

Koroush SHIRVAN

Assistant Professor

Innovative Nuclear Reactor Design and Systems

Executive Director of Accident Tolerant Fuel IRP

Co-Director of RTC for Utility Executives

MIT CASL Education Chair

Department of Nuclear Engineering, MIT

Kshirvan@mit.edu

77 Massachusetts Avenue 24-215a

Cambridge, Massachusetts 02139

Cell: (352) 872-6272

Office: (617) 452-3017

EDUCATION

Sept. 2012 **Ph.D. Nuclear Science and Engineering**
Massachusetts Institute of Technology, Cambridge, Massachusetts
Major: Reactor Design and Analysis
Minor: Probabilistic Risk Assessment

Ph.D. Dissertation Title: Development of Optimized Core Design and Analysis
Methods for High Power Density BWRs
Ph.D. Supervisor: Professor Mujid Kazimi

May 2010 **Masters of Science in Nuclear Science and Engineering**
Massachusetts Institute of Technology, Cambridge, Massachusetts

MS Thesis Title: Optimization of Small Integral Light Water Reactors

May 2008 **Bachelor of Science in Nuclear Engineering**
University of Florida, Gainesville, Florida
Graduated with Summa Cum Laude (Highest Honors)

February 2011 **Swiss Federal Institute of Technology, Zürich (ETHZ),**
Short Course with certificate: Modeling & Computational Multi Phase Flow

WORK EXPERIENCE

Sept 2008 – Sept 2012	Research / Teaching Assistant
Sept 2012 – Dec 2016	Research Scientist
Jan 2017 – July 2017	Principal Scientist
July 2017 – present	Assistant Professor
	Center for Advanced Nuclear Energy Systems (CANES)
	Department of Nuclear Engineering
	Massachusetts Institute of Technology

Research Activities

Research work primarily includes modeling and simulation (M&S) informed experimentation and multi-physics simulations and their applications for advanced reactor technology. Specific recent research/education responsibilities include:

- Present: Supervise 3 PhD, 4 Masters, 3 Post-Docs and a visiting PhD student.
- 2015-Present: Executive Director of Accident Tolerant Fuel Integrated Research Project – Responsible for project organization involving multiple universities and industry partners. Technical lead on both experimental and simulation effort at MIT related to coated Zircaloy cladding with Chromium and Moly/FeCrAl and fuel with additives/dopants. Simulation work is focused on development of ATF material models and their validation in TRACE and MOOSE/BISON tools.
- 2015-Present: Principal Investigator of Fuel-in-Fiber Concept (SBIR subcontract) – Responsible for project on use of additive manufacturing technique to produce high purity SiC fibers and allow online fuel deposition to produce more compact TRISO-type fuel. Work involves investigating SiC fibers corrosion performance in autoclave and characterize their mechanical behavior to inform M&S models to design an optimum new fuel concept.
- 2012-Present: Reduced Moderated Boiling Water Reactor Safety Assessment (DOE NEUP, HITACHI-GE Nuclear) – Responsible for system level safety and stability assessment and fuel performance of the fast spectrum BWR design to burn or breed transuranic. The work involved thermal hydraulic model development within TRACE source code and fuel performance development within FRAPCON source code.
- 2012-Present: SiC cladding R&D for LWRs (CTP, Lockheed Martin, Westinghouse, General Atomics) – Responsible for the R&D of the ceramic matrix composite SiC cladding.
- 2015-16: Primary Investigator of Uranium Nitride fuel performance for AP1000 (ExxonMobil)
- 2015-16: Primary Investigator of Thorium-Plutonium fuel performance (Lockheed-Martin).
- 2013-Present: Chair of MIT CASL (simulation hub) Education activities – Responsible for development of fuel performance education material with MOOSE/BISON and co-organizer of a two week CASL school covering multi-physics simulation topics to ~35 US students.
- Co-instructor of design, nuclear safety and nuclear systems class.
- Lead organizer of the Advanced Nuclear Technology Module for 2017 Innovation Bootcamp.
- Development of reactor system and perform safety analysis for nuclear reactors including BWRs, PWRs, Small Modular Reactors, Sodium and Lead Bismuth Fast Reactors and Light Water Breeders.
- Performing both Validation through experimentation and Verification through high fidelity simulation in areas of thermal hydraulics and fuel performance.
- Development of methodology for design of Light Water Reactor (LWR) cores using coupled multi-physics analysis.
- Power cycle optimization including Rankine and Supercritical CO₂ cycles
- Development of single and two-phase CFD and empirical models for performance analysis of nuclear fuels and safety systems.
- Development and assessment of nuclear fuel performance models (both cladding and fuel) under 2D and 3D finite element framework.
- Development of methods to analyze BWR two-phase stability modes in both frequency and time domains.
- Technology selection of nuclear reactor concepts for different energy applications.

