

NUCLEAR ARMS RACE

TECHNOLOGY
AND
SOCIETY



PAUL P. CRAIG JOHN A. JUNGEMAN

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Technology and Society

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PREFACE

GENERAL COMMENTS

Measured in terms of its implications for human survival, the nuclear arms race is the single most important activity on the face of the earth. For 40 years, since the Trinity nuclear test shot was detonated in Alamogordo, New Mexico on July 16, 1945, nuclear weapons have been the dominant feature of international geopolitics. Today there are an estimated 50,000 warheads in the arsenals of the world, the bulk of them under the control of the United States and the Soviet Union. These weapons affect all of our lives. There is no way to avoid this.

Since 1945 no nuclear weapons have been used against civilians. It may or may not be true that the fact that the United States and the Soviet Union are holding each other hostage in a strategy termed Mutually Assured Destruction, or MAD, is responsible for the absence of nuclear war over most of these four decades. One could, for instance, note that there has been no earthquake in San Francisco since 1906. Does this fact give one comfort? Of course, the analogy is weak because mankind has no control over earthquakes.

Should nuclear war occur, it will be the result of human decisions. What human decision one can't say. Decisions to undertake the physics research that made the weapons possible? Decisions to build nuclear weapons? Deliberate decisions to fight a war? Mechanical accident? Institutional accident? A misinterpretation of an act of God? (The Strategic Air Command was once alerted because radar thought the rising of the moon was a Soviet attack.)

The situation is complex and controversial. Does a nuclear freeze proposal contribute to or detract from the prospects for nuclear weapons stability? How many weapons and of what type are "enough"? Do the Soviets cheat on arms agreements? Is an MX missile needed? Will our strategic submarine fleet be vulnerable in the 1990's? What can and cannot be verified by "national means"? Is space defense or other defense viable? These and many, many

more questions are being raised, and will be extensively debated in the coming years. For the nation—if not for the individual—there is no avoiding the questions.

THEMES

We believe, with Jefferson, that the strength of a democracy lies in the wisdom of its citizens. Nuclear issues are complex, to be sure, but they are not outside the scope of understanding of any American who wishes to inform himself or herself about them.

This text was written with two audiences in mind. One is the student interested in obtaining background on the arms race. Another larger audience is the citizen intent on gaining technical understanding of the scientific basis of the arms race. The book is arranged so that it can readily be used as a reference. Many technical questions of the form “what is it?” and “how does it work?” are addressed in an understandable way that should be of use to citizens of all orientations. We particularly hope that high school students will use the book to help find answers to some of their questions about the implications of the arms race for their lives.

The text grew out of a course we offered for the first time in the winter of 1983 at the University of California at Davis. It is intended for students from all backgrounds, and all political persuasions. We created in the course a microcosm of C. P. Snow’s “two cultures”. The humanities-oriented person (a member of one of the cultures) may often be intimidated by equations and numbers. The scientifically-oriented student (a member of the other culture) may be bored at times with the technical level of the course but disturbed by having to deal with issues which are impossible to quantify. Both perspectives are important. We can learn from each other how to wrestle with the almost overwhelming problem of nuclear arms. This question is a survival issue, and it is truly interdisciplinary.

Applied to the question of nuclear arms, “two cultures” attitudes can lead on the one hand to leaving the technical matters to the “experts”, and on the other to a situation in which technically trained persons are so ignorant of the way in which people think that they commit themselves to solutions which are made risky by human factors. We can afford neither attitude.

We believe that every informed citizen should be familiar with the technical facts of life in a nuclear age. An informed citizen should be able to discuss, for example: how an atomic weapon works; what is the difference between an A-bomb and an H-bomb; what is the trade-off between accuracy and warhead size; what are the effects of blast, heat and radiation; what is fallout and what will it do; what are MAD, the strategic triad, MIRV, LOW, Cruise, SS-18, MX. What are the capabilities to absorb the effects of nuclear war of people, cities, the ecosphere? What does it mean for the fabric of the nation if 50% of the populace is killed? If the industrial infrastructure is decimated? If oil refineries

and electricity generating plants are destroyed? What would such losses mean for the Soviet Union? How much could a vigorous civil defense program protect? What might a nuclear terrorist hope to accomplish? What are the consequences of a global exchange of nuclear arsenals of the superpowers to humankind and the ecosystem?

The text does not attempt to answer all of these questions. But it does provide a foundation that makes possible the understanding of the issues, and it will ease the interpretation of information appearing in the press and elsewhere.

Our goal is to provide you with the tools to make your own judgments about political and technical issues surrounding the nuclear arms race. As informed citizens you will be better able to be meaningfully involved in the political process on the critical issue of nuclear arms.

