EGR219 Introduction to Weapons Systems Spring, 2017

Texts: Craig M. Payne, Ed., *Principles of Naval Weapons Systems*, Naval Institute Press, 2010
The Diagram Group, *The New Weapons of the World Encyclopedia*, St. Martins Griffin, 2007
Scheduled class times: MWF 9-9:50 SLC378
Instructor: John B. Gilmer Jr. Office hours: TBD Office:SLC220 Phone: x4885
Prerequisite: Physics 1, 2 (Can be taking Physics 2 at the same time. Doesn't have to be 201/202)

Background:

Weapons are about as old as civilization. Originally weapons were all individual instruments – swords, bows and such. But a need for bigger things arose. In antiquity, an "engineer" was someone who created "engines". What were these engines? They were weapons – specifically siege engines such as ballistae and catapults. These were crew served weapons. It took special skills to design and build them. Engineers also proved capable of building defensive works, roads, bridges, aqueducts, and so the engineering profession got its start.

With the industrial revolution and, more recently, the discovery of nuclear fission, and now the mass use of computers, the nature of weapons have changed greatly. Weapons are no longer just used in isolation by individuals, but in systems including target acquisition, control, and the weapons themselves, often with these components spread over an enormous area. This course will examine the nature of the weapons themselves, including the engineering principles and physics. But it will also examine some of the systems principles that are necessary for the weapon to be effective, including aiming (at moving targets), guidance, and sensing.

The course is going to focus on military weapons. Yes, weapons are also used for policing and hunting. But, the technical challenges of the military environment, and the variety of weapons used, is much greater and more complex. (Nobody uses nuclear weapons for hunting, and they are a bit expensive for crowd control.) The opportunities for jobs involving military weapons systems are much greater.

In the early days of weapons up to the 19th century, weapons were used by individuals, or a small crew for a cannon. Finding a target and aiming it, over a relatively short distance, was entirely manual. It was not "rocket science." But with the development of longer range artillery, by the mid 19th century, it became possible to fire at a target you could not see. Mortars and Howitzers were used during the American Civil War in this way for siege operations. This development required coordination, and organization. But it was the twentieth century that saw truly revolutionary developments.

One development was increasing range. By World War 1, naval guns and heavy siege weapons could fire a shell 15 miles or more. To hit a moving target with any chance of success, manual aiming was impractical. Early mechanical computers were developed, tied to range finders, corrections made for "spotting," and a gyro stabilized reference plane. The "weapons system" had been invented. As the problem of engaging fast moving aircraft developed in World War 2, a high degree of automation in the use of weapons became necessary. Guided missiles moved some of that automation into the weapon itself in the second half of the 20th century. Modern small computers and GPS make it possible to, in effect, deliver a weapon to an address.

At the same time, from the 19th century through the 20th century, weapons were increasing in destructiveness. Mid 1800's cannon fired shells, explosive projectiles, of up to about 100 pounds. By the early 20th century, large caliber shells weighed about a ton. Explosives and propellants were improving as well. By World War 2, aircraft were able to carry

and drop several tons of bombs at a time. The British developed a 10 ton conventional bomb of enormous destructive power. The nuclear weapon increased the destructive power of weapons several orders of magnitude, to 20K tons (end of WW2) to about 20MTons (the largest practical missile warhead).

The response to the increasing destructiveness of weapons was dispersal. In the 19th century, it was common for soldiers to march into battle and endure enemy fire side by side. Even against the early rifles of the day, this kind of fire could not be long endured. By the end of the War Between the States soldiers were fighting more dispersed, and taking cover in trenches and other field works. Throughout the 20th century, military formations on land, at sea, and in the air became ever more dispersed. This, in turn, made coordination more difficult, and weapons systems needed to cope with trying to hit dispersed, moving targets at long range.

The late 20th century and early 21st century have seen yet another revolution in weapons: the highly precise computer guided weapon. One reason nuclear weapons were attractive was that the sheer destructive power could overcome a lack of accuracy. Nuclear weapons were developed for use against aircraft, submarines, and surface ships for exactly this reason. A conventional weapon would have to hit to be disabling, but a nuclear weapon wouldn't have to hit the target; anywhere close would do. But, with modern guidance, conventional weapons can now reliably hit small targets. As a result, "tactical" nuclear weapons are disappearing. They are not really needed, and their employment is, shall we say, politically problematic. But, the use of modern precision weapons is extremely complex, and presents many engineering challenges. We will be looking at some of these challenges in this course.

Schedule: A tentative schedule listing reading assignments and topics to be covered is listed below. The schedule is somewhat tentative with respect to the dates on which topics are covered. We will skip around in the book quite a bit as you can see.

