New
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Series

NUCLEAR CHOICES

A Citizen's Guide to Nuclear Technology

Richard Wolfson

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Series Foreword

The Alfred P. Sloan Foundation's New Liberal Arts (NLA) Program stems from the belief that a liberal education for our time should involve undergraduates in meaningful experiences with technology and with quantitative approaches to problem solving in a wide range of subjects and fields. Students should understand not only the fundamental concepts of technology and how structures and machines function, but also the scientific and cultural settings within which engineers work, and the impacts (positive and negative) of technology on individuals and society. They should be much more comfortable than they are with making calculations, reasoning with numbers and symbols, and applying mathematical and physical models. These methods of learning about nature are increasingly important in more and more fields. They also underlie the process by which engineers create the technologies that exercise such vast influence over all our lives.

The program is closely associated with the names of Stephen White and James D. Koerner, both vice-presidents (retired) of the foundation. Mr. White wrote an internal memorandum in 1980 that led to the launching of the program two years later. In it he argued for quantitative reasoning and technology as "new" liberal arts, not as replacements for the liberal arts as customarily identified, but as liberating modes of thought needed for understanding the technological world in which we now live. Mr. Koerner administered the program for the foundation, successfully leading it through its crucial first four years.

The foundation's grants to 36 undergraduate colleges and 12 universities have supported a large number of seminars, workshops, and symposia on topics in technology and applied mathematics. Many new courses have been developed and existing courses modified at these colleges. Some minors or concentrations in technology studies have been organized. A Resource Center for the NLA Program, located at Stony Brook, publishes and distributes a monthly newsletter, collects and disseminates syllabi, teaching modules, and other materials prepared at the colleges and universities taking part in the program, and serves in a variety of ways to bring news of NLA activities to all who express interest and request information.

As the program progressed, faculty members who had developed successful new liberal arts courses began to prepare textbooks. Also, a number of the foundation's grants to universities were used to support writing projects of professors—often from engineering departments—who had taught well-attended courses in technology and applied mathematics that had been designed to be accessible to liberal arts undergraduates. It seemed appropriate not only to encourage the preparation of books for such courses, but also to find a way to publish and thereby make available to the widest possible audience the best products of these teaching experiences and writing projects. This is the background with which the foundation approached The MIT Press and the McGraw-Hill Publishing Company about publishing a series of books on the new liberal arts. Their enthusiastic response led to the launching of the New Liberal Arts Series.

The publishers and the Alfred P. Sloan Foundation express their appreciation to the members of the Editorial Advisory Board for the New Liberal Arts Series: John G. Truxal, Distinguished Teaching Professor, Department of Technology and Society, State University of New York, Stony Brook, Chairman; Joseph Bordogna, Alfred Fitler Moore Professor and Dean, School of Engineering and Applied Science, University of Pennsylvania; Robert W. Mann, Whitaker Professor of Biomedical Engineering, Massachusetts Institute of Technology; Merritt Roe Smith, Professor of the History of Technology, Massachusetts Institute of Technology; J. Ronald Spencer, Associate Academic Dean and Lecturer in History, Trinity College; and Allen B. Tucker, Jr., Professor of Computer Science, Bowdoin College. In developing this new

publication program, The MIT Press has been represented by Frank P. Satlow and the McGraw-Hill Publishing Company by Eric M. Munson.

Samuel Goldberg
Program Officer
Alfred P. Sloan Foundation

Preface

Nuclear technology is an inescapable part of our lives. Nuclear reactors provide a significant share of our electrical energy. Techniques of nuclear medicine offer new promise in the diagnosis and treatment of disease. Nuclear processes help industry produce better and safer products, help airlines detect terrorists' bombs, and help archaeologists understand our past. And through the second half of the twentieth century, nuclear weapons have purportedly kept the peace by threatening the annihilation of modern civilization.

But with nuclear technology come dangers. Nuclear war is an obvious one. So are reactor accidents like those at Chernobyl and Three Mile Island. The mining of uranium, the manufacture of nuclear weapons, and the normal operation of nuclear power plants all release radioactivity to the environment. Nuclear medicine carries risks that must be weighed against its potential benefits. Even such non-nuclear technologies as aviation and house construction have nuclear dangers associated with them.