Development of common ground required that we include some material that will be elementary to everyone. Remember this, and pass quickly over topics you know well.

STRUCTURE OF THE TEXT

The text is divided into three main sections. Part 1 (Chapters 1–6) considers the nuclear status quo, and the history of how we arrived where we are. Section II (Chapters 7–18), the most technical part of the book, examines the technical background of the nuclear arms race. A summary (Chapter 7) introducing Part 2 makes it possible to draw on this material without going into it in detail. Part 3 (Chapters 19–26) explores present and potential consequences of the nuclear arms race, prospects for defense against nuclear attack (e.g. a “star wars” defense against ICBM’s), proliferation of nuclear weapons, and psychological and economic factors.

The chapters that involve technical discussion (chiefly found in Part 2) present ideas and results in non-quantitative fashion at the beginning of the chapters, with more detail and quantification at the end of each chapter. These technical sections begin with a prefix “P”, and are keyed to the descriptive sections.

WAYS TO USE THE TEXT

The text can be used in several ways:

1. If interest is principally in the non-technical areas of the nuclear arms race, Part 2 could be eliminated entirely and only the first part of other chapters containing technical material utilized.
2. If a quick resumé of technical background is desired, Choice 1 may be supplemented with the summary of Part 2, found in Chapter 7.

3. If some understanding of the science and technology of nuclear weapons and their effects is desired, section II may be included, using only the first, non-quantitative, part of the chapters.
4. Finally, if the technical material is to be fully utilized, all of the material in these chapters can be used as well as the "Additional Physics" sections of other chapters.

In our course at the University of California, Davis we interweave technical and descriptive chapters so as to introduce the technical material gradually. The following chapter sequence is one way to accomplish this: 1, 8, 9, 2, 3, 10, 11, 4, 5, 12-18, 7, 22, 19-21, 6, 23-26. Because of our backgrounds (physics), we place relatively greater emphasis on technical considerations.

An instructor's manual to the text is available. It includes lists of films and general references (with sources), discussion of subtle points in each chapter, and solutions to all problems.

SYNOPSIS

Part 1 Present Status and History and Policies of the Nuclear Arms Race

Chapter 1 overviews the nuclear predicament. It includes a brief discussion of the nuclear arsenals and delivery systems, our vulnerability to nuclear attack, and the consequences of a nuclear exchange.

Chapter 2 provides an historical overview of the development of the arms race. The material is descriptive and anecdotal. It is intended to provide some feeling for the tenor of the times when the atomic bomb was developed, and the institutional dynamic that led to its use even after the fall of Nazi Germany. There is no escaping from the shaping forces of history; the arms race today has many roots going back 40 years or more.

Weapons are useless without delivery systems. Trade-offs between weapon megatonnage and accuracy of the delivery systems are examined in Chapter 3.

Chapter 4 introduces key elements of nuclear weapons policy. There are many specialized terms and phrases, such as MAD (mutually assured destruction), LOW (launch on warning), ICBM (Intercontinental ballistic missile) which must become a part of one's vocabulary in order to discuss arms race issues.

Chapter 5 is concerned with the processes by which nuclear weapons are kept under control. How are decisions to launch nuclear weapons made, and how are these decisions communicated to the personnel in physical possession of the weapons? What kind of safeguards exist against unauthorized launch?

Discussions of the arms race tend to focus on nuclear weapons, and this is the primary focus of the text. Conventional weapons have advanced enormously in recent decades. Many conventional weapons are capable of the same

amount of destruction as even fairly large nuclear weapons. In Chapter 6 we review the characteristics of modern non-nuclear weaponry. The point is made that the elimination of nuclear arsenals, even if it could be accomplished, would by no means eliminate the enormous destructiveness of war in the late twentieth century.

Part 2 Technical and Scientific Background, Bomb Building, and Nuclear Weapon Effects

These Chapters (7–18) contain the most technical material in the book. They are introduced with a summary of key concepts (Chapter 7), which may be drawn upon by the non-technical reader, or for reference.

The chapters of the section assume little conversance with the language of science. Chapter 8 introduces notation, particularly exponential notation and units. The question of “orders-of-magnitude” is explored. We have found that even among students with substantial backgrounds in science there is a poor appreciation of the importance of “back of the envelope” calculations. In arms race issues especially there is so much uncertainty that calculations valid to within an order of magnitude are frequently quite adequate for understanding the major effects.

An example is the difference in destructive power associated with a one kiloton weapon, as contrasted to that of a one megaton weapon, and the fact that while the destructive energy is increased by a factor of 1000, the destroyed area increases by only a factor of 100.

Chapter 9 develops the concept of energy and the important idea that mass can be converted to energy. Elementary nuclear structure is described including the concepts of isotopes, atomic number, and mass number.

