

MAN AND ATOM

BUILDING A NEW WORLD THROUGH NUCLEAR TECHNOLOGY

GLENN T. SEABORG
WILLIAM R. CORLISS

MAN AND ATOM

**BUILDING A NEW WORLD
THROUGH NUCLEAR TECHNOLOGY**

**by Glenn T. Seaborg
and William R. Corliss**

E. P. DUTTON & CO., INC. NEW YORK 1971

Copyright©1971 by Glenn T. Seaborg and William R. Corliss

All rights reserved. Printed in the U.S.A.

Second Printing December 1971

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system now known or to be invented, without permission in writing from the publisher, except by a reviewer who wishes to quote brief passages in connection with a review written for inclusion in a magazine, newspaper or broadcast.

Published simultaneously in Canada by
Clarke, Irwin & Company Limited, Toronto and Vancouver

Library of Congress Catalog Card Number: 70-122795

SBN 0-525-15099-4

Grateful acknowledgment is made for permission to reprint the following copyright material:

Extract from the poem "Cape Hatteras" by Hart Crane, from the collection *The Complete Poems and Selected Letters and Prose of Hart Crane*. Copyright © renewed 1966 by Liveright Publishing Corp., New York. Reprinted by permission of publisher.

Table on page 42 and diagrams on pages 39 and 40 (adapted) from G. T. Seaborg and J. L. Bloom, "Fast Breeder Reactors," *Scientific American*, Vol. 223, November 1970. Copyright©1970 by *Scientific American*. All rights reserved.

Diagram on page 163 adapted from A. Wolman, "The Metabolism of Cities," *Scientific American*, Vol. 213, September 1965. Copyright ©1965 by *Scientific American*. All rights reserved.

Diagram on page 169 reprinted from *Science and Economic Development* by R. L. Meier, by permission of The M I T Press, Cambridge, Massachusetts. Copyright©1966 by The Massachusetts Institute of Technology.

Diagram on page 251 reprinted by permission of *Nuclear News* from its December 1970 issue.

Map on page 348 from *Science*, Vol. 157, August 4, 1967. Copyright ©1967 by the American Association for the Advancement of Science. Reprinted by permission of *Science* and Dr. P. M. Hurley.

Contents

Preface

PART I. ATOMIC TOOLS

Chapter 1. Tools to Build a New World	19
The Technological Revolution	19
The Place of the Atom in the Technological Revolution	20
The Many-Talented Atom	22
 Chapter 2. Power and More Power	24
How Atomic Power Evolved	24
Inside a Modern Atomic Power Plant	29
Why the Breeder?	34
A Captured Sun	43
Conventional and Unconventional United States and World Power Scenarios	50
The Case for Nuclear Power	54
But Don't Build It Here (or Anywhere)	57
The Dichotomy of the AEC	59
The Regulatory Process	60
Radiation—Boon or Bane?	64
Controlled Releases of Low Levels of Radioactivity and the Radiation Standards Controversy	68
The Atomic Bomb Syndrome	78
Is a "Catastrophic" Accident Possible?	79
The Hot Water Problem	81
Aesthetics and Energy	83
An Environmental Reprise	84
 Chapter 3. Labels, Bond Breakers, and Explosives	86
Power from Radioisotopes	86
2000 Unseen Labels	90

Activation Analysis	92
Nuclear Clocks	95
A New Kind of Chemistry	97
Building with Nuclear Explosives	98
Farther Frontiers	104

PART II. APPLYING THE TOOLS

C Chapter 4. More Food and Water	109
Technology's Role	109
Controlling the Hydrosphere	110
Tracing Water	111
Grand Plans	111
How Nuclear Power Fits In	114
Modifying the Hydrosphere with Explosions	115
Squeezing Water from Humid Air	116
Thermal Enrichment in Aquaculture and Agriculture	117
Aquaculture	117
Heating Things Up	118
Other Atomic Aids to Food Production	120
Gulliver Sails Again	120
The Story of the Returning Salmon	120
Nuclear Desalting Plants	121
Principal Desalting Processes	121
Development of United States Programs	123
Thinking More Positively	125
Portrait of a Nuclear Desalting Plant	126
Nuclear Desalting in Agriculture	128
The Future of the Nuplex	131
Synthetic Food	133
Tracers in Agriculture	135
Radiation and Food	136
Radiation-Induced Sterility	136
Breeding New Plants and Animals	137
Food Preservation Through Irradiation	140

