Digital Twin Applications for Advanced Nuclear Technologies
Workshop
December 1 – 4, 2020

Official Program

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WORKSHOP COMMITTEE

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Deputy Director
Division of Engineering
Office of Nuclear Regulatory Research, U.S. NRC

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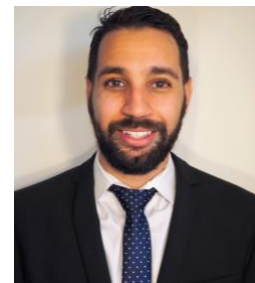Oak Ridge National Laboratory

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MODERATORS

Ray Furstenau
Director, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Ray Furstenau began serving as the Director of Nuclear Regulatory Research at the U.S. Nuclear Regulatory Commission in July 2018. Prior to joining the NRC, from 1987 to 2018, Ray held several positions in the U.S. Department of Energy (DOE). During most of those years, he provided government oversight of nuclear facility operations and nuclear energy research & development programs at the Idaho National Laboratory. He also served as Associate Principal Deputy Assistant Secretary and Central Technical Authority in DOE's Office of Nuclear Energy.

Ray holds a B.S. degree in Applied Science and Engineering from the U.S. Military Academy and a M.S. degree in Nuclear Science and Engineering from Idaho State University. He is a registered professional nuclear engineer.

Stephanie Coffin
Deputy Director, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Stephanie Coffin joined the U.S. Nuclear Regulatory Commission (NRC) in 1996 as a Technical Reviewer, Office of Nuclear Reactor Regulation (NRR). Since joining the NRC, she has held positions of increasing responsibility including Materials Engineer, Technical Assistant, and Branch Chief in NRR; Branch Chief, in the Office of New Reactors (NRO); and Deputy Director, Division of Advanced Reactors and Rulemaking, NRO.   Since joining the Senior Executive Service (SES) in 2014, Ms. Coffin has served as the Deputy Director, Division of Systems Analysis, RES ,Deputy Director, Division of Preparedness and Response, Office of Nuclear Security and Incident Response, and Budget Director, Office of the Chief Financial Officer.
Before joining the NRC, Ms. Coffin worked for Baltimore Gas and Electric at the Calvert Cliffs Nuclear Power Plant, and the U.S. Navy at the David Taylor Research Laboratory in Annapolis, Maryland.

Ms. Coffin received a bachelor's degree in Materials Engineering from Drexel University and a master's degree in Materials Science and Engineering from Johns Hopkins University.

Michael Case
Director, Division of Systems Analysis. Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Mike Case serves as the Director of the Division of Safety Analysis in the Office of Nuclear Regulatory Research (RES) at the U.S. Nuclear Regulatory Commission (NRC). He manages a diverse of set of research programs affecting the safety of the Nation's nuclear power plants. These programs include a broad range of disciplines such as thermal hydraulics, severe accidents, computational fluid dynamics, offsite accident consequences, and radiation protection. Mr. Case has also recently served as the RES director of engineering as well as the deputy director of the international program office. In his 12 years as a senior executive, he has also served in a range of roles in the Office of Nuclear Reactor Regulation. Prior to his NRC experience, Mr. Case worked for eight years at a commercial nuclear power plant including being licensed as a Senior Reactor Operator. Mr. Case also served in the United States Navy's nuclear power program.

Louise Lund
Director, Division of Engineering, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Louise Lund began serving as the Director of the Division of Engineering in the Office Nuclear Regulatory Research at the U.S. Nuclear Regulatory Commission in August 2019, also assuming the collateral duty as the Agency Standards Executive. Prior to that, she held other division level positions that included the NRR division director that oversaw licensing and oversight for research and test reactors, Fukushima activities, rulemaking, and review of topical reports, as well as the deputy division director (and acting director) for the Division of Operating Reactor Licensing. Prior to her career at the NRC, she was a Research Scientist at Pacific Northwest National Laboratory in materials engineering applied research and worked maintenance outages in commercial nuclear power plants. She holds bachelor's and master's degrees in Materials Science and Engineering.

Joe Donoghue
Director, Division of Safety Systems, Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

Joe Donoghue is the Director of the Division of Safety Systems in the Office of Nuclear Reactor Regulation. The division leads regulatory reviews of safety issues related to fuel and reactor performance, balance-of-plant systems, spent fuel storage, and containment systems.

Shana Helton
Director, Division of Physical and Cyber Security Policy, Nuclear Security and Incident Response
U.S. Nuclear Regulatory Commission

Shana R. Helton is the Director of the Division of Physical and Cyber Security Policy in the Office of Nuclear Security and Incident Response. Ms. Helton joined the NRC in 2002 and has served within the agency in a variety of technical and leadership positions, in the areas of reactor safety, spent fuel storage and transportation, operating reactor rulemaking, and security. Ms. Helton holds bachelor's degrees in Nuclear Engineering and Mathematics from the University of Illinois and a master's degree in Nuclear Engineering and Radiological Sciences from the University of Michigan.

Mark Thaggard
Deputy Director, Division of Risk Analysis, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Mark Thaggard is the Deputy Director of the Division of Risk Analysis in the Office of Nuclear Regulatory Research. Mr. Thaggard joined the U.S. Nuclear Regulatory Commission in 1989 as a Groundwater Hydrologist in the Office of Nuclear Material Safety and Safeguards. Starting in 2001, he held a number of progressively responsible positions in NMSS, the former Office of Federal and State Materials and Environmental Management Programs, the Office of New Reactors, and the Office of Nuclear Security and Incident Response before assuming his current position in 2016. Mr. Thaggard received his bachelor's degree in Geology from the University of South Florida and master's degrees in Applied Mathematics and Environmental Engineering from Johns Hopkins University. He is a graduate of the NRC's SES Candidate Development Program.

Mohamed Shams
Director, Division of Advanced Reactors and Non-Power Production and Utilization Facilities
Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

Dr. Mohamed Shams joined the U.S. Nuclear Regulatory Commission (NRC) in 2007 as a civil engineer in the Office of New Reactors, where he progressed to the Chief, Structural Engineering Branch. In 2015, he joined NRR, where he served as the Chief, External Hazards Branch and the Deputy Director, Japan Lessons Learned Division. Dr. Shams also served on Commissioner Wright's staff as a Reactor Technical Policy Advisor. His other assignments have included acting Senior Executive Service (SES) positions in Region I, Region II, and the Office of International Programs; acting Deputy Assistant for Operations, Office of the Executive Director for Operations; and his previous SES position as Deputy Director, Division of Operating Reactor Licensing in NRR.

Prior to joining the NRC, Dr. Shams served at the U.S. Department of Interior in seismic risk assessments and was a consultant to the U.S. Department of Energy for the design of a highly enriched uranium storage facility. He holds a master's and doctorate degrees in Structural Engineering from the Georgia Institute of Technology. He also holds Professional Engineer's licenses in the States of Georgia and Maryland.

Jeremy S. Bowen – *Executive Sponsor*
Deputy Director, Division of Engineering, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Jeremy Bowen joined the U.S. Nuclear Regulatory Commission (NRC) in 2007 as a Project Manager in the Office of Nuclear Reactor Regulation (NRR). Since then, he has served in various capacities, including as a Reactor Operations Engineer responsible for the NRC's reactor inspection program, NRR's Technical Assistant for Enforcement, NRR's Team Lead for Allegations and Enforcement, Chief of Plant Licensing Branch III-2 in NRR's Division of Operating Reactor Licensing, the Associate Director and Deputy Director for NRR's Japan Lessons Learned Division, and as an Executive Technical Assistant to the NRC's Executive Director for Operations where he served as the liaison for all interactions with the regional offices. Mr. Bowen completed temporary assignments as the Acting Deputy Director in the Division of Engineering in NRR, Acting Deputy Director in the Division of Physical and Cyber Security Policy in the Office of Nuclear Security and Incident Response, and Acting Deputy Director in the Division of Fuel Management in the Office of Nuclear Materials Safety and Safeguards.
Prior to joining the NRC, Mr. Bowen served over 8 years as a Naval Submarine Officer. He holds a bachelor's degree in Systems Engineering from the U.S. Naval Academy. Mr. Bowen is a graduate of the NRC's Leadership Potential Program and the NRC's Senior Executive Service Candidate Development Program.

Stephen M. Bajorek
Senior Technical Advisor for Thermal-Hydraulics, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Dr Bajorek is the Senior Technical Advisor for Thermal-Hydraulics in the NRC's Office of Nuclear Regulatory Research and has nearly forty years' experience in the nuclear industry. While at the NRC he has been involved with development of the TRACE state-of-the-art thermal-hydraulics code, advanced reactor analysis, and the NRC's thermal-hydraulic test programs and is currently leading the NRC's efforts to develop simulation codes for non-LWRs. Dr. Bajorek represents the NRC in international thermal-hydraulic research projects and has served on U.S. State Department missions in support of U.S. industry interests. Dr. Bajorek received his Ph. D. from Michigan State University, and M.S. and B.S. degrees in Mechanical Engineering from the University of Notre Dame. Prior to joining the NRC staff, he was a member of the faculty at Kansas State University and has over 15 years of industrial experience at Westinghouse Electric Corp. as a code developer and analyst. At Westinghouse Dr. Bajorek was a lead developer of the WCOBRA/TRAC systems code and of the first Best-Estimate LOCA methodology licensed in the U.S. He has authored or co-authored nearly 200 publications in areas ranging from boiling and two-phase flow, reactor safety, natural convection, and boiling of multi-component fluids.

Tamara Bloomer
Chief, Accident Analysis Branch, Division of Systems Analysis, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Tamara Bloomer joined the NRC in 1999 as a materials engineer in the Office of NMSS in the High-Level Waste Division. She subsequently served as a materials engineer in the License Renewal Branch in NRR, a materials engineer in the Steam Generator and Chemical Branch NRR, and the team leader for the Container Life and Source Term team in NMSS. In 2004, Ms. Bloomer was selected as a technical assistant in the OEDO where she held increasingly responsible positions including being selected as the Brach Chief for the OEDO Technical Assistants. In 2009, Ms. Bloomer left the OEDO for Region III where she served as the Branch Chief for the Materials Inspection Branch. In August 2013, Ms. Bloomer was selected by Commissioner Ostendorff to fill the position of Technical Assistant for Materials in the Office of Commission. In 2016, Ms. Bloomer returned to OEDO as an Executive Technical Assistant. Currently, Ms. Bloomer is the Accident Analysis Branch Chief in the Office of RES.

