General Course Information:
EESC W3018.001 WEAPONS OF MASS DESTRUCTION
Class hours 01:00P-02:15P Location MATHEMATICS 417

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Catalogue description
A review of the history and environmental consequences of nuclear, chemical, and biological weapons of mass destruction (WMD); of how these weapons work, what they cost, how they have spread, how they might be used, how they are currently controlled by international treaties and domestic legislation; and what technical issues, and policy issues, arise in current WMD debates.

Course prerequisites:
one semester of a lab science or permission of instructor
Course requirements:
Weekly readings, short quiz or problem-set every other week,
a project/presentation to be shared with the class, and
a mid-term and final exam.
A final grade will be assigned according to performance on problem-sets and quizzes (35%),
a project/presentation to be shared with the class (15%),
a mid-term exam (25%), and a final exam (25%).

This is not a science course, and it has been taken mostly by non-science majors. But informed discussion of WMD requires an appreciation of technical issues. Therefore, several classes at the beginning of the course will focus on the basic atomic physics that is needed to appreciate how nuclear weapons work, and how they are made.

Required Texts
1. Nuclides and Isotopes by Baum, Knox, and Miller, 16th ed., 2002, Lockheed Martin.
2. Hiroshima by John Hersey (any edition --- there are many)
Extensive additional reading will be from handouts and material posted on Courseworks

Overall plan for presentation of material
After an introductory lecture, we shall spend the first half of the semester examining basic technical issues concerning how WMD work as weapons, how WMD are made, and how their manufacture is linked to technologies used routinely in many countries (for example, in civilian-operated nuclear power plants). Part of the presentation in this first half of the semester will be case histories. The second half of the semester will examine efforts made to control the spread of WMD, including the main issues arising with treaties including the Geneva Protocol of 1925 (poisonous gases, and "bacteriological methods of warfare"), the Biological Weapons Convention of 1975, and the Chemical Weapons Convention of 1993. We shall spend most time on nuclear arms control treaties (principally the Non-Proliferation Treaty of 1970, indefinitely extended in 1995; and various nuclear test ban treaties negotiated from 1958 to 1996).
We emphasize nuclear weapons because of their potentially greater effects, but three classes will specifically discuss chemical and biological weapons.

In this course, we shall be describing
how these different types of weapons work,
something of their history,
what aspects of their manufacture are difficult, and what are easy; what they cost
which countries have them, openly, and in what numbers
which countries may have had them in the past, or attempted to have them, but gave them up
which countries may have them, or seek to have them, but not openly, and what steps does a country need to take to acquire WMD
the differences between WMD in terrorist hands, and in a recognizable military program
the effects of these weapons on their environment, if/when they are used
issues of public health (for example, consequences of "fallout")
what treaties or other types of controls have been attempted, or actually negotiated, intended to have some impact on WMD and their distribution, and
major issues of current concern (and the background needed to follow front-page news).

So: there is a great variety of material here. The course is offered because the existence of WMD can change the course of human history. WMD issues are often in the headlines, and are often the subject of heated disputes between policymakers. This course is intended to provide students with background to enable a more informed following of current policy debates.

Lecture Plan

1. Introduction: the different types of weapons of mass destruction (WMD); nuclear yield (what is a kiloton?); historical origins of WMD; countries that acknowledge having WMD, and the size of their current stockpiles. A review of sources of useful information for this course. A brief review of the key treaties in effect today that are intended to provide some restraint on WMD. Differences between WMD in military programs, and WMD in terrorist hands.

After the introductory lecture, we shall have three classes on basic atomic physics followed by four classes on the underlying physics of nuclear weapons and the related technology used in nuclear power reactors. The goal here is to appreciate where the energy of nuclear weapons comes from, and what are the technical challenges that stand in the way of people who seek to acquire WMD.

2 -- 4. Nuclear Basics: Atomic Structure and Nuclear Chemistry; Radioactivity; Nuclear Fission
Electrons, proton, neutrons; how they interact, and what happens when neutrons (fast or slow) are fired into an atomic nucleus.
Readings and Resources:
Nuclides and Isotopes (class textbook), with several handouts

5. The curve of binding energy
Some consequences of $E = m c^2$, and why fusion can make a much more energetic weapon than fission. The increase in nuclear weapon yield, post World War 2, and the growth of stockpiles.
Readings from
The Making of the Atomic Bomb, by Richard Rhodes, Simon and Schuster, 1986
Dark Sun: the Making of the Hydrogen Bomb, by Richard Rhodes, Simon and Schuster, 1995

6 -- 7. Technology overlap between nuclear weapons and nuclear power plants
How were the "special nuclear materials" originally produced, and how are they produced today (i.e. the fissioning isotopes U235, Pu239)? Nuclear waste, and the concept of "dirty bombs" How do different types of nuclear power reactor operate, in ways that can assist nuclear weapons development?
Readings from
Megawatts and Megatons - A Turning Point in the Nuclear Age? by R.L. Garwin and G.

