

## Nuclear Forces and Missile Defenses

Science Technology and Society 435J / Political Science 17.476J

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Schedule: Mondays 11:00 A.M.- 1:00 P.M.

First Meeting: Room E51-385

The security and policy dilemmas that are created by the limitations and capabilities of nuclear weapons will be discussed both from a technical and policy perspective. These issues will be examined from the strategic perspective of the U.S. and Former Soviet Union, and from the perspective of small states that may have acquired, or may be contemplating the acquisition of nuclear weapons. The course will be broken up into two broad areas of discussion. The capabilities of nuclear weapons – and the prospects for and capabilities of missile defenses aimed at stopping nuclear weapons. The initial lectures will focus on the technical capabilities of nuclear weapons and the policy issues raised by these capabilities. In order to better frame the unique issues raised by nuclear weapons, their capabilities and characteristics will be compared with those of conventional weapons that use high explosives, and chemical weapons, which disperse toxic agents. Subjects to be covered in the first part of the course will include the effects of nuclear weapons against civilian populations and military targets; the effects of high explosive and chemical munitions, and the technology of long-range delivery systems. The second part of the course will focus on missile defenses, including their capabilities and limitations, effectiveness in benign and hostile combat environments, and countermeasures and counter-countermeasures. The discussion on missile defenses will emphasize techniques for analyzing defense-effectiveness, and technologies that could be used to either enhance or diminish the effectiveness of various missile defense systems. An important result that will emerge from this discussion is that there are few conclusions about the capabilities and vulnerabilities of specific missile defense systems that result in general truths about such systems. This important insight means that every defense-system and countermeasure must be analyzed in a specific and carefully characterized context. Although lectures will concentrate on the technical characteristics of nuclear armaments and missile defenses, an advanced knowledge of mathematics is not necessary. .

**Texts:***The Effects of Nuclear Weapons*

Compiled and Edited by Samuel Glasstone and Phillip J. Dolan U.S. Department of Defense and U.S. Department of Energy

(Amazingly, this outstanding compilation of technical data on nuclear weapons and effects is, amazingly, no longer in print. As a result, copies of sections of this book will periodically be distributed to the class.)

*MX Missile Basing*

Office of Technology Assessment Congress of the United States

(Copies of chapters from this classic study will periodically be distributed to the class)

*Selected Readings*

(supplied in class handouts)

**Course Requirements:***Term Paper*

The term paper will be due on the Monday *prior* to the final class

*Final Exam*

There will be a final exam scheduled by the registrar

*Problem Sets*

There will be three or four problem sets assigned during the course of the semester

## Lecture Schedule: Analysis of Strategic Forces

### Lecture 1 (September 9)

Houskeeping, Overview of Course.  
The Effects of Nuclear Weapons in Urban Environments

### Lecture 2 (September 16)

The Effects of Nuclear Weapons in Urban Environments  
Including Blast, Fire Effects, and Radioactive Fallout

### No Class on September 23 (Student Holiday)

### Lectures 3 (September 30)

Examination of Different Types of Weapons:  
Small First-Generation Nuclear Weapons, Large Strategic Thermonuclear Weapons,  
Enhanced Radiation Weapons (Neutron Bombs), High Explosive Munitions, Fuel Air  
Explosives, and Chemical Weapons.

### Lecture 4 (October 7)

Probability of Kill Calculations, Cratering,  
and Height of Burst Calculations, Fallout, and  
Damage to Urban Centers from Nuclear Attacks

### No Class on October 14 (Columbus Day)

### Lectures 5 (October 21)

Ballistic and Cruise Missile Nuclear Delivery Systems  
and Attacks Against Populations and Hardened Military Installations

### Lecture 6 (October 28)

US and Russian Nuclear-Attack Early Warning Systems, Nuclear Attack Timelines,  
Command and Control, and Other Issues Related to Nuclear Force Operations

### Lecture 7 (November 4)

Methods for Analyzing the Capabilities of Ballistic Missile Defenses:  
The Effects of Imperfect Sensor Performance on ABM Leakage

### No Class on November 11 (Veterans Day)

### Lectures 8 (November 18)

The Current National Missile Defense System

### Lecture 9 (November 25)

ABM Defense System Missions and Architectures  
Boost-Phase, Mid-Course, and Reentry-Phase Missile Defense Systems  
The GALOSH ABM System, The US Safeguard/Sentinel Systems,  
Deception and Defense (The Low-Altitude Defense System, LoADS)

### Lectures 10 (December 1) *Term Papers Due*

Lessons of the Gulf War Experience with the Patriot Theater Missile Defense

### Lecture 11 (December 8)

Exotic Technologies:  
The Strategic Defense Initiative  
Space-Based Defense Systems

## Selected Topics and Issues that May Be Covered in Lectures: Nuclear Forces and Missile Defenses

### Introduction

Outline of Course + Overview of Weapons Effects Talk

General Description of Nuclear Forces

Sources of Data on Systems

(Reconnaissance/Technical Intelligence)

Delivery System Characteristics

Ballistic Missiles

Air vs. Ground Launched Missiles Air Supported/Breathers

Cruise Missiles

Bombers

Weapons Effects

### Technical and Policy Overview of Basing Systems and Issues

Objectives of Basing

#### Technical Overview

*General Description of Basing Systems and Issues*

Overview of Basing System Issues

Widely-Spaced Silo-Basing, Closely-Spaced Silo Basing,  
Multiple Shelter Systems, Land and Air Mobile Systems,  
Sea and Space-Based Systems.