Prior to joining NRC, Ms. Bloomer was a Program Manager at the AMES Laboratory—a DOE M&O, a Laboratory Manager at the University of California, Santa Barbara, and a Laboratory Instructor at the Naval Post Graduate School. Ms. Bloomer received a bachelor's degree in materials engineering from the Rensselaer Polytechnic Institute, and a master's degree in materials science and engineering from Iowa State University. Ms. Bloomer is a graduate of the NRC's Senior Executive Service Candidate Development Program.

Raj Iyengar
Branch Chief, Component Integrity Branch, Division of Engineering, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Raj Iyengar is currently the chief of Component Integrity Branch in the Office of Nuclear Regulatory Research, NRC. He oversees the regulatory research activities in the areas of reactor vessel and piping integrity, probabilistic fracture mechanics, non-destructive evaluation and inspection, and advanced reactors materials. Since 2009, he has held various positions at the NRC, including Acting Deputy Director, Senior Materials Engineer and Technical Assistant in the Office of Nuclear Regulatory Research, as an Executive Technical Assistant at the Office of Executive Director of Operations, and as a Project Manager in Nuclear Materials Safety and Safeguards. Before joining NRC, Raj has held corporate management positions in the automotive industry, where he led product development and applications efforts, and research positions at Battelle - Columbus, and University of Pennsylvania. Raj holds a Ph.D. in Solid Mechanics and a Sc. M. in Applied Mathematics from Brown University, an M. S. in Mechanics and Materials Science from Rutgers University, and an M. S in Metallurgy from Indian Institute of Science.

Jeanne Johnston
Branch Chief, Long-Term Operations and Modernization Branch, Division of Engineering and External Hazards
Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

Jeannie Johnston is the Chief of the Long-Term Operations and Modernization Branch, which focuses on electrical engineering and Instrumentation and Controls (I&C) special projects, in the Office of Nuclear Reactor Regulation. She joined the NRC as a Digital I&C engineer in 2009. While at the NRC, Ms. Johnston has served as a licensing project manager, acting branch chief, and as a technical assistant to Office and Division level leadership. Prior to joining the NRC, Ms. Johnston worked as nuclear engineer at Sandia National Laboratories in Albuquerque, NM. Jeanne also has prior work experience as an engineer in the industrial controls and data acquisitions development division at National Instruments in Austin, TX. Jeanne has a B.S. in Mechanical Engineering from the University of Texas at Austin and a M.S. in Nuclear and Radiological Engineering from the Georgia Institute of Technology.

Angela Buford
Branch Chief, Mechanical Engineering & In-Service Testing Branch, Division of Engineering and External Hazards
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

Angela Buford joined the U.S. Nuclear Regulatory Commission (NRC) in 2010 as a Structural Engineer in the Office of Nuclear Reactor Regulation (NRR). Throughout her NRC career, she served as: a Structural Engineer in the Division of Engineering, in multi-faceted roles as a Technical Reviewer, Technical Assistant and Project Manager in the Division of License Renewal, as well as an Acting Chief of the Piping and Head Penetrations Branch in the Division of Materials and License Renewal in NRR. In addition, she completed temporary assignments as a Construction Inspector in Region II and as a Venture Agent in NRR's EMBARK Venture Studio. Ms. Buford now serves as Chief of the Mechanical Engineering and Inservice Testing Branch in NRR.

Prior to joining the NRC, Ms. Buford spent six years working as a Structural Engineering consultant in the private sector. Ms. Buford graduated from the University of Maryland, College Park, with a Bachelor of Science degree in Civil Engineering, and received a Master of Science in Civil Engineering and Engineering Mechanics from Columbia University. She is a registered Professional Engineer licensed in Maryland and Washington, D.C.

Ramón L. Gascot Lozada
Structural Engineer, Division of Engineering, Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Ramón L. Gascot Lozada is currently a Structural Engineer in the Office of Nuclear Regulatory Research, Division of Engineering. Mr. Gascot joined the agency in 2014, has worked for several positions during his young career, including the formerly known NRO and Region II. Mr. Gascot holds a B.S. degree in Civil Engineering and a M.S. degree in Structural Engineering from University of Puerto Rico Mayaguez Campus.

DAILY SCHEDULE

Day 1 - December 1st

Time	Organization	Speaker
9:00 EST	*Opening Remarks*	**Stephanie Coffin, NRC**
	Opening Pleanary: Reactor Digital Twins – Shifting the Paradigm – Moderator: Jeremy Bowen, NRC	
9:30 – 9:50	Florida Institute of Technology	Michael Grieves
9:50 – 10:10	IBM	Joseph Berti
10:10 – 10:30	Oak Ridge National Laboratory	Jeremy Busby
10:30 – 10:50	National Reactor Innovation Center, INL	Ashley Finan
10:50 – 11:10	ARPA-E	Jenifer Shafer
11:10 – 11:30	Combined Q&A	
11:30 – 1:30	**BREAK**	
	Technical Session: Advanced Reactors – Moderator: Mohamed Shams, NRC	
1:30 – 1:45	X-Energy	Ian Davis
1:45 – 2:00	Kairos Power	Anthonie Cilliers
2:00 – 2:15	Oklo, Inc.	Clyde Huibregtse
2:15 – 2:30	HolosGen, LLC	Charles R. Martin
2:30 – 3:00	Combined Q&A	
3:00 – 3:15	**BREAK**	
	Technical Session: Non-Nuclear Applications of DT– Moderator: Tamara Bloomer, NRC	
3:15 – 3:30	General Electric	Abhinav Saxena
3:30 – 3:45	IBM	Chandler Maskal
3:45 – 4:00	US Army RIEM	Mark Buller
4:00 – 4:15	University of Pittsburgh	Kevin P. Chen
4:15 – 4:45	Combined Q&A	
4:45	**ADJOURN**	

Day 2 - December 2nd

Panel Session: ARPA-E GEMINA – Moderator: Louise Lund, NRC

Time	Organization	Speaker
9:00 – 9:15	ARPA-E	Joel Fetter
9:15 – 9:30	General Electric	Abhinav Saxena
9:30 – 9:45	X-Energy	Yvotte Brits
9:45 – 10:00	Kairos Power	Anthonie Cilliers
10:00 – 10:30	Combined Q&A	
10:30 – 10:45	BREAK	

Technical Session: Industry Vision – Moderator: Joe Donoghue, NRC

Time	Organization	Speaker
10:45 – 11:00	Westinghouse	Brian Golchert
11:00 – 11:15	BWXT Technologies	Matthew LeVasseur & Ryan Kitchen
11:15 – 11:30	Electric Power Research Institute	Hasan Charkas
11:30 – 11:45	Analysis and Measurement Services Corporation	Dr Hash Hashemian & Dr Jacob Houser
11:45 – 12:15	Combined Q&A	
12:15 – 1:30	BREAK	

Technical Session: Applications of Advanced Technologies – Part I – Moderator: Mark Thaggard, NRC

Time	Organization	Speaker
1:30 – 1:45	Oak Ridge National Laboratory	David E. Womble
1:45 – 2:00	Argonne National Laboratory	Richard Vilim
2:00 – 2:15	Idaho National Laboratory	Christopher Ritter
2:15 – 2:45	Oak Ridge National Laboratory	Ben Betzler & Vincent Paquit
2:45 – 3:00	Combined Q&A	
3:00 – 3:15	BREAK	

Technical Session: Applications of Advanced Technologies – Part II – Moderator: Angie Buford, NRC

Time	Organization	Speaker
3:15 – 3:30	Framatome	Eric Helm
3:30 – 3:45	Argonne National Laboratory	Richard Vilim
3:45 – 4:00	University of Illinois at Urbana-Champaign	Rizwan Uddin
4:00 – 4:15	Argonne National Laboratory	Subhasish Mohanty
4:15 – 4:45	Combined Q&A	
4:45	ADJOURN	

Day 3 - December 3rd

Technical Session: International Activities in DTs - Moderator: Mike Case, NRC

9:00 – 9:15	Ontario Power Generation Canadian Nuclear Safety Commission	Richard Henry & John Sladek
9:15 – 9:30	Jacobs	Albrecht Kyrieleis
9:30 – 9:45	Tecnatom	Susana Lopez Lumbierres
9:45 – 10:05	Euratom – European Community Sustainable Nuclear Energy Technology Platform	Panagiotis Manolatos & Abderrahim Al Mazouzi
10:05 – 10:30	Combined Q&A	
10:30 – 10:45	BREAK	

Technical Session: Cyber Security - Moderator: Shana Helton, NRC

10:45 – 11:00	Idaho National Laboratory	Christopher Spirito
11:00 – 11:15	Oasis System, LLC (U.S. NRC Contractors)	Cynthia DeBisschop
11:15 – 11:30	International Atomic Energy Agency	Rodney Busquim
11:30 – 11:45		
11:45 – 12:15	Combined Q&A	
12:15 – 1:30	BREAK	

Technical Session: Multiphysics Modeling – Moderator: Stephen Bajorek, NRC

1:30 – 1:45	Oak Ridge National Laboratory	David Kropaczek
1:45 – 2:00	Zachry Nuclear Engineering	Jeffrey Lane
2:00 – 2:15	Argonne National Laboratory	Rui Hu
2:15 – 2:30	University of Central Florida	Felipe A.C. Viana
2:30 – 3:00	Combined Q&A	
3:00 – 3:15	BREAK	

Technical Session: Diagnostics, Prognostics, and Condition Monitoring - Moderator: Jeanne Johnston, NRC

3:15 – 3:30	University of Massachusetts Dartmouth	Lance Fiondella
3:30 – 3:45	NC State University	Linyu Lin
3:45 – 4:00	University of North Carolina at Charlotte	Timothy Kernicky
4:00 – 4:15	Oak Ridge National Laboratory	Pradeep Ramuhalli
4:15 – 4:45	Combined Q&A	
4:45	ADJOURN	

Day 4 - December 4th

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Closing Plenary - Moderator: Ray Furstenau, NRC

9:00 – 9:20	University of North Carolina at Charlotte	Michael Mazzola
9:20 – 9:40	Idaho National Laboratory	Mike Calley
9:40 – 10:00	Idaho National Laboratory	Christopher Ritter

Panel Session: DT Regulatory Discussion - Moderator: Jeremy Bowen, NRC

10:00 – 10:15	Energy Impact Center	Bret Kugelmass
10:15 – 10:30	NuScale Power	Neil Olivier
10:30 – 10:45	Oklo	Pat Everett
10:45 – 11:00	Westinghouse Electric Company	Gregory A Banyay
11:00 – 11:15	Combined Q&A	

Wrap Up Session - Raj Iyengar, NRC

11:15 – 11:45	U.S. Nuclear Regulatory Commission	
11:45	**ADJOURN**	

PLENARY SESSIONS

Tuesday December 1st

OPENING PLENARY SESSION   Jeremy Bowen

9:30 – 9:50   *Nuclear Digital Twins*
Dr. Michael Grieves, *Chief Scientist of Advanced Manufacturing, Executive VP Operations*
Florida Institute of Technology
Dr. Michael Grieves is currently at the Florida Institute of Technology in Melbourne, FL where he helped form the Center for Advanced Manufacturing and Innovative Design (CAMID). He is an internationally renowned expert in Product Lifecycle Management (PLM) and originated the concept of the Digital Twin. His focus is on virtual product development, engineering, systems engineering and complex systems, manufacturing, especially additive manufacturing, and operational sustainment. Dr. Grieves wrote the seminal books on PLM, "Product Lifecycle Management" and "Virtually Perfect: Driving Innovative and Lean Products through PLM." He has consulted and/or done research at some of the top global organizations, including NASA, Boeing, Newport News Shipbuilding, and General Motors. Dr. Grieves has presented at industry and academic conferences world-wide.

