NATIONAL ACADEMIES
*Sciences*
*Engineering*
*Medicine*

**Board on Mathematical
Sciences and Analytics**

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

Beckman Center, 100 Academy, Irvine, CA 92617

**March 11 - 13, 2024**

ALL TIMES PACIFIC
Register:
https://www.nationalacademies.org/event/41699_03-2024_statistical-and-data-driven-methods-for-additive-manufacturing-qualification-a-workshop

## March 11: Dimensional Accuracy, Part Quality, and Process Stability

**9:00 a.m.**  **Workshop Logistics**
Brittany Segundo, *National Academies of Sciences, Engineering, and Medicine*

**9:05 a.m.**  **Welcoming Remarks**
Thomas Kurfess, Committee Chair, *Georgia Tech*

**9:20 a.m.**  **Panel 1: Data, Statistics, and Analytics for Additive Manufacturing in National Labs**
*Moderator:* Maria Emelianenko, *George Mason University*
*Panelists*:
John Carpenter, *Los Alamos National Laboratory*
Allen Roach, *Idaho National Laboratory*
Chris Spadaccini, *Lawrence Livermore National Laboratory*
Tyler LeBrun, *Sandia National Laboratory*

**10:35 a.m.**  **BREAK**

**10:50 a.m.**  **Enhancing Dimensional Accuracy and Stability with Digital Integration**
Melissa Orme, *The Boeing Company*

**11:45 a.m.**  **LUNCH**

**12:45 p.m.**  **Panel 2: Dimensional Accuracy, Part Quality, and Process Stability in Additive Manufacturing**
*Moderator*: Ade Makinde, *VulcanForms, Inc.*
*Panelists:*
Jianjun Shi, *Georgia Tech*
Anthony Rollett, *Carnegie Mellon University*
Jesse Boyer, *Pratt & Whitney*

**2:15 p.m. BREAK**

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

**2:30 p.m**. **Panel 3: Dimensional Accuracy, Part Quality, and Process Stability in Post-Additive Processes**
> *Moderator*: Teresa Clement, *Raytheon*
> *Panelists:*
>> Zhimin Xi, *Rutgers University*
>> Tanner Kirk, *QuesTek Innovations LLC*
>> Ping Guo, *Northwestern University*
>> Vlastimil Kunc, *Oak Ridge National Laboratory*

**4:00 p.m.**  **ADJOURN**

## March 12: Statistics, Data Analytics, and Artificial Intelligence (AI) for Additive Manufacturing

**9:00 a.m.**  **Workshop Logistics**
Brittany Segundo, *National Academies of Sciences, Engineering, and Medicine*

**9:05 a.m.**  **Recap of Day 1: Major Themes and Overview for the Day**
Maria Emelianenko, Ade Makinde, Teresa Clement

**9:30 a.m.**  **Statistics, Data Analytics, and AI: A Primer**
Alyson Wilson, *North Carolina State University*
Wei Chen, *Northwestern University*

**10:30 a.m.**  **BREAK**

**10:50 a.m.**  **Panel 4: Statistics, Data Analytics, and AI for Automated Machine Calibration and Toolpath Correction**
> *Moderator:* Wei Chen, *Northwestern University*
> *Panelists:*
>> Julia Greer, *Caltech*
>> Roshan Joseph, *Georgia Tech*
>> Wing K. Liu, *Northwestern University*
>> Vincent Paquit, *Oak Ridge National Laboratory*

**12:30 p.m.**  **LUNCH**

**1:30 p.m.**  **Overview on Measurement and Metrology**
Bradley Jared, *University of Tennessee, Knoxville*

**2:00 p.m.**  **Panel 5: Measurements and Calibration for Statistics, Data Analytics, and AI**
> *Moderator:* Ralph Nuzzo, *University of Illinois Urbana-Champaign*
> *Panelists:*
>> Lyle Levine, *National Institute of Standards and Technology*
>> Keerti Kappagantula, *Pacific Northwest National Laboratory*
>> Laura Bruckman, *Case Western Reserve University*
>> Tao Sun, *Northwestern University*