The news media regularly bring nuclear technology and its dangers to our attention. Nuclear technology provokes vigorous debates at the local, national, and global levels. Nuclear issues force us to make nuclear choices—individually in the voting booth, through our elected representatives, and through our leaders at the highest levels of international negotiation.

I have written this book on the premise that nuclear choices are best made by citizens who know something about the underlying issues, who understand the basics of nuclear technology, and

who can judge for themselves statements advocating particular positions. In that spirit, the book demands no prior knowledge of nuclear matters. It does ask that readers be open to the range of opinions, be willing to grasp some basic technological considerations, and be willing to bring informed judgment to their own choices.

Nuclear Choices arises from a course I have taught in recent years at Middlebury College. As I hope the book will do, that course has given people with no particular scientific, technological, or political background the understanding to help them make informed choices about nuclear issues. Although the book should find use in similar college courses, its intended audience is much broader. Citizens of today's industrialized societies cannot avoid nuclear technology, and the book should help them to become familiar with it and to gain confidence in making nuclear choices.

My specific goal here is to introduce readers to the ideas they will need in order to understand nuclear issues as they are presented in the contemporary news media. By covering essentially all nuclear technologies in one book, I have been able to stress the connections among them—especially the multifaceted relation between nuclear power and nuclear weapons. Readers seeking a deeper understanding of individual nuclear technologies are referred to the more thorough works listed at the ends of the chapters.

A great many people and institutions contributed to the making of this book. Corporations, government agencies, national laboratories, universities, and individuals supplied photographs. The reference staff of Middlebury College's Starr Library—especially Terry Plum—accepted enthusiastically the often obscure challenges I put to them. John Truxal and several unnamed reviewers made helpful suggestions on the entire manuscript. Geneticist George Saul kindly reviewed chapter 4, while Rush Holt of the Princeton Plasma Physics Laboratory supplied helpful comments on the treatment of nuclear fusion. Political scientists Russ Leng and Ted Rueter assessed the coverage of strategic nuclear doctrines. The support of the Alfred P. Sloan Foundation's New Liberal Arts Program has been most important. Through major grants to liberal arts colleges, the NLA program has sought to bring technological literacy to students with academic interests well removed from science and technology. Middlebury's multi-year NLA grant allowed, among other activi-

ties, the development and teaching of the course from which this book grew. And a subsequent NLA Special-Leave Grant gave me the time and support that allowed me to complete this book in a timely fashion. I am grateful to the Sloan Foundation for its generous backing of this project. It was a pleasure to work with Paul Bethge at The MIT Press as the book went through its editing, and with George Nichols, Robin Brickman, and Amanda Tate as they prepared the final artwork. Finally, I thank my family for their patience and encouragement during the time this book was in the making.

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Nuclear News, Nuclear Choices

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In 1988, Massachusetts voters were confronted by a ballot question asking whether they approved of a proposed law providing that "there shall be no further generation of electric power by commercial nuclear power plants . . . by means which result in the production of nuclear waste." Since all nuclear power plants produce nuclear waste, the effect of a Yes vote would have been to shut down Massachusetts' two operating nuclear plants and to forbid the startup of any new ones.

If you lived in Massachusetts, how would you have voted? On what would you have based your vote? What *is* nuclear waste, anyway? How much waste do nuclear power plants produce? How dangerous is the waste? What should we do with it? Are nuclear power plants safe? Safe relative to what? Do we really need nuclear power? What are some alternatives? How is nuclear power related to nuclear weapons? Could a Chernobyl-type accident occur in Massachusetts? What is radiation, and what can it do to me? What's so special about things nuclear?