9:50 – 10:10   *IBM Digital Twin*
Joseph Berti, *VP of Offering Management*
IBM
Mr. Joseph Berti provides detailed direction on key technical and marketing tasks to launch an offering feature, offering, or collection of offerings. Accountable for key outcome metrics, including customer satisfaction, accessibility and revenue and profitability of assigned offering. Joe also demonstrates offering capabilities and value proposition to external stakeholders (customers, partners, and analysts), analyzing feedback to identify potential gaps or opportunities and make recommendations on how to address them. Mr. Berti has 25+ years of leadership experience in software and services in 8+ industries with a focus on transforming industries using optimization technologies. As an experienced Innovator, Joe launched 10+ products and services, transforming entire industries. Prior to joining IBM, Mr. Berti lead the company Oniqua into a rapid-growth cycle while launching new products and achieving new levels of innovation. Since Oniqua has been acquired by IBM, Joe continues to lead the IBM® Maximo® Inventory Optimization product offering. Mr. Berti received a Bachelor of Science in Finance and MIS (Management Information Systems) at Ohio State University.

10:10 – 10:30   *ORNL Resources to Support Digital Twin Applications for Nuclear Systems*
Dr Jeremy Busby, *Division Director, Reactor and Nuclear Systems Division*
Oak Ridge National Laboratory (ORNL)
Dr. Busby's research is focused on materials performance and development of materials for nuclear reactor applications. While at ORNL, Dr. Busby has participated in materials research efforts for space reactors, fusion machines, advanced fast reactors, and light water reactors. Ultimately, the results of this diverse research will enable the development of operating criteria for structural materials in a variety of adverse environments that will allow for design and operation of safe, reliable, and cost-effective nuclear systems.

Dr. Busby was the lead for the Materials Aging and Degradation Pathway for the DOE –Office of Nuclear Energy Light Water Reactor Sustainability Research and Development program from 2009 to 2015. He also led the Nuclear Energy Enabling Technologies Materials Cross-cut effort, in addition to participation in several nuclear industry-sponsored research tasks. As principal investigator for the DOE Office of Science ITER Program, he led an investigation into the feasibility of utilizing an innovative cast austenitic stainless steel (SS) for the first wall structure of the international ITER project. In 2010, Dr. Busby received the Presidential Early Career Award for Science and Engineering, following this effort for "excellence in research leading to the development of high performance cast stainless steels, a critical part of the U.S. Contributions to ITER project, and for his mentoring of students both as an Adjunct Assistant Professor at the University of Michigan and at ORNL." In 2011, he was awarded a Secretary of Energy Achievement Awards for contributions to DOE's response to Fukushima. The American Nuclear Society presented Dr. Busby with the Landis Young Member Achievement award in 2006 and, in 2007 he received the ORNL Early Career Award for Engineering Accomplishment for his leadership in the cast stainless steel effort.

10:30 – 10:50   **Dr Ashley Finan,** *Director*
National Reactor Innovation Center
Dr Ashley Finan is the Director of the National Reactor Innovation Center. In this role, she is responsible for overseeing initiatives to provide resources to reactor innovators to test, demonstrate, and conduct performance assessments to accelerate the deployment of advanced nuclear technology concepts. Dr. Finan holds an SB degree in Physics as well as SB and SM degrees in Nuclear Science and Engineering from MIT.

Dr. Finan earned her Ph.D. in Nuclear Science and Engineering at the Massachusetts Institute of Technology. Her doctoral work focused on energy innovation investment and policy optimization, both in nuclear and renewable energy technologies. She has played a key role in studies of the use of advanced nuclear energy to reduce greenhouse gas emissions in several applications, including hydrogen production, coal to liquids processes, and oil production methods. She has worked as a strategy and engineering consultant, primarily on nuclear energy applications. She has also contributed to analyses of the techno-economic potential of energy efficiency improvements in the residential and commercial sectors and several related topics.

10:50 – 11:10   Dr Jenifer Schafer, *Special Government Employee Consultant*
Advanced Research Projects Agency – Energy (ARPA-E)
Dr Jenifer Schafer currently serves as a Special Government Employee Consultant at the Advanced Research Projects Agency-Energy (ARPA-E). Her focus at ARPA-E is developing innovative and proliferation resistant technologies to manage nuclear waste and used nuclear fuel. She is an expert in nuclear separations, nuclear forensics and the fundamentals of actinide chemistry. Before joining ARPA-E, Shafer served on the faculty at Colorado School of Mines as an Associate Professor in the Chemistry Department and Nuclear Science & Engineering Program. Prior to that, she worked for two years at Pacific Northwest National Laboratory.
Shafer received a Ph.D. from Washington State University in 2010, and a B.S. from Colorado State University in 2005. She was a Department of Energy (DOE) Early Career awardee and currently serves on the ACS Committee on Science. She is the co-author of several book chapters, nearly 60 technical manuscripts and has led or collaborated on several projects for the Departments of Energy, Homeland Security, and Defense, as well as the National Science Foundation.

11:10 – 11:30   Combined Questions and Answers

CLOSING PLENARY SESSION   Ray Furstenau

9:00 – 9:20   *Managing Regulated Change: An Enterprise-Level Digital Twin for the Nuclear Industry*
Michael Mazzola, *Executive Director, Energy Production and Infrastructure Center (EPIC)*
University of North Carolina at Charlotte
Michael Mazzola attended the University of North Carolina Charlotte Ph.D. from Old Dominion University in 1990 in electrical engineering. From 1990 to 1993 employed by the U.S. Navy at the Naval Surface Warfare Center Dahlgren. From 1993 to 2017 served on the faculty in Electrical & Computer Engineering at Mississippi State University. In 2009 appointed Associate Director for Advanced Vehicle Systems, Center for Advanced Vehicular Systems (CAVS), a unit of the High-Performance Computing Collaboratory (HPC2) at Mississippi State University. July of 2017 appointed the Executive Director of EPIC and the Duke Energy Distinguished Chair in Power Engineering Systems at UNC Charlotte.
Presentation Overview: An enterprise-level Digital Twin integrates all business, technical, and regulatory compliance on an enterprise wide digital platform. This will allow the NRC to participate more collaboratively in the process of making changes while maintaining the intent of the approved DCD (Design Controlled Document). With adequate provision for the independence of the NRC's oversight, both sides will utilize a certified Digital Twin to make assessment and approval of changes efficient while maintaining the as-constructed plant's performance to license.

9:20 – 9:40   *Including Risk in Digital Twins*
Michael Calley, PhD, *Department Manager, Regulatory Support NSRR Division*
Idaho National Laboratory
Mike Calley has over thirty-one years of experience in probabilistic risk assessment (PRA), safety evaluations, and hazards assessments, including project management. His experience includes performing PRAs for both commercial nuclear power plants and nuclear research and test reactors, supporting the NRC on inspections at commercial nuclear power plants, and providing PRA technology transfer both domestically and internationally. Knowledge with preparing hazards assessments, developing guidelines for safety analysis report (SAR) preparation, and resolving adequacy of SAR concerns. Background also includes comprehensive use of PRA software. He holds an M.S. in Nuclear Science and Engineering and a B.S. in General Engineering from Idaho State University.
Presentation Overview: Presentation will look at including risk in digital twins applications. Digital twin technology will be part of next generation reactors. Risk in terms of performance shortfalls is a powerful way to characterize and understand complex systems and public health frequency-consequence is a key part of next generation risk-informed approach. Completeness in design and operation must take into account uncertainties. Major efficiencies in design, operation, and licensing of advanced reactors using a digital twin approach can be obtained if risk elements are taking into consideration.

9:40 – 10:00   *Towards a Digital Twin to Detect Nuclear Proliferation Activities*
Christopher Ritter, *Director, Digital Innovation Center of Excellence*
Idaho National Laboratory

Education/Experience: Christopher S. Ritter is a Group Lead with the Digital and Software Engineering group at Idaho National Laboratory. His expertise is in software engineering, software development, leading software teams, systems engineering software integration, and database management. Before coming to INL, he was director of software development at SPEC Innovations, in Manassas, Virginia. He served as the chief architect of Innoslate, a popular systems engineering tool that leverages elastic cloud technologies and AI/NLP for high scalability and advanced analytics. Architected the software system and consulted on the data ontology for a centralized mission risk management system for the Joint Staff at the Pentagon and supported Marine Corps business process reengineering for its Capability Portfolio Management processes. He was also a computer programming teacher at St. Michael's Academy in Warrenton, Virginia, and developed an elementary school computer programming curriculum. He holds a bachelor's degree in computer science from Virginia Polytechnic Institute and State University.

Presentation Overview: This project will develop technologies to enable a digital engineering and digital twinning technology to assist in diversion pathway analysis and apply safeguards by design concept for advanced reactors and power plants. Digital twinning and digital engineering have demonstrated significant performance and schedule reduction in the aerospace, automotive, and construction industries. This integrated modeling approach has not been fully applied to nuclear safeguards programs in the past. Digital twinning combined with artificial intelligence technologies can lead to new innovations in process monitoring detection specifically in event classification and data tampering.

