuclear Engineering, Ohio State University
Ph.D. Nuclear Engineering, Ohio State University

Qualifications

Dr. Kurth has over 30 years of experience in research and development in the areas of remaining life and aging analysis of aircraft, piping, and welded structures. Programs he has developed have encompassed maintenance, inspection, and spare part reliability and risk-based analyses. Prior to starting at Emc², Mr. Kurth led the probabilistic fatigue and fracture mechanics modeling of structures at Battelle since its inception in 1981. He performed the first probabilistic damage tolerant analysis of aerospace structures.

Progressive Experience

November 2010 to present Emc², Senior Research Leader, Probabilistic Mechanics
2002 to October 2010, Battelle, Research Leader, Probabilistic Mechanics
1996 to 2002, Battelle, Program Manager
1989 to 1996, Science Applications International Corporation, Research Leader
1984 to 1989, Battelle, Senior Research Scientist
1981 to 1984, Battelle, Principal Research Scientist
1979 to 1981, Battelle, Research Scientist
1977 to 1979, Battelle, Researcher

Relevant Experience

Dr. Kurth has developed a new method of performing extremely low probability calculations for physic model simulations. This method is being applied in a program jointly funded by the NRC/EPRI and for the alpha model development has shown a decrease of 400 to 1,000 in the number of simulations needed to estimate probabilities on the order of 1 in 1,000,000 or lower.

He led the effort to incorporate advanced probabilistic methods in the analyses of nuclear piping fracture. This effort, funded by an international consortium, has reduced the computational time by a factor of 150 allowing extremely low probability of fracture events to be calculated (on the order of 1×10^{-10} events per rector lifetime).

Dr. Kurth was the principal investigator on a program to develop a probabilistic damage tolerance model for the combined interactions of fatigue, corrosion pitting, and stress corrosion cracking in aircraft aluminum structures. Aircraft structural models, pitting models, SCC models, and fatigue models have been linked together into the probabilistic analysis tool making it possible to predict the life reduction due to corrosion impacts on damage. Without any inspections we can predict the reduced life versus the density of corrosion damage sites and determine the impact of various damage conditions on the aircraft. Inspection models are included in the model so that various inspection and

maintenance (repair) strategies can be investigated. The model has been tested and a Graphical User Interface (GUI) has been written to allow the code to be used by non-experts in fatigue, stress, fracture, and probabilistic analysis.

Dr. Kurth was the principal investigator for the reliability and risk assessment of the Mobile Oxygen Storage Tank (MOST). In this study the risk of using the MOST to evacuate injured soldiers from near combat zones was assessed. The reliability of the system in non-combat conditions was first ascertained, then the risk of fire or explosion in combat situations was assessed. This risk was low and the United States Air Force is now using the system in the middle east.

Dr. Kurth led the investigation of the probabilistic risk analysis for extending the life of the TRIDENT II-D5 missile. The initial phase of this study has been completed in which the initiation system for the missile was modeled using event tress and fault tree models to insure that the mission success rate is within acceptable limits. Similar methods were extended to other subsystems.

Dr. Kurth was the principal investigator and code designer for the probabilistic analysis of a commercial aircraft lap splice test. The experimental program performed a simulated aircraft pressurization loading on a 6 foot by 8 foot section of the aircraft. The probabilistic analysis code, designated TRACLIFE, simulated the experiment from its pristine state to first crack link-up and panel failure. The predictions were made prior to the test completion making it a true blind prediction. The results of the experiment demonstrated that the prediction of first crack link-up was within 3.5% of the experimental result and the cycles until panel failure were within 0.5%. This provided an experimental validation of a complex computer analysis that can include crack initiation, crack growth, non-destructive inspections, crack repair, corrosion, crack link-up, and residual strength.

Dr. Kurth was the principal investigator for a program to develop programmatic risk decision analyses tools for the Federal Aviation Administration (FAA). This program provided the probabilistic structural analysis of aircraft structures, integrated non-destructive inspections and corrosion impacts to allow a risk assessment of alternative programs to be compiled and evaluated. The tool, TRACLIFE, was demonstrated by its application to past FAA programs.

Dr. Kurth was the principal investigator and code developer for the analyses of the risk of leak before rupture of a large gas transmission pipeline. In this study the probabilistic analysis of the growth of three dimensional cracks in the pipeline were simulated up to the point of the crack becoming a through wall crack. At this point the system pressure and material properties were used to determine if the calculated crack length was sufficient to gas a rupture of the pipeline. The calculations are used to determine if damage during pipeline construction or maintenance pose a significant safety risk. From these results the crack sizes that must be found with a high reliability during non-destructive inspections can be determined.