> **3:00 p.m. BREAK** before panel Q&A

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

**4:00 p.m.**       **ADJOURN**

## March 13: Material Qualification and Part Certification & Meeting Conclusion

**9:00 a.m.**       **Workshop Logistics**
Brittany Segundo, *National Academies of Sciences, Engineering, and Medicine*

**9:05 a.m.**       **Recap of Day 2: Major Themes and Overview for the Day**
Wei Chen, Ralph Nuzzo

**9:25 a.m.**       **Panel 6: Barriers to the Rapid Advance of Additive Manufacturing Material Qualification and Part Certification**
*Moderator*: Adrian Onas, *Webb Institute*
*Panelists:*
Mark Benedict, *Air Force Research Laboratory*
Davis McGregor, *University of Maryland*
Aaron Stebner, *Georgia Tech*

**11:30 a.m.**      **BREAK & LUNCH**

**1:00 p.m.**       **A Review: Themes from the Workshop**
*Moderator:* Thomas Kurfess, Committee Chair, *Georgia Tech*
*Committee Members and Discussants*:
Alyson Wilson, *North Carolina State University*
Melissa Orme, *The Boeing Company*
Teresa Clement, *Raytheon*

**2:15 p.m.**       **Final Comments from Sponsors**

**3:00 p.m.**       **ADJOURN**

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

## Speaker Biographies

**Mark D. Benedict** is the Senior Scientist for Convergent Manufacturing for the Air Force Research Laboratory. He has focused his research portfolio in the areas of Advanced Manufacturing (AM), Data Science, and Verification & Validation (V&V) of Integrated Computational Materials Science and Engineering (ICMSE) models. Dr. Benedict conducts and directs research in the areas of metals and plastic advanced manufacturing and is a recognized expert on additive manufacturing process modeling, machine development, data management, and airworthiness qualification/certification. In his role as America Makes Chief Technical Advisor he has been integral to the planning, requirements definition, selection, and execution of the $446M technical portfolio that America Makes has in the area of convergent manufacturing over the last decade. Additionally, he has directed a research portfolio in excess of $50M annually in AFRL funds focused on Advanced Manufacturing.

**Jesse Boyer** is a Fellow in Additive Manufacturing at Pratt & Whitney with a demonstrated history of working in the automotive and aviation and aerospace industries. He is skilled in Surface Metrology, Systems Engineering, Six Sigma, Root Cause Analysis, and Lean Manufacturing. He received a Bachelor of Science (B.S.) focused in Naval Architecture and Marine Engineering as well as Aerospace Engineering from the University of Michigan College of Engineering.

**Laura Bruckman** is an Associate Professor in Materials Science and Engineering at Case Western Reserve University. She develops predictive lifetime models for materials degradation related to stress conditions and induced degradation mechanisms evaluated by quantitative spectroscopic characterization of materials. She received her B.S. in chemistry from the University of Michigan-Flint, and her Ph.D. in Analytical Chemistry from the University of South Carolina.

**John S. Carpenter** is a scientist within the manufacturing science and metallurgy division at Los Alamos National Laboratory. He has broad manufacturing expertise across rolling, forming, welding, casting, spraying, and additive manufacturing. He currently serves as the chair for NA-115's Additive Coordination Team which looks at the development of additive manufacturing holistically across the NNSA in support of technology maturation for the nuclear deterrence mission.