Week of:	Topics covered	Reading, Tests
1 Jan 18*	Weapons and war: trends and issues (overview)	supplement
2 Jan 23	Making a bang: explosives and destruction	Chapter 16,17,18
3 Jan 30	Getting it there: propulsion, and guns	Chapter 13
4 Feb 6	Ballistics and fire control	Chapters 13,14
5 Feb 13	Personal weapons: Rifles, Pistols	Supplements, encyclopedia
6 Feb 20	The guidance and aiming problem	Chapter 14(continued)
7 Feb 27	Propulsions and rockets	Chapter 13(continued)
8 Mar 13	The biggest bang: Nuclear Weapons	Chapter 19
9 Mar 20	Finding the target: Radar and electromagnetics	Chapters 1-4
10 Mar 23	Tracking the target: controlling sensors	Chapter 5
11 Mar 27	Electro-optic and other sensors	Chapters 7-8
12 Apr 3	Weapons control, overview	Chapter 12
13 Apr 10*	Guidance systems	Chapter 15
14 Apr 17	Messing with the enemy's sensors: electronic combat	Chapter 6
15 Apr 24	Recent developments and trends	Supplements
16 May 1*	Catch-up if needed, or special topics	
16	Exam	(comprehensive)

* indicates a "short" week with only one or two class meetings.

About the text and readings: The book being used for this course mentions in it's title specifically "Naval" weapons. However, that is because the text was developed for a "Weapons 101" course at the U.S. Naval Academy. (It's similar to the book used long ago when I took that course!) In fact, most of the principles covered in this book apply to military weapons in general. However, because of its origin, there is less emphasis on personal weapons and more on the larger ones. We need to supplement the text with some additional material, the second book, which is an encyclopedia of weapons. The Payne book also contains considerable material on electromagnetics and antennas that duplicate material found in other engineering courses. We will not cover this in any more depth than necessary for our purposes. The book includes several chapters on underwater systems that we will also not cover. We are going to start with the simpler principles of explosives and propulsion rather than radar, so we are not reading the chapters in the original order.

The available edition of the book, in hard cover format from the U.S. Naval Institute, is fairly expensive, $60 or so. Earlier or used editions, some in paperback, may be found online. I cannot guarantee that these will be fully satisfactory; I have not seen them, but they likely will be satisfactory; the basic principles have not changed much.

Grading: Tests will cover all material through the previous week. Tests will generally be on the last day of the week listed, unless an announcement is made setting the date differently. Tests are open book. You will not have time to open your book very much, and still complete the test. Be well prepared. The exam will be comprehensive, but will have the major emphasis on the most recent topics.

There will be several homework assignments. The intent is to give you some practice on meaningful problems. Homework solutions will be reviewed at the beginning of the class when the assignments are due. These assignments will be ungraded, but I will take them up to see how students have done, and may mark some of the problems. After discussion, there may be a pop quiz that covers some aspect of the homework material.

A research paper will be part of the course. Each student will research some particular weapon and make a formal report. Details will be developed later.

Grading Allocation:

2 tests at 20% each :	40%	up to 2 pop quizzes, total of	6%
class participation (do HW? attend?...)	4%	Written Report	15%
Final examination:	35%		

All material will be graded on a basis of 0-100, with most graded material allowing for grades higher than 100 with bonus questions (usually up to 10% extra) considered. On tests and the examinations some questions may be "compensated" if large numbers of students miss them (indicating possibly a badly posed question or inadequate coverage of the topic in class). On such questions, some proportion of the "lost" credit will be returned. This is the only form of "curving" of grades in the course. All written work is expected to be neat and well presented. A penalty of up to 10% will be assessed for poor presentation, and in extreme cases perhaps more.

The grades from all work will be weighted as given in the above table, totaled, and converted into the Wilkes 4.0 scale grading system using the following conversion:

93+:	4.0	83-87:	3.0	70-76:	2.0	60-64:	1.0
88-92:	3.5	77-82:	2.5	65-69:	1.5	below 60:	0.0

Since the homework assignments are not graded, you may receive help on these or even work with another student. However, if you do this, please indicate the degree of your own involvement. If you simply submit a xerox copy of another student's work, explain your own role in doing the assignment, which should not be limited to just operating the copier. The degree to which students participate in doing homeworks will be subjectively judged and may influence the final grade by up to a point in either direction in borderline cases, as well as affecting the subjective "class participation" part of the grade. The intent here is to allow any degree of cooperation and help on the homework, and use the pop quiz as the grading mechanism to motivate doing homework. A pop quiz is most likely to be given on the day that a homework assignment is due, or the following class.

Notes: I have notes for the course that will be available as reserve material in the library to students who want to see them. I do not guarantee that my notes will match the lectures, since I do tend to depart from prepared notes on occasion, and often skip topics that I decide not to cover in class due to time limitations. A loose-leaf notebook of these class notes will be kept in the library on reserve. This will include some of the lecture materials or handouts used, worked homework assignments, and test solutions. You are not obligated to copy any of this; it is merely meant to be helpful. Any material that is really needed will be distributed in the form of handouts in class.