Chapter 5. Old Cities/New Cities/No Cities	144
Clean Power/Clean Cities	146
Pollution Sleuths	150
Smokeless Fuels	152
Electric Transportation	156
Gold to Garbage and Back Again	162
Nuplex: An Integrated Energy Center	167
A Longer View	172
 Chapter 6. Planetary Engineering	 174
A Slightly Flawed Planet	174
Atomic Underground Engineering	175
Releasing Trapped Natural Gas	175
Subterranean Oil Retorts	180
Mining Operations	182
Large-Scale Nuclear Excavation	183
Some Problems	183
Canal Construction	184
Instant Harbors	188
Soviet Accomplishments in Planetary Engineering	189
Climate and Weather Control	191
Earthquake Control	195
Defending the Earth Against Cosmic Projectiles	196
A Few Concluding Thoughts	197
 Chapter 7. New Worlds Above and Below	 198
New Dimensions	198
Automated Precursors	198
Men Follow Automata	204
Proxy Astronauts	207
Interplanetary Shuttle	211
Some Advanced Propulsion Concepts	217
Planetary Engineering: Phase II	220
The <i>Lenin</i> , the <i>Savannah</i> , the <i>Otto Hahn</i> , the <i>Mutsu</i> , and the <i>Enrico Fermi</i>	222
The Atom in Inner Space	223

The Undersea Frontier	223
The Nether Frontier	232
Potentialities and Realities	234
Chapter 8. Sustaining and Augmenting Man	235
Atomic Aids to Diagnosis	237
Human Activation Analysis	243
Radiation Therapy	244
Medical Spin-Off from Centrifuges and Activation Analysis	248
Nuclear-Powered Hearts and Other Devices	250
The Cyborgs Are Coming	254
The Atom in Genetic Research	259

PART III. THE ATOM AND SOCIETY

Chapter 9. The Atom as a Moving Force in Society	265
Building the Technological Infrastructure	266
Impact of Atomic Technology Centers	272
Future Roles of United States AEC Laboratories	277
Management of Large-scale Systems	280
Nuclear Economics on a Grand Scale	281
The Power Reactor Business	282
The Uranium Enrichment Business	282
The Radioisotopes and Allied Products Business	283
The Plutonium and Heavy Isotopes Business	284
The Atom and Automation	286
Gauging	287
Radiography	287
Activation Analysis	289
Tracing	289
Radiation Processing	290
Luminescent Signs	291
A New Isotope, New Uses	291
Atomic Forensics	293

Chapter 10. The International Atom	295
Cooperative Arrangements	297
East-West Cooperation	298
World Nuclear Power	299
International Exchange of Technology	303
Multilateral Cooperation	304
The IAEA	304
Euratom	306
IANEC and ENEA	306
Origin of Safeguards	307
On Keeping the Peaceful Atom Peaceful	309
Early Attempts at International Control	310
Atoms for Peace and International Safeguards	313
Possibility of Nuclear Proliferation	315
Non-Proliferation Treaty (NPT)	319
Beyond the Non-Proliferation Treaty	322
After SALT	323
Chapter 11. New Understanding	325
Probing the Structure of Matter	325
Synthetic Elements	332
Cosmology and Astronomy	340
Robot Geologists and Biologists	344
Tracking the Drifting Continents	345
Archeology with a Geiger Counter	349
The Atom in the Humanities	354
Chapter 12. Man to Mankind—The New Optimism	361
Appendix I. Applications of Radioisotopes in Medicine	367
Appendix II. Universities Cooperating in AEC Programs	375
Glossary	380
Suggested Reading	390
Index	399

Preface

Man and Atom, conceived partly as a "labor of love," became during the course of its writing a work of necessity, the completion and publication of which seemed to become more urgent each day.

This book, written during a period of both great progress and controversy in atomic affairs, has dwelled in the mind of the senior author for many years prior to its actual writing. He has spent the better part of his life engaged in investigating and working with this new source of energy and with colleagues involved with nuclear matters in the United States and throughout the world. During this time he became increasingly aware that as our knowledge of the atom and our ability to use it grew, so also did there grow a gap of understanding between those engaged in nuclear affairs and the general public.

Broadly speaking, a deficiency of public understanding of science poses a problem in a democratic society—especially one that is also a technological society so dependent for its human progress on scientific progress. But in recent years we have become impressed with the fact that public understanding of the atom specifically is an even more urgent problem, as to a growing extent our very future may hinge on how wisely we manage this great new source of energy and its myriad applications.

Human civilization is rapidly approaching a series of crises that can be managed only through some radical departures in man's dealings with the relationship between energy and matter. Nuclear energy holds one key—a crucial one—to the successful resolution of these crises. Without it there is no doubt that civilization, as we know it, would slowly grind to a halt. With it not only will we be able to raise a greater part of the world's people to a decent standard of living, but we will be able to move all mankind ahead into an era of new human advancement—human advancement which takes place in harmony with the natural environment that must support it.