May 2007 – August 2008

Core Design Intern
Southern Nuclear Company
Birmingham, Alabama

PWR Core Analysis, Summer 2008

- Worked extensively on PWR Pellet Clad Interaction risk assessment and created new methodologies to analyze fuel performance during power changes.

Plant Vogtle Core Analysis, Summer 2007

- Created a new core design methodology used by industry to reduce CRUD deposition on fuel rods through utilization of neutronics, thermal hydraulics and plant chemistry assessment tools.

Teaching Experience

Teaching Instructor

Fall 14/Spring 18 MIT Nuclear Engineering 22.06: Engineering of Nuclear Systems

Fall 15/17 MIT Nuclear Engineering 22.033: Manned Mission to Mars (co-Instructor)

Spring 2016 MIT Mechanical Engineering 2.006: Fluids/Heat transfer (Recitation Ins.)

Fall 2017 MIT Nuclear Engineering 22.39: Nuclear Reactor Design and Safety

COMPUTER & COMPUTATIONAL SKILLS/EXPERIENCE

- CANES Manager of Computer Software Repository and Cluster Systems
- Proficient in Fortran language and familiar with Python, C++, C#, Xml, JAVA, Visual Basic, Maple, Matlab, MOOSE, Goldsim, GNU, CMake, HDF5, git
- Expert User of major Nuclear Engineering modeling, analysis and licensing codes including:
 - **Radiation Transport:** ANC, CASMO, SIMULATE, S3K, MCNP5/X, SERPENT, SCALE, PARTISN, DRAGON, ROSA, MPACT, PARCS
 - **Thermal Hydraulics/CFD:** RETRAN, RELAP, TRACE, VIPRE, COBRA, MAAP, MELCOR, TRANSAT, FLUENT, CFX, STARCCM+, ASPEN
 - **Structural Materials and Nuclear Fuel:** ABAQUS, BOA, FRAPCON, FRAPTRAN, MOOSE, BISON, FALCON, SOLID WORKS, ADINA

PROFESSIONAL ACTIVITIES

Co-Director of Reactor Technology Course (RTC) for Utility Executives	2016-Present
Director of Accident Tolerant Fuel (ATF) DOE Integrated Research Project	2015-Present
Technical Thermal Hydraulic Track Leader for ICAPP Conference	2013-Present
Chair of the MIT CASL Education Activity	2013-Present
Completed Multiphysics Model Validation Workshop	2017
Technical Program Member, Int. Conf. on Advanced Ceramics & Composites	2015
Technical Advanced Reactor Track Leader for ICAPP Conference	2015
Member, EPRI Gen-IV Reactor Group	2015
Completed Micro and Nanotechnologies in Medicine Workshop	2014
Tech. Prog. Com. member for Nuclear Fuels and Structural Materials Conf.	2014
Technical Program Committee member and chair for TopFuel Conference	2013
Peer Reviewer, FRAPCON/FRAPTRAN Fuel Performance codes	2013
Referee, major nuclear journals including NED, NT, Progress, Anals	2012-Present
Member, ANS Small and Medium Sized Reactor Committee	2011-2012

Co-Developers and Administrator of MIT NSE website in response to Fukushima-Daiichi Accident (more than one million hits in the first 5 days)	2011-2013
Delegate and Presenter at the Global Conference on Energy (Ishigaki, Japan)	2010
MIT International Energy Conference Organizer and Presenter	2010-2015
American Nuclear Society Member	2006-Present
American Society of Mechanical Engineers Member	2018-Present