TECHNICAL SESSIONS

ADVANCED REACTORS   Mohamed Shams

1:30 -1:45: *Xe-100 Digital Technologies Overview*
Ian Davis, X-Energy
Role: Senior Digital Twin System Engineer
Education/Experience: Master and Bachelor of Science degrees in Nuclear Engineering from Penn State University. A Nuclear Engineer with 6+ years of experience in the nuclear power generation industry, specializing in simulation of thermal hydraulics & neutronics, software programming, and data science.
Presentation Overview: X Energy, LLC (X-energy) is transforming the nuclear energy marketplace through the development of the Xe-100 High Temperature Gas-Cooled Generation IV Advanced Reactor. X-energy sees the innovation digital technologies to be an integral part of that transformation, especially with the Digital Twin. Contrary to Digital Twin use cases in the todays existing nuclear fleet, the Xe-100 Digital Twin will provide invaluable feedback into the design process. It will help shape our systems design, control strategy, operations & maintenance programs, and much more.

1:45 -2:00: *Digital Twin Development for Advanced Reactors, Accelerating Time to Market, Increasing Safety Margins, Maximizing Value*
Anthonie Cilliers, Kairos Power
Role: Senior Manager, Instrumentation, Controls and Electrical
Education/Experience: PhD (Nuclear Engineering). M.Eng & B.Eng (Computer & Electronic Engineering). 12 years' experience in nuclear specific plant control and protection systems. Specializing in model reference plant control & diagnostics and Control system architecture
Presentation Overview: The development of Advanced Reactors today, are coinciding with the fast maturing of digital modeling tools, virtual reality, machine learning and the ever-increasing compute power becoming available to reactor designers and operators. As Advanced Reactor developers we have a unique opportunity to incorporate a number of Digital Twin use cases from the conception of the project. In this discussion we explore the fundamental use cases of Digital Twins and how it can impact and support Advanced Reactor Designs

2:00 -2:15: *Advanced Reactor Design Meets Silicon Valley*
Clyde Huibregtse, Oklo, Inc.
Role: Reactor/Software Engineer
Education/Experience: B.S. Mathematics for Computer Science, B.S. Physics from MIT; been with Oklo in some capacity for almost 3 years
Presentation Overview: Contrary to the conventional notion of a Digital Twin as a tool exclusively for simulating system dynamics, at Oklo we've adopted a methodology known as a surrogate model in the early stages of reactor design. Leveraging the containerization capabilities of the Docker engine, we've constructed a virtualized analysis Pipeline, through which we can feed a large number of permutations of our nominal design, each of which outputs a scalar-valued performance metric. We train a surrogate model to map a vector of input dimensions to a performance value. With it, we can efficiently compute gradients of our performance function with respect to input parameters, allowing us to optimize our design's performance.

2:15 -2:30:   *Revolutionary Reactor Designs for a Changing and Challenged World*
Charles R. "Chip" Martin, Ph.D. , HolosGen, LLC
Role: Scientific/Technical Advisor
Education/Experience: Dr. Martin holds a Ph.D. in Nuclear Engineering from the U.S. Air Force Institute of Technology. His B.S. is in Nuclear Engineering from N.C. State University. He is currently an Executive Consultant with Longenecker & Associates, but he has held many interesting positions over the years. In 2018, he was the Glenn T. Seaborg Science and Technology Policy Fellow for the American Nuclear Society and the American Association for the Advancement of Science. In this role, he served as a staffer in the U.S. House of Representatives. Prior to that, he was the Chief Nuclear Officer for the Nevada National Security Site. He has served on the faculties of the University of Nevada, Las Vegas; the University of Maryland; and the U.S. Air Force Academy. He served as a technical specialist at the U.S. Defense Nuclear Facilities Safety Board; he was a nuclear research officer in the Office of the U.S. Secretary of the Air Force; he managed the U.S. Advanced Space Reactor Program at DOE; and he served as Technical Director for three underground nuclear weapon tests.
Presentation Overview: Dr. Martin will provide an introduction to micro-reactor designs that feature the elimination of the traditional "balance of plant" through integration of the power conversion components together with the nuclear core. The design utilizes modern high-speed motors and generators to convert thermal energy from the nuclear core to load-following electricity with design simplifications that enable competitiveness with non-nuclear electricity producing technologies. The Holos-QUAD design has been modeled with high-fidelity simulators by the national laboratories and academia and a sub-scale helium closed-loop simulator. The Risk Reduction Demonstration Monolithic-Holos (M-Holos) design is further simplified to facilitate the "Virtual Build" through digital twins, leveraging national laboratory and industry expertise, to reduce risks and accelerate deployment.

2:30 -3:00:   Combined Questions and Answers

NON-NUCLEAR APPLICATIONS IN DTs   Tamara Bloomer

3:15 – 3:30:   *Industrial Digital Twins: GE Experience and Perspectives*
Abhinav Saxena, General Electric (GE)
Role: Senior Scientist, Machine Learning GE Research, PI - GEMINA Award 2174-1511
Education/Experience: Dr. Abhinav Saxena is a Senior Scientist in AI & Learning Systems at GE Research and the PI for GE led GEMINA Award. Abhinav has been developing ML/AI-based PHM solutions for various industrial systems (aviation, nuclear, power, and healthcare) at GE and has been driving integration of AI-based PHM analytics in GE's industrial systems. Prior to GE, Abhinav worked as a research scientist at NASA Ames Research Center in carrying out fundamental research on prognostics methods and evaluation. Abhinav has over 15 years of experience in developing predictive maintenance methods and technologies. Abhinav is also an adjunct professor in the Division of Operation and Maintenance Engineering at Luleå University of Technology, Sweden. Abhinav's interests lie in developing PHM methods and algorithms with special emphasis on deep learning and data-driven methods in general for practical prognostics. Abhinav has published over 100 peer reviewed technical papers and has co-authored a seminal book on prognostics. He actively participates in several SAE standards committees, IEEE prognostics standards committee, and various PHM Society educational activities, and is a Fellow of the PHM Society. He is also the chief editor of International Journal of Prognostics and Health Management since 2011 and actively participates in organization of PHM Society conferences.
Presentation Overview: This talk will present GE's definition of Digital Twins for industrial assets. Specifically, application examples in several industrial domains such as aviation, healthcare, power, and transportation will be presented. Given GE's digital twin experience in the field, current challenged and research directions will be touched upon.

3:30 – 3:45:   *Overcoming Digital Twin Data Scarcity and Accelerating the Journey to Predict*
Chandler Maskal, IBM
Role: Offering Manager, IBM AI Applications
Education/Experience: Chandler graduated from Rensselaer Polytechnic Institute in 2018 with a bachelor's and master's degree in Information Technology and Web Science. She has worked for IBM as an offering manager for 2 years on multiple products in the Enterprise Asset Management space. She most recently led the launch of IBM's digital twin initiative this past May.
Presentation Overview: Learn about two of the greatest technical challenges in adopting digital twin technology and IBM's strategy for overcoming these challenges. This session will introduce the challenges we see across many industries and discuss the technical steps that IBM is taking to drive adoption of digital twin technology for equipment operations.

3:45 – 4:00:   *Pacing Optimization Enabled by Human Thermoregulatory System Digital Twin*
Dr. Mark Buller, US Army RIEM
Role: Principal Investigator with the Biophysics and Biomedical Modeling Division of the U.S. Army Research Institute of Environmental Medicine
Education/Experience: Dr. Mark Buller gained his doctorate in Computer Science from Brown University (Providence RI) in the area of Computational Physiology. Dr. Buller has over 20 years of experience in designing and fielding ambulatory physiological monitoring systems for warfighters. Dr. Buller's current research interests are: real-time algorithms that determine health state from wearable sensors, and performance optimization from physiological feedback. Dr. Buller is currently the principal investigator of a multi-institute research study to identify non-invasive markers of exertional heat stroke. Dr. Buller has authored more than 100 publications and is currently serving as a Chair for the NATO working group "Development of a NATO STANREC for Physiological Status Monitoring to Mitigate Exertional Heat Illness."
Presentation Overview: In this presentation we describe how a human-thermoregulatory system digital-twin enabled physiological-feedback pacing to optimize both performance and safety for military relevant tasks. We show that using a digital twin enabled a simple Markov Decision Process (MDP) representation of military pacing problems. By solving these MDP's the construction of pacing policies to optimize human physiological resources while minimizing thermal-work strain safety risks were realized. What had been identified in the literature as expert "black box" pacing templates were successfully enumerated by the use of a digital twin and can now be applied to novices on new and novel tasks.

4:00 – 4:15:   *A Digital Twin Approach to study Sensor Fused Additive Manufacturing Toward Smart Component Fabrications*
Kevin P. Chen, University of Pittsburgh
Role: Professor
Education/Experience: PhD 2002 from University of Toronto
Presentation Overview: One of the major challenges for metal-powder-based additive manufacturing to design optimized manufacturing strategy to mitigate residual strain induced during the manufacturing processes. This talk discussed distributed fiber optic sensors embedded in Inconel alloy components as experimental means to validate numerical models of additive manufacturing process. Using high spatial resolution data harnessed by distributed fiber sensors, digital twin models can be tuned to accurately model the manufacturing process, leading to design and manufacturing optimization.

4:15 – 4:45:   Combined Questions and Answers

Wednesday, December 2nd

INDUSTRY VISION   Joe Donoghue

10:45 – 11:00   *Synopsis of Westinghouse Machine Learning, Artificial Intelligence, and Digital Twin Developments for Nuclear Power Applications*
Brian Golchert, Westinghouse Electric Company
Role: Principal Engineer at Westinghouse
Education/Experience: Doctorate in Nuclear Engineering from the University of Illinois, Engineering work experience at Argonne National Laboratory, Fluent, General Electric Nuclear, and Westinghouse. Teaching experience at DePaul (mathematics/statistics) and Purdue Calumet (engineering)
Presentation Overview: An overview of digital twin related activities at Westinghouse with emphasis on current and future applications of digital twins

11:00 – 11:15   *Digital Twin for the Manufacture and Qualification of Additively Manufactured Nuclear Components*
Matthew LeVasseur, BWXT Technologies
Role: Director of Research
Education/Experience: 21 years with BWX Technologies preceded by 10 years of United State Marine Corps as an aerospace officer; Duke University, Global Executive Management, M.B.A. 2007 (With Honors), University of Michigan, Aerospace Science, M.S., 1995, University of Michigan, Astronomy, B.S., 1989, Qualtec Six Sigma Master Black Belt 2006, (Process Analytics and Data Methods), US Space Command, Space Control Qualification, Data Modeling/Infrastructure, 1997

Ryan Kitchen, BWXT Technologies
Role: Research and Development Data Scientist
Education/Experience: Lead data scientist and innovator for BWXT on a shared project with ORNL to develop digital twin technology for electron beam melt additive manufacturing, as well as additional R&D for nuclear manufacturing. Ryan brings expertise in High Performance Computing, GPU computing, bio-computing as well as machine vision and instrumentation for integration into manufacturing systems. Oregon State University, Computer Science, B.S., 2018

11:15 – 11:30   *EPRI's Digital Twin Related Activities for the Nuclear Industry*
Hasan Charkas, EPRI
Role: Principal Technical Leader, EPRI
Education/Experience: PhD. in Structural Engineering and engineering mechanics. Has been with EPRI almost five years. Before EPRI worked for AREVA/FRAMATOME and was engineering supervisor in the component's analysis and fracture mechanics group (Stress analysis for NSSS components and reactor vessel internals). Before AREVA/FRAMATOME was design engineer for structural group (strengthening of deficient structures)
Presentation Overview: Overview of EPRI's recent activities and research projects in digital twin technology.