**Julia Greer** is a Ruben F. and Donna Mettler Professor of Materials Science, Mechanics, and Medical Engineering at Caltech, as well as the Fletcher Foundation Director of the Kavli Nanoscience Institute, and the Editor in Chief of the Journal of Applied Physics. Her research focuses on creating and characterizing nano- and micro-architected materials with multi-scale microstructural hierarchy using 3D lithography, nanofabrication, and additive manufacturing (AM) techniques, and investigate their mechanical, electrochemical, chemo-mechanical, and photonic properties as a function of architecture, constituent materials, and microstructural detail. Her group strives to uncover the synergy between the internal atomic- and molecular-level microstructure and the multi-scale external

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

dimensionality, where competing material- (nano) and structure- (architecture) induced size effects drive overall response and govern these properties. Specific topics include applications of 3D nano- and micro-architected materials in devices, energy absorption, ultralightweight energy storage systems, chemically-assisted filtering, damage-tolerant fabrics, additive manufacturing, and multi-functional materials.
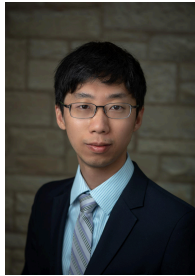
**Ping Guo** is an Associate Professor at the Department of Mechanical Engineering at Northwestern University. He received his B.S. degree in Automotive Engineering from Tsinghua University in 2009 and his Ph.D. degree in Mechanical Engineering from Northwestern University in 2014. Before joining Northwestern University in September 2018, he spent four years at the Chinese University of Hong Kong as an Assistant Professor. Dr. Guo's research interests center on the paradigm of micro/meso-scale manufacturing, including surface texturing, process micro-mechanics, miniature machine tools, metrology, micro-additive manufacturing, etc. He currently serves as the Associate Editor of Journal of Manufacturing Processes and Journal of Micro and Nano Manufacturing. He is the recipient of F.W. Taylor Medal from CIRP 2023, Kornel F. Ehmann Manufacturing Medal from ASME 2021, Outstanding Young Manufacturing Engineer Award from SME 2020, Young Investigator Award from International Symposium on Flexible Automation 2018, Hong Kong Research Grants Council Early Career Award 2016. He was elected as the Associate Member of the International Academy for Production Engineering (CIRP) in 2022.

**Bradley Jared** is an Associate Professor at the University of Tennessee Knoxville, specializing in additive manufacturing of structural materials. Prior to joining UTK in 2020, he worked at Sandia National Laboratories, 3M and Corning. He has 30 years of experience in mechanical design and advanced manufacturing process development; having presented and published work in the fields of ultra-precision machining, metrology, ultrafast pulsed laser processing and additive manufacturing. His current research is focused on the integration of design, robotics and controls into metal deposition processes such as welding, wire-arc additive manufacturing and laser-powder bed fusion.

**Roshan Joseph** is an A. Russell Chandler III Chair and Professor in the Stewart School of Industrial and Systems Engineering at Georgia Tech, Atlanta. He holds a Ph.D. degree in Statistics from the University of Michigan, Ann Arbor. His research focuses on computational and applied statistics with applications to engineering. He is a recipient of CAREER Award from NSF in 2005, Jack Youden Prize from the ASQ in 2005, Best Paper Award from IIE Transactions in 2009, Edelman Laureate from INFORMS in 2017, SPES Award from the ASA in 2019, SPAIG Award from the ASA in 2020, Lloyd S. Nelson Award from ASQ in 2021, and Wilcoxon Award from ASQ in 2023. He is a Fellow of the ASA and ASQ, and was the Editor-in-Chief of Technometrics from 2020-2022.

**Keerti Kappagantula** is a Senior Scientist and the Team Leader for Functional Materials and Enabling Technologies Team. Her research focuses on developing high performance materials through the use of nanotechnology, advanced manufacturing processes, atomistic-to-mesoscale modeling and machine learning/artificial intelligence/data-driven methods. Prior to joining PNNL in 2019, she was an Assistant Professor (Tenure

Track) of Mechanical Engineering at Ohio University. She also helped manage the Center for Advanced Materials Processing as the Assistant Director. Dr. Kappagantula manages projects that manufacture metal, polymer and ceramic composites that are used in applications ranging from energy-efficient electric machines to sustainable carbon-negative building materials. She is funded by various DOE Offices such as Vehicles Technology Office, Advanced Manufacturing Office, and Fossil Energy in identifying materials of interest, developing manufacturing approaches, and transitioning the technologies into commercial use.