HONORS & AWARDS

Elite Nuclear Engineering Fellowship (Univ. of Florida)	2006-08
Alpha Nu Sigma Nuclear Honor Society	2007-Present
TAU BETA PI Honor Society	2007-Present
Reinhold Rudenberg Memorial Award (MIT)	2011
Signature Fission Doctorate Seminar Selectee (MIT)	2012
Outstanding Student Service Award (MIT)	2012

PUBLICATIONS

Peer-Reviewed Journals/Conference Proceedings

<i>Focus Area</i>	<i># Of Published Peer Reviewed Papers</i>
<i>Design and System Modeling</i>	15
<i>Reactor Physics Modeling</i>	15
<i>Thermal Hydraulic Modeling</i>	14
<i>Structural Materials/Nuclear Fuel Modeling</i>	11

Peer-Reviewed Accepted/Published Journals:

Li W., Wu X., **Shirvan K.**, Su G., “An Investigation of Numerical Performance Enhancement of RELAP5: Numerical Stability, Higher Resolution and an Alternative Constitutive Relation”, Nuclear Engineering and Design, Vol 328 pp. 309-320, March 2018.

Sevecek M., Gurgun A., Seshadri A., Che Y., Wagih M., Phillips B., Champagne V, **Shirvan K.**, “Development of Cr Cold-Sprayed Fuel Cladding with Enhanced Accident Tolerance,” Nuclear Engineering and Technology Journal, available online 13 Jan 2018.

Hino T., J. Miwa, T. Mitsuyasu, Y. Ishii, M. Ohtsuka, K. Moriya, K. **Shirvan**, V. Seker, A. Hall, T. Downar, P. M. Gorman, M. Fratoni and E. Greenspan, “Core Design and Analysis of Axially Heterogeneous Boiling Water Reactor for Burning Transuranium Elements,” Vol. 187, Issue 3 Journal of Nuclear Science and Technology, 2017.

Avincola V., Guenoun P., **Shirvan K.**, “Mechanical Performance of SiC Multi-layer Cladding in PWRs,” Nuclear Engineering and Design, vol. 310, pp. 280-294, Dec, 2016.

Zhao, X., **Shirvan K.**, Wu Y., Kazimi M., “Critical Power and Void Fraction Prediction of Tight Bundle Designs” Nuclear Technology, vol. 196(3), pp. 553-567, Dec 2016

Shirvan K., Ballinger R., Buongiorno J., Forsberg C., Kazimi M., Todreas N., “Technology Selection for Offshore Underwater Small Modular Reactors”, Journal of Nuclear Engineering and Technology , vol. 48(6), Dec, 2016.

Shirvan K., Kazimi M., “Superheated Water Small Modular Underwater Reactor Concept,” Journal of Nuclear Engineering and Technology vol. 48(6), Dec, 2016.

Shirvan K., “Numerical Investigation of the Boiling Crisis for Helical Cruciform-Shaped Rods at High Pressures,” Journal of Multiphase Flow vol. 83, pp. 51-61, July, 2016.

Shirvan K., Forrest E., “*Design of an Organic Simplified Nuclear Reactor,*” Journal of Nuclear Engineering and Technology, Vol. 48(4), August, 2016.

Andrews N., **Shirvan K.**, Kazimi M., “*Steady State and Accident Transient Analysis Burning Weapons Grade Plutonium in Thorium and Uranium with Silicon Carbide Cladding,*” Nuclear Technology, 15-41, March 2016.

Busquim R. Marques A., Cruz J., **Shirvan K.**, Kazimi, M., “*Reactivity estimation during a reactivity-initiated accident using the extended Kalman filter,*” Annals of Nuclear Energy, vol. 85, pp. 753-762, 2015.

Andrews, N., **Shirvan K.**, Kazimi M., “*Viability of Uranium Nitride Fueled High-Conversion PWR,*” Progress in Nuclear Energy, Vol 82 pp. 28-32, 2014.