Those questions and many more might have come up as you considered how to vote in the Massachusetts referendum. And Massachusetts voters are not the only ones who are called to make nuclear choices. A year earlier, Maine voters faced a similar referendum. In 1989 it was California's turn, as voters focused on the fate of a single nuclear power plant. At least twelve similar referenda have been held in the United States, and more than 150 U.S. communities have voted to ban nuclear weapons or other nuclear

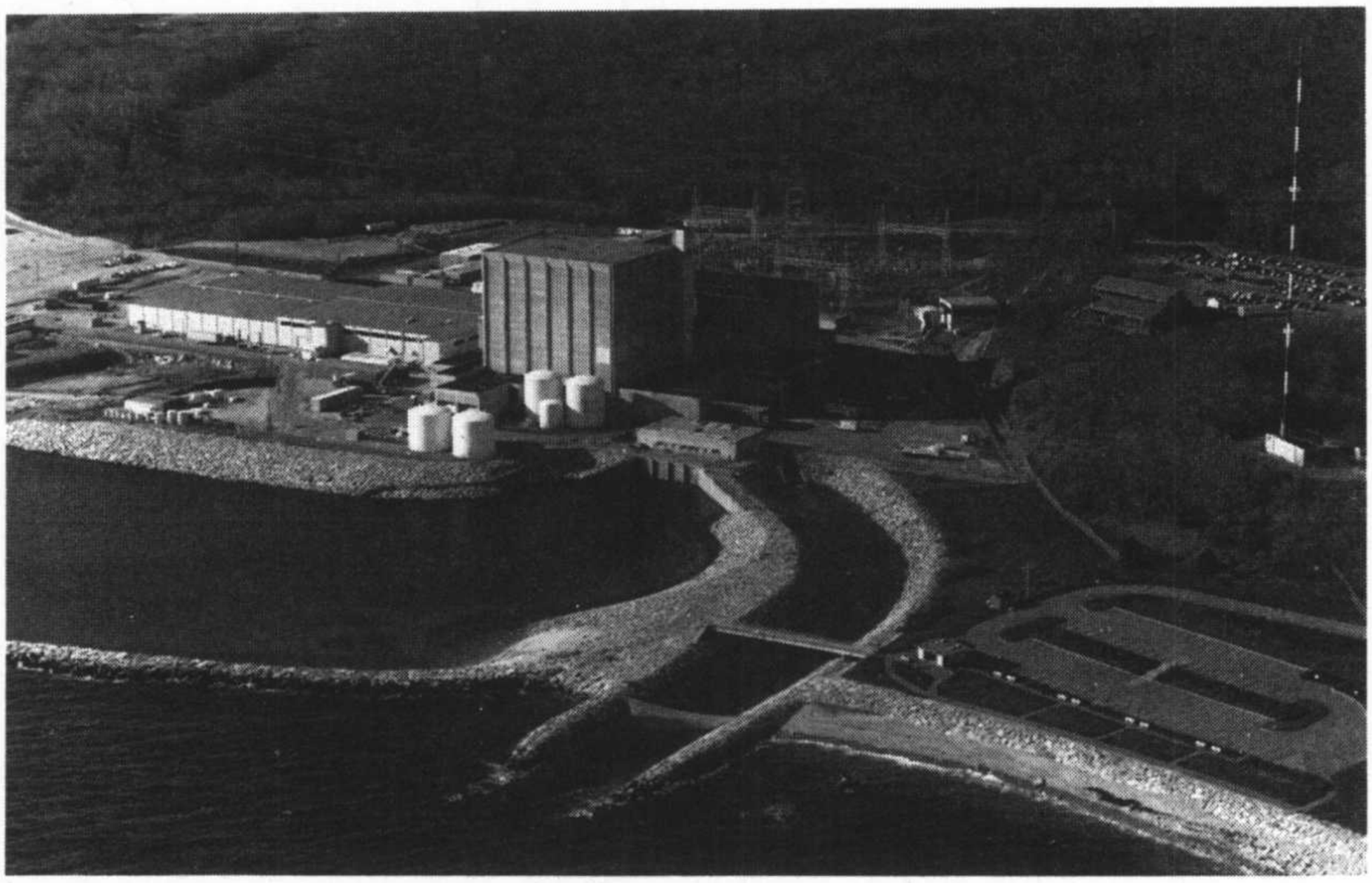

Figure 1.1 The Pilgrim nuclear power plant in Plymouth, Massachusetts. (Boston Edison)

QUESTION 4

LAW PROPOSED BY INITIATIVE PETITION

Do you approve of a law summarized below, *upon which no vote was taken by the House of Representatives or the Senate before May 4, 1988?*

SUMMARY

The proposed law would provide that, after July 4, 1989, there shall be no further generation of electric power by commercial nuclear power plants in the Commonwealth by means which result in the production of nuclear waste.