11:30 – 11:45   *Digital Twins for Advanced Reactor Applications*

Dr Hash Hashemian, Analysis and Measurement Services Corporation (AMS)
Role: President and CEO
Education/Experience: D.E., Electrical Engineering
Lamar University Beaumont, Texas 2009; Ph.D., Nuclear Engineering Chalmers University Gothenburg, Sweden 2010; Ph.D., Computer Engineering Western University London, Ontario 2011

Dr Jacob Houser, Analysis and Measurement Services Corporation (AMS)
Role: Senior Research Engineer
Education/Experience: Doctor of Philosophy Mechanical Engineering University of Tennessee Knoxville; Master of Science Mechanical Engineering University of Tennessee Knoxville; Bachelor of Science Mechanical Engineering/Management; Rensselaer Polytechnic Institute

Presentation Overview: AMS will make a short power point presentation on adaptation of Digital Twins For improved I&C maintenance in current and next generation of nuclear reactors. We have integrated process data from measurements we have made in nuclear power plants with empirical and physical modeling to produce reliable predictions for process and sensor behavior to be use for anomaly detection, diagnostics, and prognostics.

11:45 – 12:15:   Combined Questions and Answers

APPLICATIONS OF ADVANCED TECHNOLOGIES – PART I   Mark Thaggard

1:30 – 1:45   *On AI Research at ORNL and its Application at SNS*
David E. Womble, Oak Ridge National Laboratory
Role: Director of Artificial Intelligence Programs
Education/Experience: Dr. Womble received his Ph.D. in Applied Mathematics from Georgia Tech in 1986. Before joining ORNL in 2017, Dr. Womble served as the Program Deputy for Advanced Simulation and Computing (ASC) at Sandia National Laboratories, responsible for developing and deploying modeling and simulation capabilities. He also served as the senior manager for the Computational Simulation Group and for the Computer Science and Mathematics Group. His recognitions include two R&D100 awards and the Gordon Bell Award. Dr. Womble's research interests include numerical algorithms and methods for machine learning and high-performance computing, including the solution of linear and nonlinear systems, multigrid and multiscale algorithms, time-series analysis, and scalable algorithms in HPC. Dr. Womble has also worked across several domain applications, including seismic imaging, semiconductor device simulation, computational mechanics and wind energy.

1:45 – 2:00   *Overview of Digital Twin Work at ANL*
Richard Vilim, Argonne National Laboratory
Role: Senior Nuclear Engineer, managing the Plant Analysis & Control & Sensors Department in the Nuclear Science and Engineering Division
Education/Experience: He has over 30 years of professional experience in the design and safety analysis of nuclear reactors with ongoing research projects involving control system design, modeling and simulation of nuclear systems, the operation of advanced nuclear reactors employing load following and load leveling using energy storage, and artificial intelligence and machine learning for plant performance improvement. He is an author on over 300 reports and publications and nine U.S. patents.

2:00 – 2:15   **Extending a Digital Engineering Framework through Operations**
Christopher Ritter, Idaho National Laboratory
Role: Director, Digital Innovation Center of Excellence
Education/Experience: With a bachelor's degree in computer science from Virginia Polytechnic Institute and State University, Mr. Ritter is a Group Lead with the Digital and Software Engineering group at INL. His expertise is in software engineering, software development, leading software teams, systems engineering software integration, and database management. Before coming to INL, he was director of software development at SPEC Innovations, was the chief architect of Innoslate, he architected the software system and consulted on the data ontology for a centralized mission risk management system for the Joint Staff at the Pentagon and supported Marine Corps business process reengineering for its Capability Portfolio Management processes and he also served as a computer programming teacher at St. Michael's Academy in Warrenton, Virginia.

2:15 – 2:30   *Digital Platform for the Transformational Challenge Reactor*
Dr Ben Betzler, Oak Ridge National Laboratory
Role: Nuclear Engineer
Education/Experience: Dr. Benjamin R. Betzler is an outcome-focused reactor physics nuclear engineer with demonstrated experience and performance on research and development programs for a variety of sponsors, including leading diverse multi-organization teams. He has recognized expertise in both reactor analysis and methods development, with specialized knowledge of advanced reactor systems (e.g., molten salt reactors, microreactors, high-temperature gas-cooled reactors, and space propulsion systems) and Monte Carlo radiation transport methods (alpha-eigenvalue methods, time-dependent problems, and matrix methods and applications of Markov processes). Dr. Betzler received his Ph.D. in Nuclear Engineering and Radiological Sciences from the University of Michigan in 2014.

Dr Vincent Paquit, Oak Ridge National Laboratory
Role: Senior Research Scientist, Electrical and Electronics Systems Research (EESR) Division
Education/Experience: Before joining ORNL, he worked at the University of Burgundy (France) as an engineer in technology transfer for the Laboratoire Electronique Informatique Image (Le2i) for all commercial and technical applications in the fields of Electronic, Computer Science and Signal Processing. Since then, Dr. Paquit has been an active member of the Imaging, Signals, and Machine Learning (ISML) group, working on multiple projects and programs supporting two core missions of the Department of Energy: Energy sustainability and National Security. He is contributing to ORNL's scientific endeavor by conceiving, designing and implementing complex computer vision and multidimensional imaging systems - combining both hardware and software development - to perform quantitative analysis of complex datasets and/or to make quantitative measurement of various objects. Currently, Dr. Paquit is the Data Analytics lead for the Manufacturing Demonstration Facility (MDF). His team is developing a Data Analytics Framework for Manufacturing aiming at better understanding additive manufacturing processes for the purpose of process certification and control. His research interests include applied signal and image processing, algorithm development on GPU platform, 2D and 3D image segmentation, multispectral and hyperspectral imaging, biomedical imaging, pattern recognition, remote sensing data understanding, and machine learning. He has published numerous peer-reviewed articles, one book chapter, submitted multiple invention disclosures, and served on program committees of several international conferences.

2:30 – 3:00:   Combined Questions and Answers

APPLICATIONS OF ADVANCED TECHNOLOGIES – PART II   Angie Buford

3:15 – 3:30:   *Digital Twin-Based Asset Performance and Reliability Diagnosis for the HTGR Reactor Cavity Cooling System Using Metroscope*
Eric Helm, Framatome
Role: Framatome Product Manager - Metroscope
Education/Experience: BS M.E./Master Systems Eng.; 5 years automotive manufacturing industry; 15 years Framatome in a variety of engineering roles including fuel fabrication, large projects, system engineering methods, field service, equipment analytics, and advanced diagnostics with Metroscope
Presentation Overview: This presentation will provide an overview of the technical and commercial challenges relative to use of digital twins for system diagnostics along with savings and regulatory basis and the initial project approach meant to address those challenges.

3:30 – 3:45:   *Data-Driven Optimization of Moisture Carryover in an Operating BWR*
Richard Vilim, Argonne National Laboratory
Role: Senior Nuclear Engineer, managing the Plant Analysis & Control & Sensors Department in the Nuclear Science and Engineering Division
Education/Experience: He has over 30 years of professional experience in the design and safety analysis of nuclear reactors with ongoing research projects involving control system design, modeling and simulation of nuclear systems, the operation of advanced nuclear reactors employing load following and load leveling using energy storage, and artificial intelligence and machine learning for plant performance improvement. He is an author on over 300 reports and publications and nine U.S. patents.

3:45 – 4:00:   *Role and Status of VR/AR/MR in Digital Twins in the Nuclear Industry*
Rizwan Uddin, University of Illinois at Urbana-Champaign
Role: Professor and Head of the Department of Nuclear, Plasma, and Radiological Engineering
Education/Experience: Professor Rizwan-Uddin is a Fellow of the American Nuclear Society. He directs the Virtual Education and Research Lab (VERL) and is also the Director of Master of Engineering in Energy Systems Program. He was awarded the American Society of Engineering Education's Glenn Murphy Award in 2015, American Nuclear Society's Arthur Holy Compton Award for his teaching and research accomplishment (2016), and 2017 UIUC's Campus Award for Excellence in Guiding Undergraduate Research.
Presentation Overview: Having made seminal research contributions in the development and analysis of: two-phase flow and BWR stability; advanced numerical methods for thermal hydraulics problems, CFD, and large scale, high performance computing for nuclear applications; analytical benchmarks for heat transfer problems; and new self-consistent turbulence models and associated closure laws for flow in porous media. He is also, with much assistance from undergraduate students working in his lab, one of the pioneers in the development and use of 3D immersive, virtual reality systems and computer-games for education and training in the nuclear field.

4:00 – 4:15: *On-line AI/ML & Computational-Mechanics Based Predictive Tools for a Digital-Twin Framework*
Dr Subhasish (Subh) Mohanty, Argonne National Laboratory
Role: Principal R&D engineer
Education/Experience: Dr. Subhasish Mohanty is currently working as a principal R&D engineer at the Nuclear Science and Engineering (NSE) division of Argonne National Laboratory. Dr. Mohanty working in Argonne from 2010 after finishing his PhD in Aerospace Engineering from Arizona State University. Dr. Mohanty also has four years of experience in aerospace industry. His experience and interest primarily focus on 1) Structural mechanics and digital twin of nuclear reactor and aerospace systems, 2) Machine learning, artificial intelligence and data analytics techniques, and 3) Internet-of-Things or IoT concepts.
Presentation Overview: The presentation will focus on various aspects of digital twin with some example results related to laboratory scale testing, 3D finite element modeling, online state estimation based on heterogeneous sensor measurements, online condition-based state forecasting and remaining life estimation.