**Tanner Kirk** is a Senior Materials Design Engineer at QuesTek Innovations, where he specializes in computational alloy design and additive manufacturing and is a lead developer of QuesTek's ICMD® Software. Before joining QuesTek, Tanner earned his Ph.D. in Mechanical Engineering from Texas A&M University.

**Vlastimil Kunc** is the Section Head for Composites Science and Technology Section within the Manufacturing Science Division at Oak Ridge National Laboratory. Dr. Kunc also serves as an adjunct professor at Purdue University. This section consists of four groups with physical and human resources capable of all composite manufacturing steps starting from fiber pre-cursor synthesis to part manufacturing and recycling across multiple scales. Within this large team, the Advanced Fibers Manufacturing Group focuses on scale up of carbon and silicon carbide fiber manufacturing, and selected intermediate feedstock forms. The Composites Innovation Group focuses on scale-up of additive and high-rate composites processes. The work of the Sustainable Manufacturing Technologies Group centers around bio-derived composite materials and composites recycling. The Extreme Environment Materials Process Group investigates carbon-carbon and ceramic composite structures.

**Tyler LeBrun** is an Additive Manufacturing Lead at Sandia National Laboratory. With a background in aerospace, he helps create strategies for deploying 3D printing equipment in the most productive and cost-effective manner possible, leveraging additive manufacturing to produce hardware specifically for space propulsion. He is involved in defining qualification strategies and methods for the parts, materials, and processes that may support one of the many end-use applications Sandia delivers.

**Lyle Levine** is a physicist in the Material Measurement Laboratory (MML) of the National Institute of Standards and Technology in the USA, where he leads MML's Additive Manufacturing of Metals Project. Dr. Levine also founded and co-leads AM Bench, an international organization that provides AM benchmark measurement data to the AM community.

**Wing Kam Liu**, Walter P. Murphy Professor of Northwestern University, is a Co-founder of HIDENN-AI, LLC, a start-up focusing on the HIDENN-AI Platform for Scientific and Materials Systems Innovation, the former Director of Global Center on Advanced Material Systems and Simulation, the Past President of the International Association for Computational Mechanics (IACM), the Past Chair and Chair of the US National

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

Committee on Theoretical and Applied Mechanics (TAM) and Member of Board of International Scientific Organizations, both within the US National Academies. Selected synergistic activities includes Hierarchical Deep-learning Neural Network-Artificial Intelligence (AI) (HiDeNN-AI) and Integrated Computational Materials Engineering (ICME) multiscale data-driven theories and software development for design and manufacturing of material systems, advanced and additive manufacturing, polymer matrix composites, fracture and fatigue analysis of alloys, and technology transfer.

**Davis J. McGregor**, Ph.D., is Director of the MIRAGE Lab and Assistant Professor of Mechanical Engineering at the University of Maryland, College Park. His research focuses on how software and data can be leveraged to improve manufacturing and part qualification. He investigates methods for automating metrology of diverse part geometries using computer vision and computational geometry, and is developing machine learning models for rapidly qualifying additively manufactured parts. Before joining the University of Maryland, Dr. McGregor was Staff Manufacturing Scientist at Fast Radius / SyBridge Technologies, where he led the development of manufacturing intelligence algorithms. He received his Ph.D. from the University of Illinois Urbana-Champaign.