Why Survivable Basing of Strategic Forces

Became Such a Challenging Technical/Political Task

### Hidden Policy Issues Associated with the Basing of Strategic Forces

Central Importance of Survivability

Crisis Stability

Management Burden on Political Leadership

Leverage in Arms Control

Military Effectiveness

Other Views on Survivability

Makes "Controlled" War Fighting More Plausible

(Depends on "Model" of what actions/events /leadership  
perspectives could lead to nuclear war.)

Survivability of a Single Force is Unimportant

Raises questions about why then build another force

(To make other forces more survivable)

Derived from extension of "conventional" reasoning to Nuclear Systems

## Political and Military Requirements on Strategic Forces

### Objectives of Targeting

- Limit the Enemy's Ability to Sustain a Large-Scale Conventional War  
(Urban / Industrial Targeting)
- Limit the Enemy's Ability to Inflict Damage on Your Society  
(Damage Limitation)
- Limit the Enemy's Ability to Damage Your Forces  
(Survivability of Forces / Launch On-Warning / Preemption)
- Punish the Enemy

### Damage Limitation: How Good is Good Enough?

- Limiting Enemy Urban/Industrial Potential
- Limiting Enemy Counterforce Potential

### Ways of Measuring the Effectiveness of Forces

- Fraction of Force (i.e. Number of Warheads) on "Alert"
- Fraction of Enemy Targets Destroyed
- Number of Warheads Guaranteed On-Target

## Land-Based Systems

### *Basic Tools for Analyzing Land-Based Systems*

- Weapons Effects:
  - Blast Scaling
  - Fire Effects
  - Fallout (Minimum HOB for Fallout)

### Silo-Based Forces:

#### Significance of Improved Missile Accuracy:

- Probability of Kill ( $P_k$ ) Calculations
- "Exchange" Calculations and Measures of "Stability"
- Hardness (From perspective of System Operator)
- Hardness (From perspective of Attacker)

### Land-Mobile Missile Systems:

#### Basic Reasons for Choosing Mobile Systems

#### Operational Schemes

- Constantly Dispersed Forces
- Dash On-Warning Forces
- Garrisoned Forces (Disperse in Crisis or Launch Undispersed On-Warning)

#### Practical Limitations on Land Based Systems:

- Hardness:
- Mobility:
  - On-Road, Off-Road, Railroads, and Waterways
  - Availability of Land for Operation/Deployment
  - Weapons Safety and Security
  - Public Acceptability

Land-Mobile Missile Systems (continued):

Examples of Systems

Midgetman-Garrison/Silo/Southwest/Minuteman Sitter

Rail Mobile vs. Rail Garrison

Multiple Protective Shelters:

Similarity to Mobile Basing

Hiding the Missiles

Reverse Fractionation Problem

Defended Multiple Protective Shelters:

Defense with Deception -

The Army's Low Altitude Defense System (LoADS)

Air-Mobile Systems:

Missile Carrying Aircraft

Bombers

Air Breathing System Issues:

Bomber Escape

Bomber Endurance

Bomber Communications

Other System Concepts:

South-Side Basing, Deep Underground Systems,

Grass-Hopper, Sea-Sitter, Air-Mobile Systems

### **Sea-Based Missile Systems**

*How Sea-Based Systems Try to Attain Survivability*

Mobility

Concealment

Dissimulation (i.e. Camouflage)

Removal of Observables

Deception

Hardening

Accuracy of Sea and Land-Based Ballistic Missiles

Communications to Sea and Land-Based Nuclear Forces

Surface Ship Basing:

Submarine Basing: SSBNs - How They Attain Survivability

Search Calculations

False Alarm Rates

Base Loss Factors

## Force Size Requirements:

- Damage Criteria Against the Enemy:
  - Counterforce Attack Objectives
  - Attacks Against Soft Targets
- Force Availability Criteria
  - Retaliate Against Bolt-Out-of-the-Blue
  - Retaliate After Period of Crisis

## Costs of Strategic Forces:

- Bombers
- Submarines
- ICBMs

## Methods for Estimating Costs:

- Research and Development
- Investment
- Operations and Management (or Support)
- Shared Assets/Platforms

## Measures of "Cost-Effectiveness":

- Alert W/H
- Surviving and Available W/Hs
- W/H Guaranteed On-Target Enemy
- "Hard-Targets" (Silos) Destroyed
- Enemy "Soft-Targets" (Urban/Industrial/OMT) Destroyed

**Missile Early Warning and Defense Systems**

## Objectives of Various Missile Defense Concepts

## Early Warning Systems and Vulnerabilities of Land-Based Nuclear Forces

## Space-Based Infrared Early Warning Systems

- Space-Based Infrared System (SBIRS) –High
- Space-Based Infrared System (SBIRS) –Low

## Ground-Based Radar Early Warning Systems

## Ballistic and Cruise Missile Technology and Systems

- Rocket and Jet Engine Technology
- Guidance and Control of Technology and Capabilities  
for Cruise and Ballistic Missiles

## Command and Control of Nuclear Forces

## Boost-Phase, Mid-Course, and Reentry Defense Systems, Technology, and Science

## Accidental Launch Protection Systems

## Infrared and Radar Sensors and Discriminants

- Measurement Capabilities and Discriminants
- Countermeasures