4:15 – 4:45: Combined Questions and Answers

Thursday, December 3rd

INTERNATIONAL ACTIVITIES IN DTs   Mike Case

9:00 – 9:15   *Qualification of the Pickering A Test Facility*
Richard Henry, Ontario Power Generation
Role: Section Manager, Ontario Power Generation; Computers and Control Design, Central Engineering
Education/Experience: B. Eng., Electrical Engineering, McMaster University, Hamilton, ON

John Sladek, Canadian Nuclear Safety Commission
Role: Specialist, Canadian Nuclear Safety Commission; System Engineering Division, Directorate of Assessment and Analysis
Education/Experience: B. Sc., Electrical Engineering, Queen's University, Kingston

Presentation Overview: A software-based test facility can be used for verification & validation testing of nuclear control computer software modifications. This digital twin application was successfully implemented by Ontario Power Generation at one of their plants. Regulatory requirements, software qualifications, and an overview of the test facility will be discussed.

9:15 – 9:30   *UK Nuclear Virtual Engineering Capability*
Dr Albrecht Kyrieleis, Jacobs
Role: Senior Consultant
Education/Experience: With more than 10 years' experience in the nuclear industry and a background in physics, Dr Albrecht Kyrieleis has worked on a broad range of projects in the areas of simulation software development, radiation shielding and protection, nuclear physics and criticality. Involved in fission as well as fusion he has led various R&D and application projects and is the Technical Lead for the UK Nuclear Virtual Engineering project, responsible for the overall technical programme.

9:30 – 9:45   *Benefits of Digitalizing and Employing Simulation to Increase Plant System Performance and Ensure Compliance with Technical Specifications*
Susana Lopez Lumbierres, Tecnatom
Role: Senior Project Manager
Education/Experience: Industrial Engineer / Simulation Engineer
Presentation Overview: Tecnatom designed, implemented and tested a design modification for the on-line monitoring of the essential services water system in a BWR nuclear power plant by integrating it in the existing Digital Control System (DCS). Key system parameters were acquired in real time to be displayed in the Human System Interface, used in performing calculations and stored their historical evolution. The objective was to optimize monitoring and surveillance of this system. Furthermore, Tecnatom developed an engineering simulator ("What if" simulator) consisting of a hydraulic model of the system. This simulator takes as inputs each heat exchanger performance parameters from the plant DCS, allows the user to change the essential services water system configuration (valves position, UHS level…) and calculates theoretical process values predicting the system real behavior. In a second stage, more system instruments were wired to the DCS for Technical Specifications compliance automatic surveillance regarding opening and closing times of system valves.

9:45 – 9:55   *EURATOM Research and Training Programme - Fission Research*
Panagiotis Manolatos, Euratom European Community
Role: Project Officer
Education/Experience: Engineer, PhD in Materials sciences - Ecole des Mines – France, 10 years
laboratory research on materials and components behavior in different European National laboratories
(FR, NL), 5 years tutoring in Ecole Centrale de Paris - FR, 20 years coordination of research in nuclear
safety at the European Commission DG-RTD.
Presentation Overview: The "modus operandi" of the Euratom Programme for research and training,
examples of currently funded research projects in nuclear safety, status of preparation of the next
Framework Programme 2021-2027 (Horizon Europe) and possibilities for international cooperation.

9:55 – 10:05   *European R&D&I Towards Digital Twins*
Abderrahim Al Mazouzi , EDF France
Role: Expert Groupe of EDF in charge of the European affairs of the R&D programme on energy
production
Education/Experience: Abdou was acting as the general secretariat and member of the executive
committee of the international association NUGENIA (www.nugenia.org) for 7 years.
After his PhD in materials science 1989, he spent 3 years as Post Doc at Hahn Meitner Institute in Berlin,
Germany, followed by a position as visiting scientist at Kyoto University/ Japan 1993-1995.
In 1995 he joined the CRPP of the Ecole polytechnique federale of Lausane/CH to work on fusion
technology, then moved to Paul Sherrer Institute/CH to act as project manager at the hot-lab facility
1999--2001. From 2002 until 2009, he was appointed as senior scientist then group leader at SCK.CEN,
Belgium, just before joining EDF R&D.
Presentation Overview: Within the technological platform SNETP, many collaborative projects (most of
them are sponsored by Euratom) are developing several technological/scientific projects that are helping
the association members to progress towards building several Digital Twins of critical components up to
the entire reactor. The presentation will give a flavor of some on-going projects and highlight some
examples that are considered by the SNETP members.

10:05 – 10:30   Combined Questions and Answers

CYBER SECURITY   Shana Helton
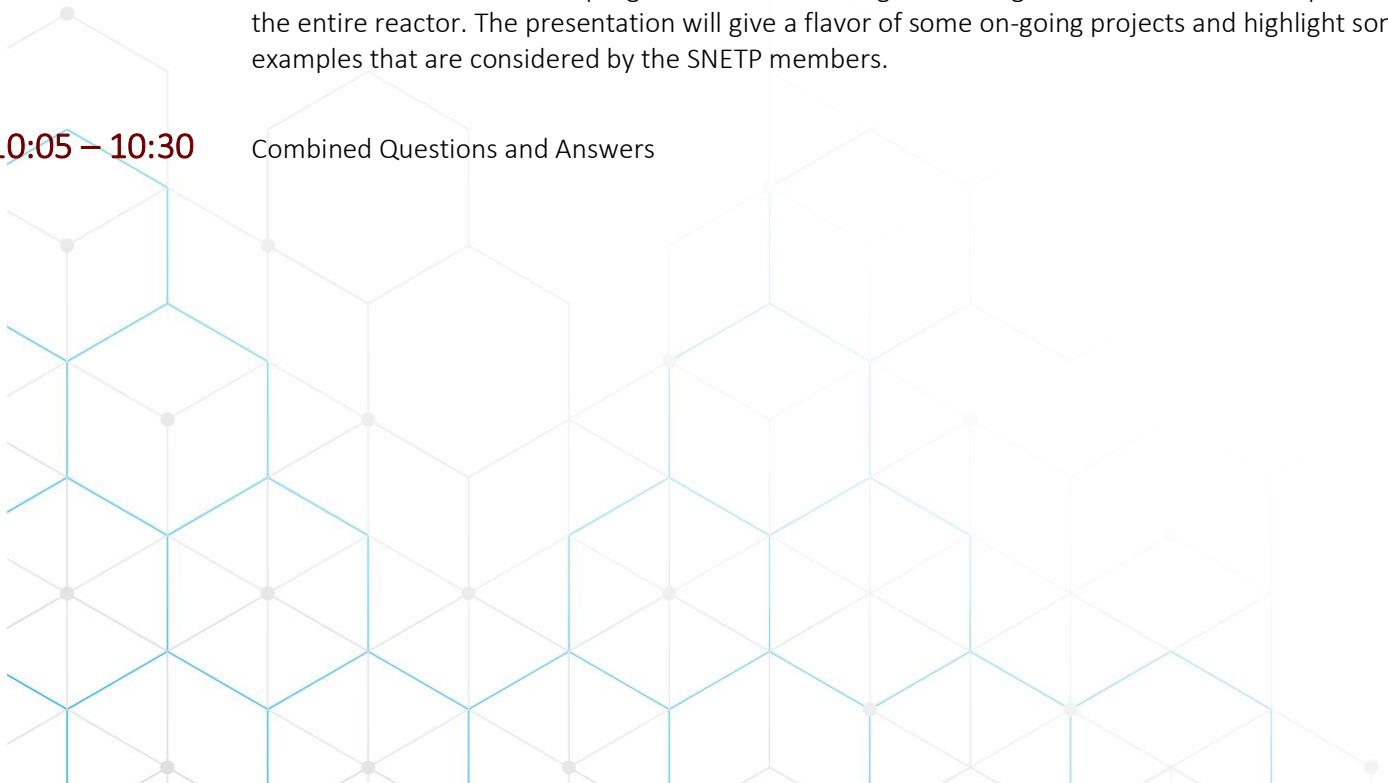
10:45 – 11:00   *Digital Twins and Cybersecurity*
Christopher Spirito, Idaho National Laboratory
<u>Role:</u> Nuclear Cyber Security Consultant
<u>Education/Experience:</u> BA, Mathematics, Boston College
<u>Presentation Overview:</u> How to use Digital Twins to improve your Cyber capabilities

11:00 – 11:15   *Cyber Security for Digital Twins*
Cynthia DeBisschop, Ph.D., Oasis System, LLC (U.S. NRC Contractors)
<u>Role:</u> Senior Cyber Security Analyst
<u>Education/Experience:</u> Dr. DeBisschop holds a bachelor's degree in chemical engineering from Drexel University and master's and doctoral degrees in Engineering Sciences and Applied Mathematics from Northwestern University. Inspired by computational mentors at Mobil Research and Development Corporation where she worked as a cooperative education student early in her career, she pursued graduate research focused on mathematical modeling of physical processes at Northwestern as a National Science Foundation Graduate Research Fellow. She engaged in computational interdisciplinary research as a postdoctoral researcher in the Department of Mathematical Sciences at the University of Delaware and as a professor in the Department of Mathematics and Statistics at Old Dominion University. In 2009, Dr. DeBisschop began work as a Research Analyst for CNA's Institute for Public Research under contract to the Federal Aviation Administration where she conducted research in data and information management and in systems engineering for the NextGen modernization effort. While at CNA, she co-authored a paper that won two David Lubkowski Memorial Best Paper awards in 2011. Since 2017, Dr. DeBisschop has supported the cyber security program at NRC and has conducted and supported 18 cyber security inspections of nuclear power plants. She assisted in the presentation of the Advanced Cyber Security Inspection Training course offered at the NRC Technical Training Center in Chattanooga, TN. More recently, she assisted in the development of regulatory guidance for the NRC.
<u>Presentation Overview:</u> This presentation offers considerations from a regulatory perspective while digital twin technology is in development. Before procurement or use of technology, there is a need to understand the attack surfaces and environments associated with digital assets. Nuclear power plant operators maintain the following throughout the life cycle of digital assets: a security defensive architecture to address the attack surfaces and environments, and multiple layers of cyber security protections to establish sufficient defense-in-depth. Defense-in-depth protective strategies are maintained to ensure the capability to detect, respond, and recover from cyber-attacks. Such an objective depends on understanding and careful consideration of technology before procurement or use.