YES ➧

NO ➧

Figure 1.2 The 1988 ballot question that would have forced Massachusetts' nuclear power plants to close. Voters rejected the proposition by a 2-to-1 margin. (Massachusetts State Elections Division)

materials. (With the exception of the 1989 California vote on the Rancho Seco nuclear plant, voters rejected propositions that would have shut down existing power plants.)

Whether or not you encounter nuclear questions in the voting booth, you can't escape nuclear issues in the news. Often that news calls for nuclear choices, either by you or by your elected representatives. Some recent examples follow.

> New York Times, *November 29, 1989: U.S. WILL START OVER ON PLANNING FOR NEVADA NUCLEAR WASTE DUMP . . . The Government has abandoned a two-year effort . . . to plan the nation's only dump for highly radioactive nuclear waste because it lacks confidence in its work. . . . The decision delays until at least 2010 . . . the opening of a repository . . . for the spent fuel of more than 110 civilian nuclear reactors. . . .*

Will they *ever* find a way to dispose of nuclear waste? Is this a technical problem, or is it really political? Would I want a nuclear waste dump in my state? Should I have voted Yes on the referendum to close down nuclear plants because of this waste problem?

> New York Times, *March 29, 1990: 30-YEAR PLUTONIUM LOSS AT PLANT EQUALS 7 BOMBS . . . Seven nuclear bombs' worth of plutonium escaped into air ducts at the Rocky Flats weapons plant near Denver. . . . "a very substantial quantity of plutonium that was simply not accounted for". . . . as filters became clogged, workers had been punching holes in them so the air, although contaminated, could pass through.*

Seven bombs' worth unaccounted for? How do I know the plutonium hasn't gone to a terrorist group? And what is this about bypassing filters to let plutonium-contaminated air through? Why put a bomb plant near a big city like Denver? Where else are there nuclear weapons plants? What kind of operation is my government running, anyway?

> New York Times, *September 13, 1988: MAJOR RADON PERIL IS DECLARED BY U.S. IN CALL FOR TESTS . . . Cancer threat is called wider than had been believed. . . . the Government today issued a national public health advisory urging that most homes be tested. . . .*

What is radon? Should I get my house tested? Will I need to move? Is my family safe? Does this have anything to do with nuclear power? With nuclear weapons? Why wasn't I told about this earlier?

> New York Times, *September 28, 1988: SCIENTIST SAYS LOW RADON LEVELS MAY BE HARMLESS . . . Government warnings may be exaggerated. . . .*

But the government just recommended that I get my house tested. Who am I supposed to believe?

> New York Times, *November 27, 1988: ATOMS FOR PEACE AND WAR: IS THERE A CLEAR DISTINCTION? . . . Under an executive order issued by President Reagan . . . the Nuclear Regulatory Commission must draw up detailed plans for dealing with a national security emergency, including a plan to seize civilian nuclear power plants to obtain material for weapons.*

Does this mean my local nuclear power plant is a bomb factory? Am I making plutonium every time I turn on an electric light? How much? Could a terrorist get hold of this stuff? Should this presidential order change my vote on nuclear power?

> New York Times, *September 12, 1989: NEW MACHINES CAN DETECT TERRORISTS' BOMBS, USUALLY . . . The new . . . analyzer at Kennedy Airport passes suitcases through a cloud of subatomic particles and analyzes the radiation produced for signs of nitrogen, which is a component of virtually every . . . explosive.*

Here is a beneficial use of nuclear radiation. But will my luggage become radioactive? And can I be sure that my wool sweater won't set off the alarms? I've heard that wool contains a lot of nitrogen.

> Boston Globe, *September 19, 1989: SCREENING SOUGHT IN CANCER LINK TO PILGRIM . . . Two prominent health specialists said . . . that evidence linking the Pilgrim nuclear plant to elevated rates of cancer is so strong that nearby residents should be screened for cancer. . . .*

Should I get tested? I thought nuclear plants were safe. Should I have voted to shut down Pilgrim? Is this one of those media scare stories, or is there something to it? Who can I believe?