Charpak, Alfred A. Knopf, 2001.

8. The modern three-stage nuclear weapon
How can much of the yield come from ordinary U238? Early nuclear testing history, of the first five nuclear weapons states. Some reasons why stockpiles grew so large in the late 1950s -- early 1960s. The Single Integrated Operational Plan. What are the differences between modern nuclear weapons, and those which began the nuclear age? Why has nuclear weapons testing been such an important activity (approximately one nuclear weapons test explosion per week for more than forty years, from the late 1940s to the late 1990s)?
Handouts,
and class begins reading the book Hiroshima by John Hersey; also using
http://www.pcf.city.hiroshima.jp/peacesite/English/Stage1/S1-5E.html (describes damage to the people and city of Hiroshima August 6, 1945, and after-effects)

9 -- 10. Ionizing radiation
The different stages of radiation sickness, and discussion of the units with which radiation and radiation effects are measured. What has been learned from Hiroshima and Nagasaki, and from Three Mile Island, Chernobyl and other specific accidents?
Reading from
Frederic Solomon and Robert Q. Marston, editors, The Medical Implications of Nuclear War, Institute of Medicine, National Academy Press, 1986.

11 -- 12. Nuclear weapons effects --- what happens when one goes off?
Movies in class, showing the main effects (blast, thermal, prompt radiation, fallout) as measured from nuclear weapons tests in Nevada. Homework will include evaluations of the area out to which the main effects will be felt, for nuclear explosions of different size and height of burst. The special problems of a surface burst.
Readings and Resources:
http://www.pbs.org/wgbh/amex/bomb/sfeature/mapablast.html (provides an interactive set of maps of blast damage and spread of radioactivity, following a nuclear explosion)
The Prompt and Delayed Effects of Nuclear War, by Kevin N. Lewis, Scientific American, Oct. 1984.
The Effects of Nuclear Weapons, by Samuel Glasstone and Philip J. Dolan, U.S. Department of Defense and U.S. Department of Energy, third edition, 1977.

13. The challenges to building a fission weapon
Uranium hexafluoride; uranium enrichment by diffusion plants and centrifuges. How the United States does this work. How other countries do it, and how this might differ from what terrorists might do. Linkage to current events (e.g. in Iran), as appropriate.

14. Dirty bombs
Also called Radiological Dispersal Devices. We will use a detailed fictional account (movie) of such a device used near the City of London. Consequences of such an attack, and issues of what radiation levels are acceptable. Though RDDs are not WMD, they could have a huge economic impact.

Mid-term

During the two weeks following the mid-term, students will be asked to chose a subject related to this class, for which to prepare a presentation (PowerPoint or some other type of electronic presentation). These presentations will be posted on the (restricted) Courseworks site for discussion by all students, and some will be presented in class.

The second half of the semester will be concerned mainly with a review of the efforts to try and control WMD; and with discussion of chemical and biological weapons.

15. Basic issues of arms control
A review of WMD arsenals of the world, of infrastructure that supports WMD, and the principal sources of information available to the public. The role of treaties in controlling production and preventing use of WMD; the negotiation, verification and enforcement process. What are the key treaties (what is a treaty, what stages does it go through before entry into force)? What does ratification mean in different countries? How have arms control treaties been viewed by military organizations? What issues of sovereignty are involved? What sanctions can be applied to treaty violators? What role does the United Nations play?
Reading from
Committee on International Security and Arms Control, Nuclear Arms Control: Background and Issues, National Academy of Sciences, 1985.