11:15 – 11:30   *The Asherah Nuclear Power Plant Simulator in a Closed-Loop Digital Twin Environment*
Rodney Busquim e Silva, International Atomic Energy Agency (IAEA)
Role: Computer Security Officer
Presentation Overview: Nuclear power plants (NPP) consist of several complex industrial processes with a large number of IT and automation systems, implementing process control, safety and security functions. The need to understand the impacts – and how they propagate – of cyber-attacks led to the development of a specific simulator, the Asherah NPP Simulator (ANS), for an International Atomic Energy Agency Coordinated Research Project. Digital Twins open new possibilities of simulating, monitoring, estimating and optimizing the state of nuclear energy systems. Within this scope, digital twins can be leveraged for computer security purposes when integrated into nuclear power plants simulators like the ANS.

11:30 – 12:00   Combined Questions and Answers

MULTIPHYSICS MODELING   Steve Bajorek

1:30 – 1:45   *Advanced Modeling and Simulation and its Future Role in Nuclear Systems Digital Twin Technology*
Dave Kropaczek, Oak Ridge National Laboratory
Role: Director for the U.S. Department of Energy innovation hub – Consortium for Advanced Simulation of Light Water Reactors (CASL)
Education/Experience: Formerly President and CEO of Studsvik Scanpower, the nuclear software division of Studsvik AB, Kropaczek holds a BS degree in Engineering Science from New Jersey Institute of Technology and Master of Nuclear Engineering (MNE) and PhD degrees in Nuclear Engineering from NC State University. He has over 27 years of experience in the nuclear industry with areas of expertise that include: fuel cycle and plant optimization, computational reactor physics and thermal-hydraulics, and numerical algorithm development. Previous experience includes positions in research, product development, and management including 9 years with General Electric (GE) Global Nuclear Fuel, developing methods and software for boiling water reactor (BWR) fuel technology; 12 years with Studsvik Scanpower, developing methods for real-time kinetics simulation and multi-cycle optimization; and 3 years in Westinghouse Fuels, with a focus on core design and monitoring applications. In addition, Dr. Kropaczek spent 3 years as a Research Assistant Professor at NC State working with students and R&D projects sponsored through the Electric Power Research Center. Kropaczek's professional activities include the American Nuclear Society (ANS) Reactor Physics Division Chair for the Advances in Nuclear Fuel Management topical meetings, and technical reviewer for several journals including Nuclear Technology and Nuclear Science and Technology.

1:45 – 2:00   *Modeling and Simulation to Support Digital Twins*
Jeffery W. Lane, Zachry Nuclear Engineering
Role: Chief Engineer and Principal Consultant
Education/Experience: Dr. Lane has 15 years of software development experience in computational thermal-hydraulics and reactor safety analysis for existing LWRs, next generation SMR and non-LWR concepts. His expertise is in multi-physics and multi-scale methods, Verification, Validation, and Uncertainty Quantification (VV&UQ), and software quality assurance. Dr. Lane has also been involved with digital twin development, autonomous control and data-driven modeling. Currently he is the technical lead and program manager for the GOTHIC coarse-grid CFD software. Dr. Lane worked for the Bettis Atomic Power Laboratory, where he was responsible for advancing simulation capabilities to support existing and future applications in the Naval Nuclear Propulsion Program, including the safety analysis for the FORD Class aircraft carrier, multi-physics methods development and integrated plant analysis development. Dr. Lane received his Ph.D. from Pennsylvania State University where he studied under the Rickover Fellowship Program in Nuclear Engineering.
Presentation Overview: This presentation will focus on the role of advanced modeling and simulation (AMS) in digital twin development and application. The focus will be on what AMS can provide and required attributes of the AMS tool to support these applications. Challenges related to data assessment and credibility will also be discussed.

2:00 – 2:15   *Multi-Physics Modeling for Advanced Reactor Safety and Digital Twin Development*
Rui Hu, Argonne National Laboratory
Role: Manger of Plant System Analysis Group
Education/Experience: Ph.D. in Nuclear Engineering from Massachusetts Institute of Technology
Presentation Overview: Inherent safety is a key characteristic for various advanced reactor concepts, which requires improved understanding of the multi-physics phenomena and modeling and simulation capabilities. This talk will give an overview on the safety characteristics and the needs of multi-scale multi-physics simulation. Then, it will provide an example of coupled multi-physics simulation of a heat-pipe-cooled micro-reactor and present some thoughts on leveraging multi-physics simulations in digital twin development.

2:15 – 2:30   *Hybrid Physics-Informed Neural Networks, Cumulative Damage Models, and Digital Twins*
**Felipe A.C. Viana**, University of Central Florida
Role: Assistant Professor
Education/Experience: Before joining UCF, Dr. Viana was a Sr. Scientist at GE Renewable Energy, where he led the development of computational methods for improving wind turbine performance and reliability. Prior to that role at GE, he spent five years at GE Global Research, where he led and conducted research on design and optimization under uncertainty, probabilistic analysis of engineering systems, and services engineering. Dr. Viana holds a PhD in Aerospace Engineering from the University of Florida and PhD and MSc in Mechanical Engineering from Federal University of Uberlandia (Brazil).
Presentation Overview: Dr. Viana will challenge the myth that building digital twins with machine learning requires large datasets. First, he will address how physics-driven and data-driven kernels can be combined within deep neural networks. This framework pioneered in the Probabilistic Mechanics Lab allows for neural network to directly implement differential equations while accounting for uncertainty in the model form as well as observations. Dr. Viana will give an overview on the theoretical aspects and show engineering applications in digital twins for failure prognosis of main bearing of wind turbines, aircraft fuselage panels, and batteries used to power electric vehicles.

2:30 – 3:00:   Combined Questions and Answers
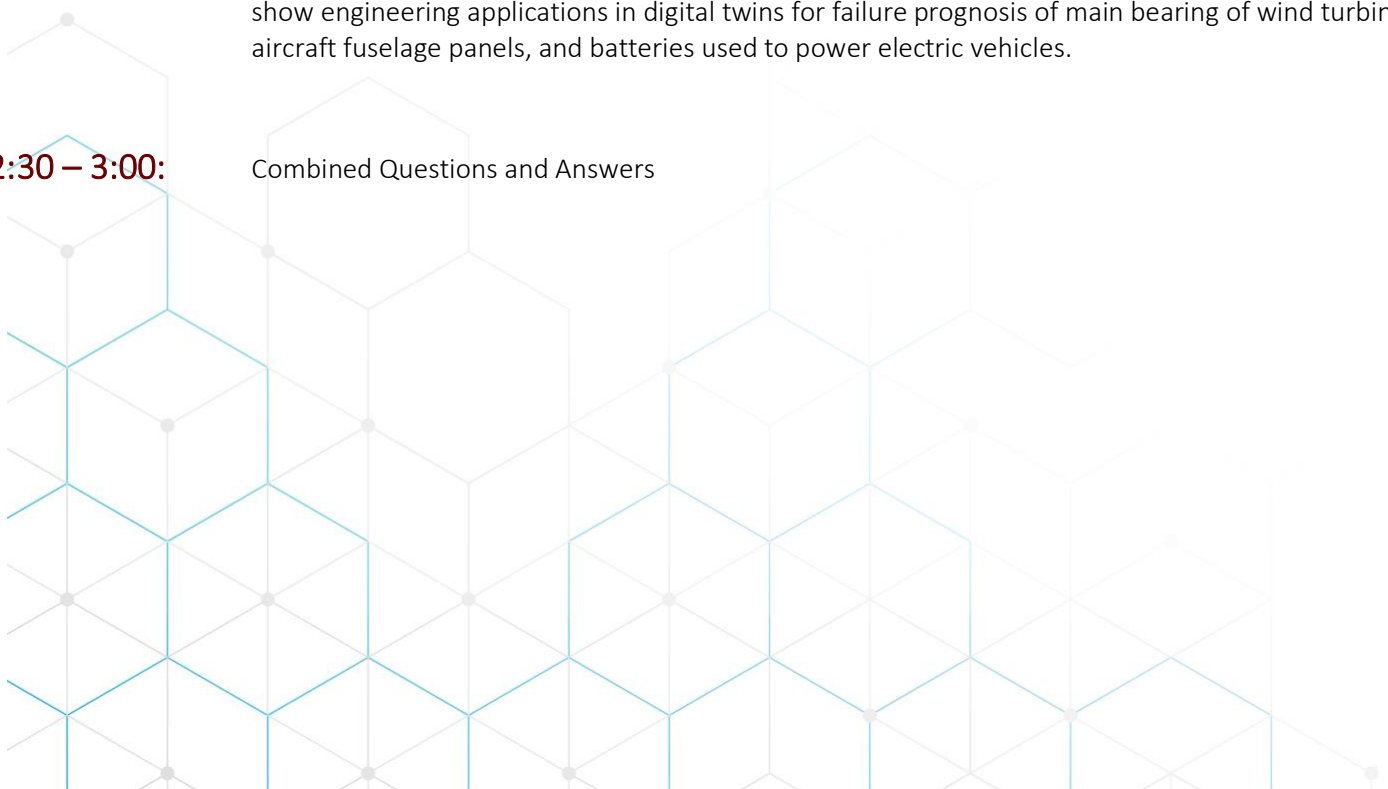
DIAGNOSTICS, PROGNOSTICS, AND CONDITIONING MONITORING   Jeanne Johnston

3:15 – 3:30:   *A Quantitative Framework to Assess Tradeoffs in Alternative Models and Algorithms for Prognostics and Health Management*
Lance Fiondella, University of Massachusetts at Dartmouth
Role: Associate Professor of Electrical and Computer Engineering
Education/Experience: Computer Science and Engineering PhD, University of Connecticut
Presentation Overview: Prognostics and health management is transforming reliability engineering by pinpointing which components or subsystems require maintenance as well as precisely predicting when these maintenance actions should be performed. While there are several metrics to quantitatively assess the accuracy of remaining useful life predictions, fewer studies have explicitly modeled the economic benefits of implementing prognostics and health management such as return on investment, life-cycle cost reduction, and average total cost over a period. Although simulation and probabilistic techniques have been developed to select a time horizon for use by remaining useful life predictions in order to guide maintenance decisions that minimize cost, these past techniques do not consider additional factors of interest. To overcome this limitation, we develop data-driven analogs to metrics from renewal theory, including average cost per unit time, utilization, safety, and availability, rendering them suitable for application in the context of PHM methods. Simultaneous consideration of multiple metrics introduces a multi-objective generalization of the cost minimization problem, necessitating a framework to compare alternative PHM methods. Therefore, we also explicitly decouple degradation models from the algorithms that iteratively update estimates of a model's parameters. This decoupling approach enables direct comparison of alternative combinations of models and algorithms as well as a method to select a time horizon that balances tradeoffs between multiple competing metrics according to stakeholder preference. The approach is applied to lithium-ion batteries. The results indicate that the approach can be used to select a combination of model and algorithm that balances tradeoffs between competing objectives such as cost and utilization. Moreover, the framework is general and accommodates both existing and future degradation models and algorithms.