New York Times, *March 25, 1990: NEW EXPLOSION THREAT SEEN AT NUCLEAR PLANT . . . tanks that store atomic waste at the Hanford [Washington state] nuclear reservation could explode and spew radiation into the air. . . .*

New York Times, *September 8, 1989: U.S. TO REOPEN REACTOR IN 1990; SAFETY IN CAROLINA IS STILL AT ISSUE . . . The Department of Energy . . . will reopen one of its crippled nuclear reactors, resuming production of tritium . . . vital to nuclear weapons. . . . But the department refused to commit itself to completing safety testing . . . before reopening the plant, in South Carolina.*

So there are nuclear weapons plants in Washington and South Carolina, too! Possible explosions? Doesn't sound too safe. And what is tritium? Why do nuclear weapons need it? Why do we need to make more? Do we need it so badly that we should operate an unsafe reactor?

New York Times, *February 19, 1990: NEW ESTIMATES INCREASE RADIATION RISK IN FLIGHT . . . radiation exposure for flight crews . . . greater than for average nuclear power plant workers. . . .*

New York Times, *March 1, 1990: TESTS OF COCKPIT RADIATION SHOW LEVELS ABOVE A FEDERAL STANDARD . . . more radiation than the limit set . . . for pregnant women. . . . radiation . . . of such high energy that air crews cannot be shielded . . . could lead to a significant increase in the cancer rate among crew members and adult passengers. . . .*

Do I have to worry about radiation on airplanes? Where does it come from? Is it really like working in a nuclear power plant? Does that mean that nuclear power plants are really pretty safe, or that airplanes are dangerous? Should I avoid long airplane trips? How does this new radiation danger compare with other risks I face?

New York Times, *March 29, 1990: 6 HELD IN BRITAIN IN SCHEME TO SEND ATOM GEAR TO IRAQ . . . Devices That Trigger Nuclear Arms and Equipment for Missiles are Seized . . . Government officials have described the Iraqi [nuclear] program in . . . alarming terms. . . . Iraqi program . . ."well*

advanced". . . . "It demonstrates a clear intention to acquire nuclear weapons."

Nuclear weapons in the hands of the Mideast's most aggressive nation? Who else is seeking them? Does this have anything to do with nuclear power? What is my government doing to curb the spread of nuclear weapons?

> New York Times, *September 25, 1989: ENERGY EXPERTS SEE NUCLEAR POWER AS A CURE FOR ONE ILL . . . The cure for the greenhouse effect . . . is a huge shift to nuclear-generated power, speaker after speaker told delegates at a World Energy Conference. . . .*

Maybe nuclear energy isn't so bad—in fact, maybe it's our salvation in a time of climatic crisis. But what about nuclear waste? How do we weigh the long-term burden of waste disposal against the immediate gain of a shift from fossil fuels to nuclear power? Should I encourage nuclear power or oppose it?

> New York Times, *August 14, 1988: PRETORIA SAYS IT CAN BUILD A-ARMS . . . Asked by reporters whether South Africa already had nuclear weapons, [foreign minister R. F. Botha] said "I'm not going to enlarge on that statement."*
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> New York Times, *January 29, 1989: GERMAN CONCERN SAID TO AID PAKISTAN A-WEAPONS . . . officials have told Congress that Pakistan is . . . close to developing a nuclear weapon. . . .*
>
> New York Times, *October 25, 1989: U.S. CONCERN RISES OVER NORTH KOREA ATOM PLANT . . . administration officials were increasingly worried that North Korea may be trying to develop nuclear weapons.*

So it's not just Iraq! How many countries already have nuclear weapons? Is a nuclear conflict among Third World nations likely? Will newcomers to the nuclear weapons club pose a threat to the United States? What can we do to halt the spread of nuclear weapons?

> New York Times, *November 15, 1988: EXPERTS CALL REACTOR DESIGN 'IMMUNE' TO DISASTER . . . the new*