Shirvan K., and M.S. Kazimi M., “*Three Dimensional Considerations in Thermal-Hydraulics of Helical Cruciform Fuel Rods for LWR Power Uprates,*” Nuclear Engineering and Design, vol. 270, pp. 259-272, 2014.

Shirvan K. and M.S. Kazimi, “*BWR-HD: An Optimized BWR for High Power Density,*” Nuclear Technology vol. 184, Number 3, Dec, 2013.

Shirvan K. and Kazimi M. “*Safety Analysis of BWR-HD: An Optimized BWR for High Power Density,*” Nuclear Technology vol. 184, Number 3, Dec, 2013.

Shirvan K. and Kazimi M. “*Stability Analysis of an Optimized BWR for High Power Density (BWR-HD),*” Nuclear Technology vol. 184, Number 3, Dec, 2013.

Shirvan K., Hejzlar P., and Kazimi M.S., “*The Design of A Compact Integral Medium Size PWR,*” Nuclear Engineering and Design vol. 243, pp. 393-403, Feb 2012.

Peer Reviewed Conference Proceedings

Yenatskyy M., **Shirvan K.**, Wysocki A., Morrow R., Ayre D., Green M., Cohen C., “*Modifications to the University of Florida Training Reactor,*” Transactions of the American Nuclear Society, Vol 99, New York, pp. 99-100, 2008.

Shirvan K., Hejzlar P. Shatilla Y. and Kazimi M.S., “*Enhancing the Power Density of IRIS by Compact Steam Generators,*” Transactions of the American Nuclear Society, Vol 100, New York, pp. 567-568, 2009.

Shirvan K., Hejzlar P., and Kazimi M.S., M., “*The Design of a Compact Vessel Integrated LWR,*” Proceedings of International Congress on Advances in Nuclear Power Plants (ICAPP '10), San Diego.

Shirvan K. and Kazimi M.S., “*Limitation of Control Rod Modeling with Current BWR Methods,*” Transactions of the American Nuclear Society, Hollywood, FL, 2011.

Shirvan K. And Kazimi M.S., “*Nuclear Design Behaviour of Helical Cruciform Fuel Rods,*” PHYSOR, Knoxville, TN, 2012.

Shirvan K., Andrews A., Kazimi M.S., “*Best Estimate Void Fraction and Critical Power Correlations for Tight Lattice BWR Bundles,*” International Congress on Advanced Power Plants, Korea, 2013.

Hall, A. Xu Y., Ward A., Downar T., **Shirvan K.**, Kazimi M., “*Advanced Neutronics Methods for Analysis of the RBWR-AC,*” American Nuclear Society Transactions, San Diego, 2013.

Andrews M., **Shirvan K.**, Kazimi M., “*Viability of Uranium Nitride Fueled High-Conversion PWR,*” Proceedings of Innovative Nuclear Energy Systems 4, Japan, 2013.

Shirvan K. Baglietto E., Kazimi M. “*Assessment of a baseline Two Phase CFD closure for PWR applications,*” Transactions of the American Nuclear Society, Washington D.C, 2013.

Shirvan K. Kazimi M. “*Is a PWR SMR or a BWR SMR the Better Choice for the Future?,*” Transactions of the American Nuclear Society, Washington D.C, 2013.

Hall, A., Downar T., Ward A., Jarret M., Wysocki A., Xu Y., **Shirvan K.**, “*Advanced Methods Development for Equilibrium Cycle Calculations of the RBWR*,” ICAPP, Charlotte, NC, 2014.

Shirvan K., Kazimi M.S., Cheng L., Todosow M., Hall A., Jarrett M., Ward A.M., Downar T.J., “*Stability and Safety Analysis of Tight Lattice Breeding LWR*,” ICAPP Charlotte, NC, 2014.

Sukjai Y., **Shirvan K.**, Pilat E., Kazimi M., “*The Effects of SiC Cladding Thickness on Advanced PWR Fuel Rod Performance*,” ICAPP, Charlotte, NC, 2014.

Andrews N., **Shirvan K.**, Pilat E., Kazimi M., “*Impact of SiC Cladding on Plutonium Burning in a Thorium Fueled PWR*,” ICAPP, Charlotte, NC, 2014.