Dr. Kurth was the principal investigator for the probabilistic mechanics analyses of the composite shell structure being designed for the Earth Entry Vehicle (EEV) under contract to NASA. This structure will be launched to Mars, collect soil samples, and return to the earth with these samples. The structure is a Carbon-Carbon composite wing which will re-enter the earth without a parachute system. The structure must be able to withstand several thousand degree temperature changes, large vibration loads during launch, dynamic loadings, and a 130g impact loading. Because the Mars soil must be treated as a biohazard it is necessary to demonstrate a structural failure probability of less than 1 in 100,000. The Phase I work was completed in the spring of 2000 and the preliminary design analysis indicated that such low failure probabilities could be achieved. Phase II work began in the fall of 2000 and provided

more rigorous finite element analyses, progressive damage modeling and probabilistic modeling to provide inputs to the overall mission risk assessment.

Dr. Kurth was the principal investigator for the extended life analyses of the High Mobility Multi-Wheeled Vehicle (HMMWV) for the United States Marine Corps. In this study, the TRACLIFE program was modified for use in the determination of the useful life of the structure for two different options. The first was a new vehicle purchase. The second was a "remanufacture" option. In this case new frame rails, engines, and so forth, would be installed into the HMMWV. The action of corrosion on the vehicle was modeled over a 20- to 40-year planning horizon. In addition, the results of the accelerated corrosion test performed by the Marine Corps was integrated into the corrosion analyses. The results of the study indicated that buying new vehicles would be more cost effective over a 15-year time frame and would significantly increase mission readiness capability.

Dr. Kurth was the developer of the probabilistic stress corrosion analysis tool for gas pipelines. This analysis tool allows risk and safety to be assessed for gas pipelines for a wide range of pressure and temperature operating conditions. It also has the ability to assess the effectiveness, in a risk sense, of performing hydrotesting. The program has been used to assess the effectiveness of pre-coolers and different pressure and intervals for hydrotesting. The overall pipeline risk has been improved as a result of these studies.

Dr. Kurth was the program manager of the Probabilistic Widespread Fatigue Damage analysis of Transport Aircraft program. This program is sponsored by the Federal Aviation Administration and is examining the impact of multi-site, multi-element, and discrete source damage on the safety of commercial and military aircraft operation. The program is examining the uncertainty in loadings, damage initiation and growth, corrosion, and aircraft construction in order to predict the onset of widespread fatigue damage, the probability of structural failure, and the aircraft residual strength. These results will be combined in a nondestructive inspection model to evaluate the effectiveness of inspections and maintenance actions.

Dr. Kurth was the principal author of the Requirements for Probabilistic Assessment of Widespread Fatigue Damage in Commercial Aircraft sponsored by the Federal Aviation Administration. In his document all of the important physical phenomena are reviewed and recommendations for models that address these phenomena are made. In addition, the probabilistic methodologies that are appropriate for the assessment of fatigue in aircraft are addressed. The recommendations in this report will be used to define the FAA's effort to develop computer models for widespread fatigue damage.

Dr. Kurth was the principal investigator for the Probabilistic Risk Assessment (PRA) of the modified Gulfstream II aircraft used by NASA to train the astronauts to land the space shuttle. In this study, the computerized maintenance program was integrated with event tree and fault tree models of system (e.g., electrical, hydraulic, and landing gear) failures to obtain the expected aircraft availability. The model was constructed using commercially available software that allows NASA engineers to change failure rates, downtime for repairs, and introduce new procedures to provide a dynamic tool for assessing the impact of inspection and maintenance changes on the fleet availability.

Dr. Kurth was the principal investigator for the program to perform the damage tolerant analyses and inspection evaluation of the Shuttle Training Aircraft (STA). The STA is a modified Gulfstream II aircraft used to train astronauts to land the space shuttle. Because of the unique structural configuration and the nonstandard flight profiles used during training, significant uncertainty existed about the damage accumulation in the structure. Dr. Kurth led a team to place damage tolerant methods in a probabilistic mechanics framework to account

for material property and loading variability. The team also designed an instrumentation plan, installed strain gages, and took load measurements from the aircraft. By combining the data on loads and material behavior in a probabilistic model the damage tolerant level was determined with confidence levels. The probability of detecting the damage during an inspection was investigated to allow NASA to schedule inspections more efficiently. In the case of the STA, inspection intervals were changed resulting in a savings of 9,700 labor hours while maintaining the aircraft above the NASA-defined fail safe level with 95% confidence.