3:30 – 3:45:   *Digital Twins in a Nearly Autonomous Management and Control System for Advanced Reactors*
Linyu Lin, North Carolina State University
Role: Post-Doctoral Research Scholar at the department of nuclear engineering
Education/Experience: Ph.D. in Nuclear Engineering
Presentation Overview: This presentation introduces the implementation of a nearly autonomous management and control (NAMAC) system with digital twins and machine learning algorithms. Four design principles of NAMAC are discussed including the three-layer architecture, modular framework, digital twin development and assessment process, and digital twin trustworthiness assessment.

3:45 – 4:00: *Structural Condition Monitoring with a Digital Twin: Explorations on a Nuclear Containment Vessel Model*

Timothy Kernicky, University of North Carolina at Charlotte
Role: EPIC Research Assistant Professor of Civil Engineering
Education/Experience: Ph.D. Infrastructure & Environmental Systems, M.S. Engineering, B.S. Mathematics
Presentation Overview: A preliminary study will be reported that explores the capability of a digital twin to track the onset and progression of natural or event-driven deterioration in a concrete nuclear containment vessel. Measurements of in-service behavior will be utilized with the digital twin to detect changes in the structural condition by probabilistic model updating for a series of progressive deteriorations at critical locations. Establishment of a trusted digital twin with a history of progressive degradation may be leveraged for evaluation of critical limit states and life cycle assessment.

4:00 – 4:15: *Digital Twins for Prognostic Health Management (PHM) in Nuclear Energy: Opportunities and Challenges*

Pradeep Ramuhalli, Oak Ridge National Laboratory
Role: Distinguished Scientist
Education/Experience: Over the last 18 years, he has led and contributed to advances in systems resilience and reliability, with current research focused on developing technologies that enable robust digital twins and applying them to improve the economics of nuclear power, enhancing the reliability of renewable energy systems, and in cyber-security and international safeguards. Relevant technology areas include sensors and algorithms for continuous online monitoring of stressors and systems for degradation detection and characterization, physics-informed machine learning algorithms for prognostic assessment of system and component remaining useful life, and risk-informed methodologies to assure reliability of measurements and resilience of degraded systems. He co-edited a book on integrated vision and imaging techniques for industrial inspection and has authored or co-authored 4 book chapters, over 175 technical publications in peer-reviewed journals and conferences (including over 35 peer-reviewed journal publications), and over 90 technical research reports. He is a senior member of IEEE and a member of ANS.

4:15 – 4:45: Combined Questions and Answers

PANEL SESSIONS

Wednesday, December 2nd

PANEL SESSION: ARPA-E GEMINA   Louise Lund

9:00 – 9:15   *ARPA-e Perspective: Digital twins as an Enabler of Low O&M Costs*
Joel Fetter, ARPA-E
Role: Lead Associate at Booz Allen Hamilton, where he leads the Firm's engagements to develop public-private initiatives that accelerate the uptake of advanced technologies by commercial markets.
Education/Experience: Over the past 9 years his primary focus has been on the establishment the Advanced Research Projects Agency for Energy's Technology-to-Market capability, where he advises on the development and implementation of program structures that translate science into business concepts. To date ARPA-e portfolios have accrued many billions of dollars in follow-on funding, extensive patent activity, and seminal research that has created new learning curves for advanced energy technologies. Most recently he advised on the creation of ARPA-e's initial suite of investment into advanced nuclear energy systems, which comprise nearly $100 million in enabling technologies, microreactors, and improved operations and maintenance technologies. Prior to his engagement with ARPA-e Mr. Fetter consulted to public, private and nonprofit organizations across the energy landscape. He earned an M.A. in Law and Diplomacy from the Fletcher School at Tufts University and a B.A., summa cum laude, in International Affairs from the University of Colorado at Boulder.

9:15 – 9:30   *AI Enabled Predictive Maintenance Digital Twins for Advanced Nuclear Reactors*
Abhinav Saxena, General Electric (GE)
Role: Senior Scientist, Machine Learning GE Research, PI - GEMINA Award 2174-1511
Education/Experience Summary: Dr. Abhinav Saxena is a Senior Scientist in AI & Learning Systems at GE Research and the PI for GE led GEMINA Award. Abhinav has been developing ML/AI-based PHM solutions for various industrial systems (aviation, nuclear, power, and healthcare) at GE and has been driving integration of AI-based PHM analytics in GE's industrial systems. Prior to GE, Abhinav worked as a research scientist at NASA Ames Research Center in carrying out fundamental research on prognostics methods and evaluation, has over 15 years of experience in developing predictive maintenance methods and technologies, is also an adjunct professor in the Division of Operation and Maintenance Engineering at Luleå University of Technology, Sweden.
Presentation Overview: A brief overview of GEMINA project on AI-based digital twins for reducing O&M costs for Advanced Reactors. The Presentation will describe key project goals and technology R&D towards achieving O&M cost reductions.

9:30 – 9:45   *Xe-100 ARPA-E GEMINA Program Overview*
Yvotte Brits, X-Energy
Role: Supply Chain Manager and Operator Training Simulator Program Manager
Education/Experience: Master's degree in Nuclear Engineering and Electric & Electronic engineering. Nuclear Engineer with 13 years of vital experience in the International Nuclear Industry specializing in Supply Chain Management, Operator Simulator Training Program Management, Energy Plant Transient Analyses, Instrumentation & Control Design, Cost Modelling, Plant System Design for Power Plants. Successfully completed various projects for Nuclear Companies in South Africa and the United States 12 years' experience in nuclear specific plant control and protection systems. Specializing in model reference plant control & diagnostics and Control system architecture.
Presentation Overview: X Energy, LLC (X-energy) is transforming the nuclear energy marketplace through the development of the Xe-100 High Temperature Gas-Cooled Generation IV Advanced Reactor. Levelized fixed Operation & Maintenance (O&M) costs from conventional energy-generating technologies such as coal and gas are lower than nuclear energy. The regulatory framework of traditional nuclear requires a number of operator, security, and maintenance staff resulting in high levelized fixed O&M costs of approximately $14.5/MWh for the Xe-100 plant. X-energy will demonstrate the Digital Twin's ability to reduce levelized fixed O&M costs to a target of $2/MWh using our Xe-100 plant. The Xe-100's intrinsic passive safety features make it ideal to showcase the abilities of the Digital Twin.

9:45 – 10:00   *ARPA-E Gemina Projects:*
*   Project "SAFARI" – Secure Automation for Advanced Reactor Innovation*
*   Project "MARS" – Maintenance of Advanced Reactor Sensors and Components*
Anthonie Cilliers, Kairos Power
Role: Senior Manager, Instrumentation, Controls and Electrical
Education/Experience: PhD (Nuclear Engineering). M.Eng & B.Eng (Computer & Electronic Engineering). 12 years' experience in nuclear specific plant control and protection systems. Specializing in model reference plant control & diagnostics and Control system architecture
Presentation Overviews:
SAFARI: Deliver a capability enabling smart functionalities in advanced reactor systems (ARS) such as autonomous operations (AO), flexible operations (FO), and predictive maintenance (PM). This has the potential to dramatically lower operations and maintenance (O&M) costs compared to currently operating LWRs.
MARS: Develop advanced distributed sensing and data generation techniques to characterize critical components and systems. Increase sensor diversity and develop multifunctional sensors which measure several process variables simultaneously and automate maintenance tasks through machine learning-enabled fault detection and diagnostics and intelligent sensor placement to achieve autonomous operation.

10:00 – 10:30   Combined Questions and Answers

PANEL SESSION: DT REGULATORY DISCUSSION   Jeremy Bowen

10:15 – 10:45   **Bret Kugelmass,** Managing Director, Energy Impact Center
Role: Managing Director
Education/Experience: Master's in Mechanical Engineering, Stanford University, Former Robotics Entrepreneur
Current Work: Pioneering OPEN100, open-source PWR framework

10:45 – 11:15   **Neil Olivier,** NuScale Power
Role: Director of Corporate Services
Education/Experience: With 25+ years of experience, Neil began his career as a nuclear submarine mechanic in the U.S. Navy, then went on to work as an operator at multiple commercial Pressurized Water and Boiling Water Reactors. Neil has an NRC Reactor Operator license at Columbia Nuclear Generating Station, NRC Senior Reactor Operator License at Limerick Nuclear Generating Station, a bachelor's in Nuclear Engineering Technology and master's in business administration.
Current Work: In his current position he leads the Document Control and Records Management group, Engineering Support group, Facilities Management, and the Performance Improvement group. Multiple NQA-1 compliant programs are administered by those groups, including Engineering Design Control, Document Control and Records Management and the Corrective Action Program. Neil is also currently heading the implementation of NuScale's new PLM implementation that will enable the digital twin and digital thread.

10:45 – 11:15   **Pat Everett,** Oklo, Inc.
Role: Director of Thermal Engineering
Education/Experience: BS in Nuclear and Mechanical Engineering, MIT
Current Work: Pat leads the technical design of Oklo's advanced reactor systems and is an active developer of Oklo's advanced reactor analysis infrastructure. He led the safety analysis of the Aurora, as described in the Aurora combined license application (COLA) to the NRC, which is the first and only non-LWR and microreactor COLA submitted to and accepted for review by the NRC. He is actively involved in supporting the NRC's technical review of the Aurora.

10:45 – 11:15   **Gregory A. Banyay,** Westinghouse Electric Company
Role: Modeling & Simulation Hub Technical Lead (Principal Engineer)
Education/Experience: Ph.D., Civil & Environmental Engineering, University of Pittsburgh, 2019
M.S. & B.S., Mechanical Engineering, Ohio University; Westinghouse Electric Company, 2010 to Present - Computational mechanics analyst with emphasis in flow-induced vibration, acoustics, and probabilistic analysis Parker Hannifin, 2006 to 2010 - Design engineer for aerospace fuel pumps and pneumatic valves
Current Work: Emphasis on the intersection of data-driven and physics-based modeling for objectives related to structural health monitoring (SHM) and prognostic health management (PHM) for nuclear power plants.