FSE 494 NUCLEAR PROLIFERATION, SECURITY AND SAFEGUARDS

Instructor:	Dr. Keith E. Holbert	Email: Holbert@asu.edu
Class Meeting Info:	TTh, 9:00–10:15 a.m. in ARM L1-30 and via Zoom (Sync)	
Exams:	Midterm: Thursday, March 4; Final: TBD	

Course Description: Nuclear proliferation and nonproliferation. Nuclear weapons, dirty bombs, and nuclear materials. Radioactivity, radiation, fission and fusion. Nuclear fuel cycle: enrichment, reactors, and reprocessing. Nuclear weapon physical and biological effects. Non-Proliferation Treaty, weapons testing, and nuclear latency. Nuclear security, safeguards, terrorism and forensics.

Prerequisites: CHM 114 (or 116) [chemistry]; MAT 275 (or 274) [differential equations]; PHY 131 [calculus-based physics, electricity and magnetism].

Course Objective: The prevention of nuclear terror is one of the National Academy of Engineering's *Grand Challenges for Engineering in the 21st Century*. Achieving this requires engineers who are cognizant of both the nature of the danger and the technologies that can play a role in thwarting the malevolent actions of others.

Students successfully completing this course should be able to answer questions such as:
What are the three main types of weapons of mass destruction (WMDs)?
What was developed during the Manhattan Project of World War II?
How many people were killed and injured by the atomic bombs dropped on Japan?
What is the difference between a nuclear bomb and a dirty bomb?
What are the terms of the nuclear Non-Proliferation Treaty (NPT)?
How is uranium enriched? Where does plutonium come from?
What is radiation and dose? What is the difference between nuclear fusion and fission?
What are the physical and biological effects caused by nuclear weapons?
What one person has done more to proliferate nuclear weapons than anyone in history?
Has a nuclear weapon ever been lost (i.e., a *broken arrow*)?
What is the IAEA? How does the IAEA help safeguard nuclear materials?
What technologies can be employed to detect and prevent the diversion of nuclear materials?
What are dual-use technologies? What are nuclear forensics?
To date, how many nuclear weapons have been tested by all countries?
What is in nuclear weapons fallout? What is nuclear winter?
Has a nuclear weapon ever been detonated in space?
Can a nuclear detonation cause a nationwide electromagnetic pulse?
Could terrorists build a nuclear device? What is nuclear latency?
How many countries possess nuclear weapons?
Which nation(s) possessed but later dismantled their nuclear weapons?
What is the difference between nuclear safety, nuclear security, and nuclear safeguards?
How would the effects of an urban nuclear weapon detonation compare to the Oklahoma City Bombing and the attack on the World Trade Center on September 11, 2001?

Textbook: There is no required textbook for this course, instead the reading materials (see page 3) will be provided on Canvas and online via the ASU Libraries.

FSE 494 TEACHING PLAN (Session C, Spring 2021)

The schedule below lists the lecture topics, homework due dates and test dates. Lectures may include a case study and short video clip (e.g., Duck & Cover; Operation Cue; UNSW animation on nuclear safety, security and safeguards; IAEA nuclear power plant inspection; NDA Explained; EPRI: High-Altitude Electromagnetic Pulse (HEMP) Potential Impacts; IAEA Tracing Radioactive Material with Nuclear Forensics; and CNBC: How Hypersonic Weapons Created A New Arms Race). Case studies will focus on individual countries (e.g., Iran, North Korea) as well as situations such as the A.Q. Khan Network, Russian Lt. Petrov, the NUMEC affair, and the Vela incident.

Week	Date	Lecture Topics	Homework
1	1/12	1. Course Introduction and Overview	
	1/14	2. WMDs: Biological, Chemical, and Nuclear Weapons	
2	1/19	3. Radioactivity (Dirty Bombs)	Hmwk # 1 Due
	1/21	4. Radiation and Dose	
3	1/26	5. Nuclear Fission and Fusion	Hmwk # 2 Due
	1/28	6. Manhattan Project: History to Trinity	
4	2/ 2	7. Nuclear Weapon Materials	Hmwk # 3 Due
	2/ 4	8. Nuclear Weapons (South Africa)	
5	2/ 9	9. Nuclear Weapon Effects	Hmwk # 4 Due
	2/11	10. Hiroshima and Nagasaki Bombings (Urban Detonation Today)	
6	2/16	11. Nuclear Fuel Cycle – Dual Use Technologies (India)	Hmwk # 5 Due
	2/18	12. Uranium Enrichment Methods (AQ Khan Network)	
7	2/23	13. Reprocessing and Plutonium	Hmwk # 6 Due
	2/25	14. Nuclear (Non)Proliferation	
8	3/ 2	15. Review for Midterm Exam	Hmwk # 7 Due
	3/ 4	*** Midterm Exam ***	
### Spring Break ###			
9	3/16	16. Nuclear Weapons Testing (North Korea)	
	3/18	17. Nuclear Treaties and Test Monitoring (Vela Incident)	
10	3/23	18. Radiation Detection Instruments	Hmwk # 8 Due
	3/25	19. Radiation Measurement Statistics	
11	3/30	20. Detecting Nuclear Material and Weapons	Hmwk # 9 Due
	4/ 1	21. Nuclear Security (Broken Arrows)	
12	4/ 6	22. Nuclear Safeguards 1	Hmwk # 10 Due
	4/ 8	23. Nuclear Safeguards 2 (Iran)	
13	4/13	24. Environmental Effects of Nuclear War and Testing (NWC)	Hmwk # 11 Due
	4/15	25. Electromagnetic Pulse	
14	4/20	26. Nuclear Forensics (Bulgarian HEU)	Hmwk # 12 Due
	4/22	27. Nuclear Terrorism	
15	4/27	28. Contemporary Issues	Hmwk # 13 Due
	4/29	29. Review for Final Exam	
16	5/ ?	*** Final Exam ***	

Grading: "Standard" scale (with ±) using 90-100 "A", 80-90 "B", 70-80 "C", etc.