**Vincent Paquit** serves as the section head for Secure and Digital Manufacturing in the Manufacturing Science Division at Oak Ridge National Laboratory (ORNL). Over the past two decades, he has dedicated his efforts to various projects and programs at ORNL, all in support of the Department of Energy's two primary missions: ensuring energy sustainability and enhancing national security. Since 2015, Dr. Paquit has been serving as the Data Analytics Lead for the Manufacturing Demonstration Facility. His team is dedicated to developing a Digital Platform for Advanced Manufacturing, with the aim of enhancing our understanding of manufacturing processes for part qualification, certification, and process control and correction. To achieve this goal, he manages a team of scientists and engineers working on developing and integrating hardware and software solutions to capture and analyze the digital threads associated with each manufacturing technology present in the facility.

**Allen Roach** is currently the director of the Advanced Materials and Manufacturing Initiative and the department manager of the Irradiated Fuels and Materials department at Idaho National Laboratory (INL). He has expertise and publications in materials for advanced nuclear reactors, multi-physics manufacturing processes including additive/advanced manufacturing, laser welds, flows in rigid and deformable porous media, corrosion, and high temperature processes including electroslag remelting and large-scale glass flows. He holds BS and MS degrees in Aerospace Engineering and a Ph.D. in Mechanical Engineering (1994).

**Anthony Rollett** has been a member of the faculty at Carnegie Mellon University since 1995, including five years as department head. He is the co-director of the Next Manufacturing Center on additive manufacturing. Rollett's research focuses on microstructural evolution and microstructure-property relationships in 3D, using both experiments and simulations. His interests include 3D printing of metals, materials for energy conversion systems, strength of materials, constitutive relations, microstructure, texture, anisotropy, grain growth, recrystallization, formability, and stereology. Some of his relevant techniques include high-performance spectral methods in micro-mechanics, dynamic x-ray radiography (DXR) and high-energy diffraction microscopy (HEDM). His important recent results include definition of

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

process windows in 3D printing through characterization of porosity, 3D comparisons of experiment and simulation for plastic deformation in metals, the appearance of new grains during grain growth, and grain size stabilization.

**Jianjun Shi** is the Carolyn J. Stewart Chair and Professor in H. Milton Stewart School of Industrial and Systems Engineering, with joint appointment in the George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology. He is a pioneer in the development and application of data fusion for quality improvements. His methodologies integrate system informatics, advanced statistics, and control theory for the design and operational improvements of manufacturing and service systems by fusing engineering systems models with data science methods. He received his B.S. and M.S. in Electrical Engineering from the Beijing Institute of Technology in 1984 and 1987, and his Ph.D. in Mechanical Engineering from the University of Michigan in 1992.

**Christopher Spadaccini** is currently the Materials Engineering Division (MED) Leader in the Engineering Directorate at Lawrence Livermore National Laboratory. He founded several new fabrication laboratories at LLNL for additive manufacturing and process development focused on micro and nano-scale features and mixed material printing, as well as scale-up for higher throughput. He was the founding Director of the Center for Engineered Materials and Manufacturing prior to becoming a division leader and co-led efforts to establish the Advanced Manufacturing Laboratory, a new facility in the Livermore Valley Open Campus. In his role as MED division leader, he manages an organization of approximately 600 staff including engineers and scientists, post-docs, students, machinists, and technicians, as well as over a dozen facilities. He has been a member of the LLNL technical staff for 20 years. Spadaccini has also been a lecturer in the Chemical, Materials, and Biomedical Engineering Department at San Jose State University, where he taught graduate courses in heat, mass, and momentum transport as well as an adjunct faculty member at the University of California, Davis, in the Chemical Engineering Department.

**Aaron Stebner** works at the intersection of manufacturing, machine learning, materials, and mechanics. He joined the Georgia Tech faculty as an Associate Professor of Mechanical Engineering and Materials Science and Engineering in 2020. He is known for cross-disciplinary work with a mechanical engineering core, such as developing new characterization and data analysis capabilities for studying deformation and manufacturing of materials in situ, and integrating data informatics and machine learning to accelerate discovery, development, and optimization of mechanics models and manufacturing processes. He is also known for incorporating the latest fundamental scientific discoveries into practical, usable tools for innovating engineering applications for companies and the government.