Chapter 10 introduces key ideas of radioactivity and fission. It discusses the absorption of alpha, beta, and gamma rays in matter permitting the student to estimate shielding needed for protection from these radiations. The special characteristics of the isotopes critical to weaponry are examined, particularly U-235, U-238, Pu-239, deuterium, and tritium.

Chapter 11 describes how nuclear weapons work. The basic ideas are relatively simple, but they are far from obvious. This chapter provides understanding of the differences between “A-bombs” and “H-bombs”, and why the energy release of the latter is virtually unlimited. The “secret of the H-bomb” is revealed—at least in so far as this information is to be found in the public domain.

Chapter 12 introduces concepts from electromagnetism and quantum theory that are needed to understand thermal radiation, the Compton effect, and the generation and effects of the electromagnetic pulse.

Chapters 13–17 examine physical effects of individual nuclear weapons. Included are blast effect, thermal radiation, initial nuclear radiation, fallout, and the electromagnetic pulse. Chapter 18 is concerned with the biological

effects of nuclear weapons including those that are short term as well as long-term carcinogenic and genetic effects. These chapters also introduce new concepts of physics and radiation biology including attenuation of neutrons, the photoelectric effect, the roentgen, rad, and rem.

Part 3 Consequences of the Nuclear Arms Race and other Considerations

Chapter 19 explores estimates of the short-term and long-term casualties from several nuclear exchange scenarios. The impact of a global nuclear war on humankind and the ecosystem—including the “nuclear winter” is discussed, including fallout exposure, ozone depletion, sunlight obscuration, and pyrotoxin generation.

Chapter 20 focuses on possibilities from a technical point of view of defense against a nuclear attack. It includes a discussion of terminal defense and examines extensions of present technology into a possible “space wars” or “high frontier” era that has the goal to provide defense in the “boost” and “mid-course” phases of a missile attack.

Chapter 21 examines concepts of civil defense—what can we do to protect ourselves from nuclear attack. The discussion explores not only physical defense mechanisms, but also the implications of civil defense for national attitudes of aggression or fear, and the implications for the US of Soviet civil defense practices.

The prospect of nuclear war leads to psychological impact on everyone. These effects are difficult to quantify, yet painfully real. Many—perhaps most—students studying the nuclear arms race experience dreams, and occasionally nightmares. In chapter 22 we explore the psychological impact of nuclear war on survivors, and of the prospect of nuclear war on all of us.

The uranium and plutonium used in nuclear weapons is similar to material in nuclear reactors. This is the “weapons connection” of civilian nuclear power, which is examined in Chapter 23.

Chapter 24 examines issues associated with verifying compliance with treaties.

Chapter 25 discusses the economic implications of the arms race. Dollars spent on the machinery of war are dollars not spent on developing civilian technology, or on feeding the hungry of the world. Arming ourselves in an unfriendly world may be a price of survival, but the issues of “how much is enough” demands that we understand the kind of trade-offs we are making.

In the final chapter we offer our views on the nuclear dilemma.

Appendixes provide useful references, a glossary of the nuclear arms race, and a compendium of useful numerical data.

Practical units are used throughout. While the SI (Système Internationale) units offer the advantage of consistency, we found these advantages outweighed by the confusion that results when students read other material. Thus, pressures (which appear primarily in the discussion of blast effects) are given in pounds per square inch. An appendix provides conversion factors.

CONCLUSION

One of us, JAJ, was an observer of the Trinity test. The other, PPC, served in Washington as a part of the Federal Government. Both of us have worked at Los Alamos, New Mexico, the government laboratory where the world's first nuclear bombs were designed and built. These experiences, supplemented by many years of observation of the nuclear arms race, have convinced us that the nuclear arms escalation practiced in both the United States and the Soviet Union—with each side responding to actions of the other—is leading to a decrease in the security of both Americans and Russians.

It is our hope that this text will contribute to citizen understanding of the arms race, and thereby to a reduction of tensions and a much needed increase in the security of our children, their children, and the citizens of all nations.

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Paul P. Craig
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PART
ONE

THE CONTEXT

OUR NUCLEAR PREDICAMENT

We live in the birth era of the nuclear fire. That fire was first ignited in a squash court at the University of Chicago in December 1942, where Enrico Fermi and his group started the world's first nuclear reactor. The overwhelming fact of the nuclear fire is that it is more powerful by a factor of 10 million to 100 million than chemical fires. This major advance in the ability of human beings to influence the environment has arrived into a world afflicted with deadly rivalry among nation-states. The challenge we all face is to somehow change our modes of international behavior soon enough to avoid mutual annihilation.