Dr. Kurth was a task leader on the program to incorporate aging impacts into existing nuclear power plant PRA's. He performed all of the calculations using the Vesely methodology to assess the effect of increasing failure rates on each component of the risk dominant reactors operated in the United States. He was one of the principal authors of the report Evaluations of Core Melt Frequency Effects Due to Component Aging and Maintenance, NUREG/ CR-5510.

Dr. Kurth was the principal investigator for the Space Shuttle Main Engine (SSME) weld risk study. During this program, probabilistic elastic-plastic fracture mechanics models were used to determine the most critical welds in the SSME. The results of this study are being used as part of the space shuttle probabilistic risk assessment.

He was the principal investigator of the program to develop a state-of-the-art computer model to analyze eleven sources of loadings for space propulsion engines, with the primary emphasis on the space shuttle main engines (SSME). The result of that work provided a model to NASA that included the random nature of the engine loadings in an expert system code to calculate the effect of design changes and mission history profiles on the SSME loadings at critical engine components.

Honors, Technical Societies

Invited Lecture, "The Development and Use of Probabilistic Mechanics Models in Condition Based Maintenance," *62nd Meeting of the Society for Machinery Failure Prevention Technology,* Virginia Beach, VAMay 6-8, 2008.

*Invited Lecture, "*Managing Obsolescence: Uncertainty and Aging Phenomena for Proactive Maintenance and Obsolescence Evaluations of Aviation Systems," *Panel member, Aviation Week's Military MRO Conference*, April 19-21 2005, Dallas, TX

Invited Lecture, "The Use of Probabilistic Analyses in a Systems Approach to Aging Degradation of High Value Engineered Systems," *Workshop on Failure Modes In Aging, High-Value Engineering Systems - Forecasting Models,* 21-23 June 2004, Tirrenia, Italy.

Invited Lecture, "The Use of Probabilistic Analyses in a Systems Approach to Anti-Terrorism Strategy Development and Evaluation," to the *Technical Oversight Group for Aircraft Anti-Terrorism (TOGAAT) Advisory group to the FAA Technical Center Airport and Aircraft Safety Section (AAR-400),* September 16th, 2002.

Invited Lecture, "TRACLIFE Analyses of FAA Technical Center Risk Issues for Airworthiness," *to Rotorcraft Industrial Technical Advisory (RITA) group,* June 19, 2001, University of California at Los Angeles.

Invited member to AIAA panel on *Probabilistic Methods Use and Applications for Aeronautical and Aerospace Systems,* Atlanta, Ga, AIAA National Convention, 2000.

Selected Publications

D. Rudland, R. Kurth, P. Mattie, H. Klasky, B. Bishop, D. Harris, "Development Of Computational Framework And Architecture For Extremely Low Probability Of Rupture (xLPR) Code," PVP2010-25963, *Proceedings of the ASME 2010 Pressure Vessels & Piping Division PVP Conference*, PVP 2010, July 18-22, 2010, Bellevue, Washington, USA.

Wei, Z., Kurth, R.E., Forte, T.P., "Probabilistic approach for fatigue life assessment based on S-N curve," PVP2010-25686, *Proceedings of the ASME 2010 Pressure Vessels & Piping Division/ K-PVP Conference*, PVP 2010, July 18-22, 2010, Bellevue, Washington, USA.

Zhigang Wei, Robert E. Kurth, Richard C. Rice, Thomas P. Forte, "Equivalency-based probabilistic approach for S-N and fatigue crack growth data," *International Conference on Fatigue Damage of Structural Materials VIII*, Hyannis, MA, USA, 19 – 24 September 2010.

Zhigang Wei, Richard C. Rice, Thomas P. Forte, Robert E. Kurth, "A new general two-parameter approach for fatigue crack growth and S-N curve analyses," *International Conference on Fatigue Damage of Structural Materials VIII,* Hyannis, MA, USA, 19 – 24 September 2010.

Rudland, D.L., Kurth, R.E., Scott, P.M., and Cox, A., "Continuing Development of PRO-LOCA for the Prediction of Break Probabilities for Loss-of-Coolant Accidents." *Proceedings of ASME-PVP 2009, 2009 ASME Pressure Vessels and Piping Division Conference*, July 26-30 2009 Prague, Czech Republic.

Robert E. Kurth, "Probabilistic Mechanics Analysis of the Impact of Stress Corrosion Cracking on Pipeline Leak Before Break," *62nd Meeting of the Society for Machinery Failure Prevention Technology*, Virginia Beach, VA May 6-8, 2008.

Robert E. Kurth and Frederick W. Brust, "Mechanics Based Approach to Predicting Material Life in a Corrosive Environment," *11th Joint FAA/DoD/NASA Aging Aircraft Conference* – April 16-19, 2007, Palm Springs, CA.