Reading Assignment Quizzes	25%
Homework	25%
Midterm Exam	25%
Final Exam	25%

Reading Assignments (listed by lecture number)

While complementary, the lectures and reading assignments provide differing breadth and depth (and sometimes viewpoints) into the course topics. Students will complete automatically graded Canvas-based quizzes for each reading assignment prior to the lecture.

1. Chapter 2, entitled "1939-1953: The Dual Challenge of Nuclear Energy," *History of the International Atomic Energy Agency: The First Forty Years*, IAEA Publication 1032, 1997, pp. 15-28.
2. J. Cirincione, J.B. Wolfsthal and M. Rajkumar, "Global trends," Chap. 1, *Deadly Arsenals: Nuclear, Biological, and Chemical Threats*, 2nd ed., Carnegie Endowment for International Peace, 2005, pp. 3-18.
3. M.A. Levi and H.C. Kelly, "Weapons of mass disruption," *Scientific American*, vol. 287, no. 5, Nov. 2002, pp. 76-81.

4 & 5. K.E. Holbert, "Practical Nuclear and Atomic Physics," 2021.

6. C.R. Loeber, "The Manhattan Project," Chap. 2, *Building the Bombs: A History of the Nuclear Weapons Complex*, 2 ed., SAND2005-5648P, Sandia National Laboratories, 2005, pp. 21-44.
7. S. Fetter, V.A. Frolov, O.F. Prilutsky, R.Z. Sagdeev, "Fissile materials and weapon design," Appendix A to "Detecting nuclear warheads," *Science & Global Security*, vol. 1, no. 3-4, 1990, pp. 255-263.
8. K.J. Moody, P.M. Grant, I.D. Hutcheon, "Principles of nuclear explosive devices and debris analysis," Chap. 5, *Nuclear Forensic Analysis*, 2nd ed., CRC Press, 2014, pp. 183-192.
9. L. Sartori, "Effects of nuclear weapons," *Physics Today*, vol. 36, no. 3, March 1983, pp. 32-41.
10. B.T. Bernstein, "The atomic bombings reconsidered," *Foreign Affair*s, vol. 74, no. 1, Jan.-Feb. 1995, pp. 135-152.
11. Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, "Nuclear fuel cycle and proliferation," Chap. 15, *Nuclear Matters Handbook 2020*, pp. 256-274.
12. R.L. Murray and K.E. Holbert, "Isotope separators," Chap 15, *Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes*, 8th ed., 2020, pp. 273-286.
13. B. Pellaud, "Proliferation aspects of plutonium recycling," *Journal of Nuclear Materials Management*, vol. 31, no. 1, Fall 2002, pp. 30-38.
14. V. Charnysh, "A brief history of nuclear proliferation," Nuclear Age Peace Foundation, 2009, 23 pp.
16. Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, "History of nuclear explosive testing," Chap. 14, *Nuclear Matters Handbook 2020*, pp. 245-254.
17. P.G. Richards, W.-Y. Kim, "Monitoring for nuclear explosions," *Scientific American*, vol. 300, no. 3, March 2009, pp. 70-77.

18 & 19. R.L. Murray and K.E. Holbert, "Radiation detectors," Chap. 12, *Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes*, 8th ed., 2020, pp. 203-220.

20. T.B. Cochran, M.G. McKinzie, "Detecting nuclear smuggling," *Scientific American*, vol. 298, no. 4, April 2008, pp. 98-104.
21. J.E. Doyle, "Introduction: Nuclear security in the twenty-first century," Chap. 1, *Nuclear Safeguards, Security, and Nonproliferation*, 1st ed., 2008.
22. Goldschmidt, "The IAEA safeguards system moves into the 21st Century," *IAEA Bulletin*, vol. 41, no. 4, Dec. 1999, pp. S-1 to S-20.
23. R.S. Kemp, "The Iran nuclear deal as a case study in limiting the proliferation potential of nuclear power," *Nature Energy*, vol. 4, no. 2, February 2019, pp. 99-106.
24. A. Robock, O.B. Toon, "Local nuclear war, global suffering," *Scientific American*, vol. 302, no. 1, January 2010, pp. 74-81.
25. D.G. Dupont, "Nuclear explosions in orbit," *Scientific American*, vol. 290, no. 6, June 2004, pp. 100-107.
26. E. Keegan, M.J. Kristo, K. Toole, R. Kips, E. Young, "Nuclear forensics: Scientific analysis supporting law enforcement and nuclear security investigations," *Analytical Chemistry*, vol. 88, no. 3, pp. 1496-1505.
27. M.B. Maerli, "Nuclear terrorism revisited," *Security and Peace*, vol. 19, no. 4, 2001, pp. 213-219.
28. J.R. Lindsay, "Stuxnet and the limits of cyber warfare," *Security Studies*, vol. 22, no. 3, 2013, pp. 365-404.