**Tao Sun** is an Associate Professor of Mechanical Engineering at Northwestern University. He received his B.S. and M.S. degrees in Materials Science and Engineering (MSE) from Tsinghua University and earned his Ph.D. in MSE at Northwestern University. Following his graduation, Dr. Sun pursued postdoctoral research at Argonne National Laboratory, where he advanced to the roles of Assistant Physicist and then Physicist. In 2019, he began his academic career at the University of Virginia before returning to Northwestern recently. Dr. Sun has extensive expertise in additive

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

manufacturing (AM), sophisticated instrumentation, and X-ray science. His research group is committed to understanding the fundamental physics of laser-metal interaction, heat and mass transfer, multiphase flow, and non-equilibrium material evolution within AM processes. His work highlights the critical importance of fundamental research in manufacturing science and the significant role of advanced in situ characterization and monitoring techniques.

**Zhimin Xi** is an associate professor in the Department of Industrial and Systems Engineering at Rutgers University–New Brunswick. He received his B.S. and M.S. degrees in Mechanical Engineering at the University of Science and Technology Beijing in 2001 and 2004, respectively. He obtained his Ph.D. in Mechanical Engineering (Program of Reliability Engineering) at the University of Maryland, College Park in 2010. His research interests are design for reliability and the applications for reliable autonomous vehicles/robots, lithium-ion batteries, and additive manufacturing. He has published more than 80 papers in prestigious journals and peer-reviewed conference proceedings. His research has been supported by the National Science Foundation, DARPA, Department of Energy, Ford Motor Company, Denso North American Foundation, and The Woodbridge Group. He is a member of IISE, ASME, and IEEE. He is the recipient of 2021 ASME – Design Automation Young Investigator Award, 2019 Rutgers A. Walter Tyson Assistant Professorship Award, and 2016 DARPA - Young Faculty Award. He is the winner of multiple (including twice Top 10) Best Paper Awards from ASME – Design Automation Conference in 2008, 2011, 2013, and 2015 respectively.

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

## Committee Biographies

**Thomas R. Kurfess (chair)** is the HUSCO/Ramirez Distinguished Chair in Fluid Power and Motion Control and Professor of Mechanical Engineering at Georgia Tech. During 2019-2021 he was on leave serving as the Chief Manufacturing Officer and the Founding Director for the Manufacturing Science Division at Oak Ridge National Laboratory, where he was responsible for strategic planning in advanced manufacturing. During 2012-2013 he was on leave serving as the Assistant Director for Advanced Manufacturing at the Office of Science and Technology Policy in the Executive Office of the President of the United States of America. He was President of the Society of Manufacturing Engineers in 2018, and currently serves on the Board of Governors of the ASME. His research focuses on the design and development of advanced manufacturing systems targeting secure digital manufacturing, additive and subtractive processes, and large-scale production enterprises. Kurfess is a member of the National Academy of Engineering and is a Fellow of ASME, AAAS, and SME. He received his S.B., S.M. and Ph.D. degrees in mechanical engineering from M.I.T. in 1986, 1987 and 1989, respectively. He also received an S.M. degree from M.I.T. in electrical engineering and computer science in 1988.

**Wei Chen** is the Wilson-Cook Chair Professor in Engineering Design at Northwestern University and faculty in the Department of Mechanical Engineering. As the director of the Integrated DEsign Automation Laboratory (IDEAL), her current research involves issues such as simulation-based design under uncertainty; model validation and uncertainty quantification; data science in design and advanced manufacturing; stochastic multiscale analysis and materials design; design of metamaterials; multidisciplinary design optimization; consumer choice modeling and decision-based design. She is the co-founder and director of the interdisciplinary doctoral cluster in Predictive Science and Engineering Design (PS&ED), and serves as the co-director for the Design Cluster affiliated with the Segal Design Institute at Northwestern. Dr. Chen received her Ph.D. in mechanical engineering from the Georgia Institute of Technology in 1995. She was an elected member of National Academy of Engineering (2019).