Lynn Faulkner and Robert E. Kurth, "Reliability And Risk Assessment For The Mobile Oxygen Storage Tank (MOST)," Final Report to US Army Brooks Lab, OMB No. 0704-0188, October 2006.

Robert E. Kurth, "The Use of Discrete Probability Distributions to Obtain Low Probability Event Estimates," *9th ASCE EMD/SEI/GI/AD Joint Specialty Conference on Probabilistic Mechanics and Structural Reliability* (PMC2004), Albuquerque, NM.

Robert E. Kurth and Frederick W. Brust, "Advanced Probabilistic Analysis Methods for Calculating the Reliability of a Carbon-Carbon Shell for the Earth Entry Vehicle," *9th ASCE EMD/SEI/GI/AD Joint Specialty Conference on Probabilistic Mechanics and Structural Reliability* (PMC2004), Albuquerque, NM.

Frederick W. Brust, Robert E. Kurth, N.D. Ghadiali, "Damage Initiation and Fatigue Crack Growth Modeling in Aircraft Structures," USAF Aircraft Structural Integrity Program, ASIP 2003, Dec 2-4, 2003, Savannah, GA.

Robert Kurth, Gary Brawley, Fred Leverenz, and Jon Young, "The Integration of Aging Models and Risk to Assess the Extended Life of the Trident D-5 System (D5LE): Risk Modeling of the Initiation Subsystem and Aging Models for Contact Switches," Battelle report to the US Navy, October 2003.

Kurth, R.E., Brust, F.W., and Ghadiali, N., "Damage Initiation and Residual Strength Modeling in Aircraft Structures and Comparison to Experimental Test Results," *6th Joint FAA/DoD/NASA Aging Aircraft Conference* – Sept.16-19, 2002.

Kurth, R.E., Abbott, W.E., and Brust, F.W., "Risk Based Aspects of Fatigue and Corrosion Fatigue in Aircraft Strcutures," ASTM Symposium on Probabilistic Aspects of Life Prediciton, November 6-7, 2002, Miami, FL.

Kurth, R.E., Brust, F.W., Abbott, W., and Ghadiali, N., "The Impact of Pitting Corrosion on the Fatigue Life of 2024 Aluminum Specimen under Bending," *6th Joint FAA/DoD/NASA Aging Aircraft Conference* – Sept.16-19, 2002, San Francisco, CA.

Kurth, R.E., Brust, F.W., Ghadiali, N.D., Backukas, J., and Tan P., "Damage Initiation And Residual Strength Modeling In Aircraft Structures And Comparison To Experimental Test Results From Faster," *6th Joint FAA/DoD/NASA Aging Aircraft Conference* – Sept.16-19, 2002, San Francisco, CA.

Kurth, R.E., Brust, F.W., and Ghadiali, N., "The Evaluation of Flat Panel Fatigue Tests with the 3D FEAM Applied to Stress Intensity Factors for Equivalent Initial Flaw Size Calculations," Report to FAA Technical Center, March 2002.

Kurth, R.E. and Brust, F.W., "Probabilistic Failure Assessment of a Carbon-Carbon Shell for the Earth Entry Vehicle Concept," Symposium on Computation & Probabilistic Fracture Mechanics, *10th International Congress on Fracture*, Honolulu, HI, Dec 2-7, 2001.

Leis, B. N., and Kurth, R. E., "Probabilistic Evaluation of Hydrostatic Retesting for Controlling Stress-Corrosion Cracking," *PRCI/EPRG 12th Biennial Joint Technical Meeting*, May 1999.

Leis, B.N., and R.E. Kurth, 1999, "Hydrotest Parameters to Help Control High-pH SCC in Gas Transmission Lines," PRCI Project PR-3 9404.

Kurth, R.E., "The Interaction of Multiple Damage Sites on Life Predictions for Pressurized Structures," Invited paper*, 1999 ASME PVP Conference*, Boston, MA, Aug 1-5, 1999.

Kurth, R.E. and Leis, B.N., "Probabilistic Modeling Of Stress-Corrosion Cracking: Part I – Model Development," *1999 ASME PVP Conference*, Boston, MA, Aug 1-5, 1999.

Brust, F.W. and Kurth, R.E., "Probabilistic Assessment of Aging in Aircraft Structures and Its Implications in Power Plant Aging," *1999 ASME PVP Conference*, Boston, MA, Aug 1-5, 1999.

Leis, B.N. and Kurth, R.E., "Probabilistic Modeling of Stress-Corrosion Cracking: Part II - Validation and Implications for Control," *1999 ASME PVP Conference*, Boston, MA, Aug 1-5, 1999.