16 -- 19. The Non-Proliferation Treaty (NPT) and the Comprehensive Nuclear-Test-Ban Treaty (CTBT)
Four classes will examine these treaties in some detail, reviewing key language in each treaty and the underlying issues. The NPT was structured as an agreement between five nuclear weapon states and a large group of non-nuclear weapon states. What is the history here, what is the role of the International Atomic Energy Agency, what countries chose to come into the NPT as non-nuclear weapons states, what is the record of compliance, what are the obligations of the nuclear weapon states, what key countries stayed outside the NPT, and what are some current suggestions for strengthening this treaty? Why has the CTBT been characterized as the greatest prize in nuclear arms control, and why is it not in effect (what are the arguments against it)? How is it linked to the NPT? The history of the CTBT includes three other nuclear testing treaties: the Limited Test Ban Treaty of 1963 (also known as the Atmospheric Test Ban Treaty), the Threshold Test Ban Treaty (the subject of rancorous debates on verification) and the Peaceful Nuclear Explosions Treaty (might nuclear explosions be useful for civil engineering projects?)
Readings and Resources:
Thomas B. Cochran, Proliferation and the Nuclear Disarmament Process, Energy Policy, vol 23, pp 195 - 207, 1995.
items from Arms Control Today (the journal of the Arms Control Association) and the Bulletin of the Atomic Scientists, reviewing the size of weapons stockpiles, and current issues
http://www.state.gov/s/l/treaties (the State Department's web site for the texts of treaties currently in force)
Committee on International Security and Arms Control, the report Technical Issues related to the Comprehensive Nuclear-Test-Ban Treaty, National Academy Press, 2002.

20. US policy concerning the use of nuclear weapons
How has US policy changed over the last forty years? The Proliferation Security Initiative. The rise and fall of the Nuclear Earth Penetrator Warhead. Key players in the Bush Administration and in the U.S. Congress.
Readings from
White House Documents
National Strategy to Combat Weapons of Mass Destruction (pdf file, 9p), December 2002
The National Security Strategy of the United States of America (pdf, 35p), September 2002
Congressional Record
excerpts from S6663-S6806, the Senate debate on funding new nuclear weapons, May 2003
Nuclear Posture Review [Excerpts], submitted to Congress on 31 December 2001
Nuclear Earth Penetrator Weapons, CRS Report for Congress (pdf, 6p), Jan 2003

Low-Yield Earth-Penetrating Nuclear Weapons, Robert W. Nelson, Science and Global Security, 10:1-20, 2002

21 -- 23. Three classes on WMD plans associated with states outside the NPT
India and Pakistan (their nuclear tests of 1974 and 1998), Israel, North Korea; also Iraq and Iran (which have signed the NPT). What is the history of WMD for each of these countries? Their current and planned capabilities for producing Pu239 and U235? Their current stated policies? Likely plans? The role of the International Atomic Energy Agency. Some student presentations.
Readings and Resources:
articles in Foreign Affairs, and special reports of the Council of Foreign Relations
The Samson Option: Israel's Nuclear Arsenal and American Foreign Policy, by Seymour M. Hersh, Random House, 1991.
Matthew Bunn, Anthony Wier, John P. Holdren, project on Managing The Atom, Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, commissioned by The Nuclear Threat Initiative, Controlling Nuclear Warheads and Materials, a Report Card and Action Plan (pdf document), March 2003

24 -- 26. Three classes on chemical and biological weapons
Basic principles and methods of delivery. History from World War I up to the present. Pros and cons of these weapons, as military weapons and as terrorist weapons. Environmental impacts. Sizes of chemical weapon stockpiles. The key roles of Richard Nixon and George H.W. Bush in developing and ratifying the Biological Weapons Convention and the Chemical Weapons Convention. The successes and failures of these treaties. The massive violations by the USSR. The possibility for new types of biological weapon.
Readings from
http://www.sussex.ac.uk/spru/hsp/ : the website for HSP (Harvard Sussex Program), which undertakes research, publication, and training in support of informed public policy on chemical/biological warfare (CBW).
Ashton Carter, John Deutch, and Philip Zelikov, Catastrophic Terrorism, Foreign Affairs, pp 80-94, Nov/Dec 1998.
Biohazard, by Ken Alibek (with Stephen Handelman), Random House, 1999.
Germs, by Judith Miller, Stephen Engelberg, and William Broad

27. Last class: current issues
This may include discussion of the Reliable Replacement Warhead, activities under the Nunn-Lugar program (that spends US dollars on helping Russia build down its stockpiles of nuclear warheads), and input from congressional staffers. Show and discuss the movie Last Best Chance in which Senators Nunn and Lugar make the point that restricting access to U235 and Pu239 is the best way to keep nuclear WMD out of terrorist hands.