**Teresa Clement** is a Senior Principal Systems Engineer at Raytheon. She earned her BSE in 2002, and her Ph.D in 2007, both from Arizona State University in Materials Science Engineering. She has also been the chair of the Governance Board and Executive Committee for America Makes (the National Additive Manufacturing Innovation Institute). Previously at Raytheon she has held the role as Corporate Technology Area Director for Mechanical, Materials, and Structures as well as Value Stream Manager. She has also been a Graduate Research Assistant at Arizona State University, a Graduate Intern at Sandia National Laboratories and an Undergraduate Intern at Motorola Semiconductor Corp. Dr. Clement has several patents to her name.

**Maria Emelianenko** is a Professor at George Mason University. She is an interdisciplinary mathematician whose work is focused on applying mathematical theory to a wide range of applied problems. She serve as a Director of the Industrial Immersion program and a Director of Graduate Studies for the Mathematics department. Her current research lies at the interface between mathematics and other areas of science and engineering, such as materials science, chemistry and biology. She has developed new predictive models and simulations for smart materials design and design fast data analysis algorithms in collaboration with interdisciplinary colleagues. Her research is problem driven and utilizes a wide spectrum of mathematical tools from optimization, numerical analysis, stochastic processes, PDEs and statistics.

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

**Eric Fodran** is a manufacturing engineer and metallurgist within the Manufacturing Technologies Innovation organization within the Northrop Grumman Corporation here in Southern California. He has been supporting R&D efforts within the Manufacturing Technology Innovation organization as well as Advanced Materials & Process Development organizations for the past 20 years on several aircraft platforms including F-35, F-18, B-2, T-38, as well as classified, future air and space systems. His focus has been predominantly in the areas of additive manufacturing, structural materials fabrication and processing methods, as well as corrosion prevention and high temperature thermal protection systems. His practical experience has also been based in lunar rover metallic materials while at the NASA Jet Propulsion Facility, and his previous R&D background has been in a diverse spectrum of processes and materials including: elevated temperature aluminum based alloys and intermetallics, rapid solidification processing methods, and amorphous bulk materials for structural application.

**Mike Haley** is the Senior Vice President of Research at Autodesk, Inc. He leads the world-class Autodesk Research group uncovering how new technologies can transform the ways their customers design and make the world around us while also responding to challenging concerns like climate change, automation and industry convergence. The Autodesk Research team consists of academic research (AI, Human-Computer Interaction, Simulation and Systems, Optimization, Geometry, Visualization and Robotics), industry research (Design, Manufacturing, Architecture, Infrastructure, Construction and Media), strategic foresight and our technology centers where we collaborate with customers and partners on the future of design and making. All these functions come together to create a multidisciplinary and integrated research and foresight function that guides Autodesk's future technology, product strategy and product capabilities. In addition, with a background in Machine Learning, Mike leads Autodesk's efforts in Generative AI. Mike has led many technology and product transformation efforts at Autodesk. He established and directed Autodesk's Machine Learning competency by establishing our AI Lab. Prior to that Mike led the early development of Autodesk's cloud technology and infrastructure. Mike has a background in computer-graphics, machine learning, distributed systems and mathematical analysis. He holds an MS in Computer Science from the University of Cape Town, South Africa.

**Ade Makinde** is the Principal Simulation Engineer at VulcanForms, Inc., a manufacturer of additive manufacturing machines. Previously he was a principal engineer at the GE Global Research Center. In this role, he supervised researchers in the use of finite element analysis, computational fluid dynamics, and the development of specialized numerical and microstructural tools to optimize manufacturing processes and part design for manufacturability. He was also part of the management staff responsible for overseeing the development of analytical tools and processes to aid the design of new products and parts for all of GE's businesses. Makinde worked closely with GE's suppliers using analytical tools to solve time-sensitive technical issues and to ensure that yield and quality targets were met.