Kurth, R.E., Brust, F.W., Ghadiali, N.D., Sun, X., "The Impact Of Interacting Cracks On The Probability Of An Aircraft's Residual Strength Being Less Than Limit Loads," *13th ASCE Engineering Mechanics Division Conference,* Baltimore, MD, June 13-16, 1999.

Leis, B.N. and Kurth, R.E. "Hydrostatic Retest Frequency: Its Role in Managing SCC," *12th Biennial Joint Technical Meeting on Line Pipe Research*, May 17-21, 1999 Groningen, Netherlands.

Kurth, R.E. and Bigelow, C.A., "Transport Risk Assessment Containing Widespread Fatigue Damage: TRACWFD Analysis of Longitudinal and Circumferential Splice Joints to Determine the Onset of Widespread Fatigue Damage and Its Probability of Occurrence," *Second Annual Joint Dod/FAA/NASA Conference on Aging Aircraft*, August, 1998, Williamsburg, VA.

Brust, F.W. and Kurth, R.E., "Assessment of Analysis Methodologies for Predicting Fatigue Crack Growth and Residual Strength of Aging Aircraft," *Aircraft Structural Integrity Program (ASIP) Conference*, December 2-4, 1997, San Antonio, TX.

Kurth, R.E. and Woods, K.S., "Probabilistic Damage Tolerant Analysis to Improve Aging Aircraft Maintenance and Inspection Schedules," Invited paper, *1994 ASME International Mechanical Engineering Congress and Exposition*, November 6-11, 1994, Chicago IL.

Kurth, R.E. and Yang, M., "Probabilistic Fracture Mechanics Analyses for a Subinterface Crack with Crack-Face Contact," *International Union of Theoretical and Applied Mechanics Symposium on Probabilistic Mechanics*, June 7-10, 1993, San Antonio, TX.

Kurth, R.E., et al., "Shuttle Training Aircraft Damage Tolerant Analysis for Fuselage Fatigue Critical Locations: Option I Report", Report to NASA Johnson Space Center, August 1992.

Kurth, R.E., "Probabilistic Damage Tolerant Analysis for Fatigue Critical Aircraft Components," invited paper for *1992 ASME Annual Winter Symposium*, Anaheim, CA.

Kurth, R.E., and Brust, F.W., "A Probabilistic Elastic-Plastic Fracture Mechanics Analysis of Through-Wall Crack Tubular Members," *Offshore Mechanic Arctic Engineering (OMAE) Conference*, February 19-22, 1990.

Vesely, W., Kurth, R., and Scalzo, S., NUREG/CR-5510, "Evaluation of Core Melt Frequency Effects Due To Component Aging and Maintenance," June 1990.

Fragola, J. R., et al, "Shuttle Integrated Risk Assessment Program," SAIC Report to Rockwell Space Division, Sept 1990.

Kurth, R.E. and Cox, D.C., "A Random Sampling Discrete Probability Algorithm with Condensation for Probabilistic Analysis," *Nuclear Technology*, 92, 2 (1990).

Kurth, R.E., "Nondestructive Evaluation Test Interval Optimization with Random Crack Initiation Times," Invited Paper, *1986 American Society of Civil Engineers Conference*, Boston, MA.

Kurth, R.E., "The Optimization of Test Intervals Between Non-Destructive Evaluation of Materials for Fatigue Crack Growth," Invited Paper, 1986 *American Society of Civil Engineers Conference*, Seattle, WA.

Kurth, R.E., and Cox, D.C., "An Investigation of Discrete Probability Distributions for Probabilistic Fracture Mechanics Analysis," *Risk Analysis: An International Journal*, 5, No. 3, 1985.

Kurth, R.E., "Examination of Probabilistic Methods for Material Life Analysis," invited paper, 1985 American Society of Metals Conference, Toronto, *Reliability and Process Control*, Edited by C. Ravidran and S. Sundaresan, published by ASM.

Kurth, R.E., et al., "Probabilistic Analysis of Piping Systems," ASME Publication, 72, *Random Life Prediction*, 1982.

Bishop, T.A., Collier, R.P. and Kurth, R.E., "Evaluation of ECC Bypass Data with a Nonlinear Constrained MLE Technique," *Proceedings of the 1979 DOE Statistical Symposium*, Edited by Donald A. Gardiner and Tykey Truett, September 1980.

Bishop, T.A., Collier, R.P. and Kurth, R.E., "Statistical Analysis of ECC Bypass Data Using a Nonlinear Constrained Maximum Likelihood Estimation Technique," *Nuclear Engineering and Design*, 64, pp. 87-91, 1981.