The world's first atomic bomb was exploded near Alamogordo, New Mexico, on July 16, 1945. Two weeks later, on August 6, a uranium-fueled atomic weapon nicknamed "Little Boy" killed about 100,000 Japanese in Hiroshima. Three days after Hiroshima, on August 9, 1945, a plutonium bomb, "Fat Man," killed an estimated 70,000 Japanese in Nagasaki. Within a week Japan surrendered to the United States, and World War II was over.

The primitive Hiroshima and Nagasaki bombs were the equivalent of 13,000 and 22,000 tons of chemical explosive, respectively. The largest individual bombs carried by British Lancaster bombers in World War II, called "blockbusters," contained 4000 pounds (or about 2 tons) of TNT each. The atomic bombs were roughly 10,000 times larger. In an instant, the character of warfare had changed for all time.

Since 1945 the United States and the Soviet Union have developed vast arsenals based on the fission of uranium and plutonium (*A-bombs*), and on the fusion of deuterium and tritium (*H-bombs*). Britain and France each have nuclear arsenals which, though much smaller than those of the superpowers, are quite sufficient to destroy a large number of cities. India and China have exploded nuclear weapons and may be presumed to have nuclear weapons in

their arsenals; Israel has not exploded nuclear weapons but is generally believed to have at least a dozen reliable bombs.

A 1-megaton bomb, the size of a strategic warhead in the 1980s, is equivalent to 75 Hiroshimas. The effects of even one such bomb exploded over a large city defy the imagination. But in 1982 there were in the combined strategic arsenals of the Soviet Union and the United States nearly 20,000 warheads containing about 12,000 megatons that could be delivered to each other's societies by intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs), or by aircraft. All the bombs used by all combatants in World War II amounted to about 3 megatons or 225 Hiroshimas. The combined strategic arsenals of the superpowers contain approximately 1 million Hiroshimas.

There are about 200 cities in the United States with a population of 100,000 or more. Sacramento, California, has a population of about 600,000. A 1-megaton bomb hitting Sacramento would kill about 400,000 people outright and seriously injure the remainder. The same megatonnage, but divided into three bombs of about one-third megaton, or 25 Hiroshimas, each, would be more "efficient" and leave hardly any survivors.

There are an additional 400 cities in the United States with a population of 25,000 or more. The combined population of all 600 cities is about 132 million people. If 1000 megatons exploded over these 600 cities, about 84 percent of the population, or 111 million people, would be killed directly. This does not take into account indirect casualties due to fallout, epidemics, and starvation. All of this could be accomplished with about 14 percent of the Soviet arsenal and all within 30 minutes time, any time. The United States can produce a similar catastrophe in the Soviet Union, and on the same time scale. Such is the balance of terror.

The tremendous power of nuclear weapons has turned the advantage overwhelmingly to the offensive. There is simply no technical way to provide assurance that no missiles will reach their targets. Vulnerability of both sides is a fact of the nuclear age.

The policy of *mutual assured destruction* (MAD), which has been the official policy of the United States for over two decades, states that any nuclear attack on the United States would result in an overwhelming attack on our adversary. Hence the adversary is *deterred*. In order for deterrence to be successful one's retaliatory forces must be largely invulnerable to nuclear attack and the adversary must believe in your intent to actually carry out the second strike. This the United States has accomplished by means of the *strategic triad*, which places forces in land-based missiles, in bombs on aircraft, and on submarines. The submarines are difficult to locate and hence are an important part of our second-strike retaliatory capability. The Soviets, with less access to the sea, have chosen to concentrate their nuclear forces in land-based missiles.

One can argue that deterrence has been a success, because, after all, there has not been a nuclear war, or a war of any kind, between the superpowers since the beginning of the nuclear era in 1945, even though there have been

many provocations that in other times might have led to war. The United States fought a conventional war in Vietnam, and the Soviet Union is fighting a conventional war in Afghanistan. The superpowers, despite frequent rhetoric of confrontation, have actually been circumspect in avoiding provocation of each other by actions.

The most dangerous superpower confrontation in the nuclear era was the Cuban missile crisis in 1962. That October the world peered into the nuclear abyss. The confrontation was over the emplacement of nuclear weapons. The United States felt threatened by the prospect of Soviet nuclear-tipped missiles able to hit points in the United States from Cuba. Fortunately, prudence on both sides was used. Chastened governments soon signed a treaty banning atmospheric testing of nuclear weapons (1963). Even though the Soviet Union at that time was outnumbered about 10 to 1 in effective megatonnage and 6 to 1 in delivery systems (Table 1-1), the threat of nuclear destruction of cities in the

HERMAN



**"Thank you, Burrows, for that
descriptive insight into
the nuclear arms race."**

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