**Ralph G. Nuzzo** is the G. L. Clark Professor of Chemistry Emeritus at the University of Illinois at Urbana Champaign. He is the author or coauthor of more than 350 peer-reviewed papers and 48 awarded U.S. Patents. Most recently (until 2022) he was the G. L. Clark Professor of Chemistry at the University of Illinois at Urbana-Champaign, a faculty he joined in 1991 and where he also held an appointment as a Professor of Materials Science and Engineering. In 2014 he was appointed as an affiliated member of the Chemistry Faculty at the KTH Royal Institute of Technology in Stockholm Sweden. He served as a Faculty

# STATISTICAL AND DATA-DRIVEN METHODS FOR ADDITIVE MANUFACTURING: A Workshop

Associate in Applied Physics and Materials Science at The California Institute of Technology, where he served as the Director of the Department of Energy Light-Materials Interactions in Energy Conversion Energy Frontier Research Center. He also was appointed as a faculty visitor in Chemistry at Harvard University in 2022.

**Adrian S. Onas** is Professor of Naval Architecture at the Webb Institute of Naval Architecture. Professor Onas has over twenty-five years of experience in the Maritime Industry in Europe and the United States. His work includes dealing with ships and mobile offshore units classification plan approval, certification of materials, components and systems, newbuilding surveys including sea trials, shipyard and marine product quality assessments. Part of the process includes additive manufacturing of complex marine propulsion shapes and their analysis. Research experience with nonlinear ship motion program WASIM, including time-domain simulations of roll decay, forced roll and parametric roll resonance in regular seas; frequency-domain simulation experience, including the study of trimaran roll response in beam/oblique seas and the resonant wave trapping modes in forced roll and forced heave oscillations. Investigated two nonlinear roll damping models using forced roll tests with a specially designed forced roll apparatus.

**Melissa Orme**, PhD, Vice President, The Boeing Company, oversees Additive Manufacturing activity across the three Boeing business units: Boeing Commercial Airplanes; Boeing Defense, Space and Security; and Boeing Global Services; including metal and polymer flight hardware, as well as research and factory aids to enable product development and increase factory efficiency. Orme is also responsible for guiding the development of the digital thread across the Additive Manufacturing value chain, and the implementation of data driven models from extracted and archived data from the digital thread, utilizing machine learning and artificial intelligence to drive efficiency, quality, and scale within the Additive Manufacturing end-to-end value stream. Other key responsibilities include the development of initiatives geared towards quantifying the positive sustainability trades associated with Additive Manufacturing. Orme has a diverse professional background and began her career in academia, where she rose to the rank of Full Professor at the University of California, Irvine. Dr. Orme has deep experience in technology development through the diverse frameworks of academia, small business, and large corporations. Orme received her PhD, M.S., and B.S. in Aerospace Engineering from the University of Southern California.

**Alyson G. Wilson** is the Associate Vice Chancellor for National Security and Special Research Initiatives at North Carolina State University. She is also a professor in the Department of Statistics and principal investigator for the Laboratory for Analytic Sciences. She is a Fellow of the American Statistical Association and the American Association for the Advancement of Science. Her research interests include statistical reliability and Bayesian methods. Prior to joining NC State, she was a research staff member at the IDA Science and Technology Policy Institute (2011-2013); an associate professor in the Department of Statistics at Iowa State University (2008-2011); and a technical staff member at Los Alamos National Laboratory (1999-2008). In addition to numerous publications, she has co-authored a book, Bayesian Reliability, and has co-edited two other books, Statistical Methods in Counterterrorism: Game Theory, Modeling, Syndromic Surveillance, and Biometric Authentication and Modern Statistical and Mathematical Methods in Reliability. Dr. Wilson received her Ph.D. in Statistics from Duke University.