Shirvan K., “*Assessment of BISON Fuel Performance Code and Its Application to Advanced Fuels*,” ICAPP, Charlotte, NC, 2014.

Avincola V., **Shirvan K.**, Kazimi, M., “*Stress Analysis Study of Silicon Carbide Cladding Under Accident Conditions*,” Nuclear Fuels and Structural Materials, ANS annual meeting, Reno, NV, 2014.

Shirvan K., Kazimi M.S., “*Neutronic Challenges of Advanced Boiling Water Reactor Designs*,” PHYSOR, Kyoto, Japan, 2014

Shirvan K., Kazimi M., “*Technical and Economic Viability of Ceramic Multi-Layer Composite SiC Cladding for LWRs*,” IAEA, Oakridge National Lab, 2014.

Andrews N., **Shirvan K.**, Pilat E., Kazimi M., “*Burning Weapons Grade Plutonium in Thorium and Uranium with Silicone-Carbide Cladding*,” American Nuclear Society, Anaheim, CA, 2014.

Bloore D. **Shirvan K.**, Pilat E., Kazimi M., “*Reactor Physics Implications of Advanced SiC-clad Fuel in PWRs*,” American Nuclear Society, Anaheim, CA, 2014.

Shirvan K., Haratyk G., Ballinger R., Buongiorno J., Forsberg C., Kazimi M., Todreas N., “*Advanced Offshore Seabed Reactors*,” ICAPP, France, 2015.

Shirvan K., “*AOA/CRUD Mitigation Techniques Through Core Redesign*,” ICAPP, France, 2015.

Andrews, N., **Shirvan K.**, Pilat E., Kazimi M., “*Economic Assessment of Accident Tolerant Fuel Claddings*,” Advanced Nuclear Fuel Management, Hilton Head 2015.

Mieloszyk A., **Shirvan K.**, Kazimi M., “*A Full Core Integral Fuel Performance Assessment of SiC Cladding Failure Risk*,” Advanced Nuclear Fuel Management, Hilton Head 2015.

Zhao, X. **Shirvan K.**, Wu Y., Kazimi M., “*An Updated Approach to the Prediction of Dryout and Void Fraction for RBWR Bundles*” NURETH, Chicago, 2015.

Haratyk G., **Shirvan K.**, Kazimi M., “*Compact Steam Generator for Nuclear Application*,” NURETH, Chicago, 2015.

Shirvan K., Azizian R., “*Simulation of Orientation Effects on Critical Heat Flux in Downward-Facing Channel for IVR*,” NURETH, Chicago, 2015.

Shirvan K., “*Advanced LWR Fuel Designs with Significant Potential for Power Uprate*,” IAEA Technical Meeting on Greater than 5% fuel, Vienna, 2015.

Guillaume G., **Shirvan K.**, “*Nitride Fuel Potential for Power-Uprates*,” ANS Annual Meeting, New Orleans, 2016

Shirvan K., “*High Power Density Boiling Water Reactor Assembly Design for 500 and 5000 MWth Designs*,” ICAPP, San Francisco, 2016.

Hiscox, B. and **Shirvan, K.** (2016) "Neutronics Analysis of Fuel-in-fiber Concept." Trans. Am. Nucl. Soc., 115 (2016) 1351-1354.

Sukjai Y., **Shirvan K.**, Ballinger R., “Fuel Performance Modeling of Transuranic Burning Boiling Water Reactor,” *International Congress on Advances in Nuclear Power Plants (ICAPP)*, Kyoto, 2017.

Wagih M., Che Y., **Shirvan K.**, “Fuel Performance of Multi-Layered Zirconium Based Accident Tolerant Fuel Cladding” *ICAPP*, Kyoto 2017.

Genzman G., **Shirvan K.**, Buongiorno J., Golay M., Todreas N., “Ship Collision Security for an Offshore Nuclear Platform” *ICAPP*, Kyoto 2017.

Shirvan K., Ballinger R., Kim JH, Hwang, I., “System Level Thermal-Hydraulic Assessment of a Natural Circulating LFR” *ICAPP*, Kyoto 2017.

Sevecek M., Gurgen A., Seshadri A., Che Y., Wagih M., Phillips B., Champagne V, **Shirvan K.**, “Development of Cr Cold-Sprayed Fuel Cladding with Enhanced Accident Tolerance,” *WRFM Meeting*, Jeju Island, Sept 2017.

Shirvan K., Grantom C.R., “Risk Implications of Using Accident Tolerant Fuels in LWRs,” Probability Safety Assessment Conference (PSA), Pittsburg, Sept. 2017

X. Zhao, R. Salko, A. Wysocki, K. **Shirvan**, “Validation and Benchmarking of CTF for Single- and Two-Phase Flow”, Proceedings of NURETH-17, Xi'an, China Sept. 2017.

Seshadri A., Shirvan K., “Wettability and Quench Characteristics of Zircaloy and FeCrAl Coating,” ANS Winter Meeting, Washington DC, Nov 2017.

Invited Talks

Shirvan K., “Annular Fuel Design for LWRs,” University of Reno-Nevada, April, 2013.

Shirvan K., “Fuel Performance with BISON,” Consortium for Advanced Nuclear Simulation of LWRs Summer Workshop at ORNL, Knoxville, Tennessee, 2014 & 2015 & 2017.

Shirvan K., Kazimi M.S., “Neutronic Challenges of Advanced Boiling Water Reactor Designs,” Reactor Physics of Non-Traditional LWR Fuel Design Special Session, PHYSOR, Kyoto, Japan, 2014.

Shirvan K., “Multi-layer Ceramic Matrix Composite Silicon Carbide Cladding for Light Water Reactors,” Advanced Materials for Sustainable Nuclear Fission and Fusion Energy Special Session, International Conference on Advanced Ceramics & Composites, Daytona, Florida 2016.

Shirvan K., “Assessment of the V&V Challenges of Accident Tolerant Fuels” Multiphysics Models Validation Workshop, NC State University, Rayleigh NC, July 2017.

Shirvan K., “Innovation in Nuclear Technology: Past, Present and Future,” Nuclear Innovation Bootcamp, UC Berkeley, Berkeley, CA, July 2017

Shirvan K., “Advanced Fuels R&D: Challenges and Opportunities” NPIC Advanced Methods in Nuclear Reactor Design Workshop, Chengdu, China, October 2017

Patents

Organically Cooled Nuclear Reactor for Enhanced Economics and Safety, U.S. Patent No. 20,150,348, 654. 3 Dec. 2015. Filed 27 May 2014.

Major Reports

Kazimi, M.S., Hejzlar P., Shatilla Y., Feng B., Ko Y., Pilat E., **Shirvan K.**, Whitman J., and Hamed A., “A High Efficiency and Environmentally Friendly Nuclear Reactor (HEER) for Electricity and Hydrogen”, MIT-ANP-TR-125, October 2009.

Shirvan K., Smith K., “*CRUD Collector Feasibility Study*,” *CANES FINAL REPORT*, October, 2013.

Sukjai Y, Pilat E, **Shirvan K**, Kazimi MS, “*Silicon Carbide Performance as Cladding for Advanced Uranium and Thorium Fuels for Light Water Reactors*,” MIT-ANP-TR-1492014

Shirvan, K., Ballinger R., Buongiorno J., Forsberg C., Kazimi M., Todreas N., “*Advanced Offshore Seabed Reactors*,” MIT-ANP-TR-155, MIT, Cambridge, August 2014.

Shirvan K, Daines G., Sukjai Y, Kang P., Li J., “*Silicon Carbide Performance as Cladding for Advanced Uranium and Thorium Fuels for Light Water Reactors*,” MIT-ANP-TR-167, 2016

Shaner S., **Shirvan K.**, Pilat E., Ballinger R., “*Going Beyond 5 Percent Enrichment*,” MIT-NFC-TR-134, CANES Report, 2016.

Shirvan K., Ballinger R. “*Lead Bismuth Cooled Fast Reactor System Performance Verification and Validation*”, MIT-ANP-TR-171, CANES Report, 2017.