It is understandable that a source of energy introduced to the world through the destructive force of a weapon as awesome as an atomic bomb would long be held in fear and would meet public resis-

Preface

tance in its development for peaceful uses. But it is also unforgivable that when those peaceful uses are so vital to man's needs and particularly to those needs which when fulfilled could help eliminate so much human conflict, we have failed to create sufficient understanding to overcome that fear and resistance.

In recent years we have delivered many speeches and written many papers in trying to tell the story of the atom's progress and promise. At best these could only be fragments of the complete story that we felt had to be told. The opportunity, therefore, to write a book that would assemble these fragments into a larger and more comprehensive picture of man's relationship to the atom was indeed welcomed. And as it was being written, the events of the day—the growing environmental and energy crises, the social and economic unrest and uncertainties based largely on man's apprehensions and concerns over his physical conditions—led us to feel our book might bear an increased significance in terms of these events.

These apprehensions and concerns cover many topics related to nuclear developments; and, while we have touched on as many of these as we could in one book, we have not attempted to go into great detail. For example, we have not tried to offer detailed rebuttals to specific arguments on the health and safety aspects of nuclear power. To do so would involve excessively technical explanations with which we did not want to burden our reader. Instead we hope we have provided the reader with the necessary background and stimulus to investigate such topics further. And in our bibliography we have provided a list of books, articles, and papers which are available for such a purpose.

We felt similarly about the complex subjects of weapons testing, arms limitation, arms control, and disarmament as they relate to the atom. If no detailed discussion of these subjects is present, it is not due to a lack of importance we attach to them, but, on the contrary, to the fact that they are so important that they warrant separate treatment and more thorough discussion than we could include here. Again, to assist the reader who wishes to pursue these topics further we have included in our bibliography a list of references to which he may turn.

Another decision we had to make was to select the technical level of our writing. To reduce the complex subject of nuclear energy to the primer level would have been unfair to the intelligent though

Preface

nontechnical reader; we wrote at a higher level of sophistication. We have added a glossary of terms at the end of the book to aid those unfamiliar with nuclear jargon.

The reader will find that our book is not devoted exclusively to things nuclear. Since we are believers in the future—a future we believe will be highly technological—we have presented a few examples of how inventions in other sophisticated scientific fields will relate to the advances being made in atomic energy. For example, unusual words such as “teleoperator,” “aquaculture,” “NAWAPA,” and “cyborg” will appear as we discuss that future in which man and machine will work together symbiotically and constructively.

In our discussions of the myriad peaceful applications of the atom we make a number of projections into the future. These should be regarded not so much as actual predictions but rather as illustrations of what might occur if all health and safety considerations and the problems of public understanding can be completely resolved. We do not believe that nuclear technology will achieve its true potential in the absence of public acceptance. All aspects must be, and we believe will be, debated pro and con, including considerations of the problems and hazards connected with alternate approaches. As the result of this process the atom will find its proper and deserved place in helping to meet and solve problems in our society.

Glenn T. Seaborg
William R. Corliss

April 1971.

Illustrations

Three important types of power reactors	31
The Robert Emmett Ginna nuclear power plant, Unit 1	33
Uranium cycle for fast-breeder reactor	36
The thorium cycle of breeding	36
Pot-type fast-breeder reactor	39
Loop-type fast-breeder reactor	40
A fast-breeder reactor cooled by circulation of gas at high pressure	41
Fusion reaction between deuterium and tritium	44
The Model ST Tokamak fusion experiment at Princeton	47
One concept for generating electric power from a controlled fusion reaction	49
Projections of future United States power requirements	50
The Monticello nuclear power plant near Minneapolis	58
The Fort St. Vrain nuclear power plant in Colorado	63
The nuclear fuel and waste cycle	67
Principle of neutron activation analysis	94
The Project Schooner crater, excavated by a nuclear explosion	99
The hemispherical cavity created by the Gnome explosion	102
Map of the NAWAPA system concept	113
Concept of a large nuclear agro-industrial complex	129
Sprout inhibition in potatoes using radiation	141
Use of nuclear power plants to reduce emission of sulfur dioxide and carbon dioxide	147
The metabolism of a typical city shown in input-output form	163
An early Nuplex concept	169
Underground effects from the Project Gasbuggy explosion	178
Project Rulison nuclear charge being lowered into shot hole	179
Underground retorting of oil shale	182
Cross section of sea-level canal excavated by nuclear charges	185
Cutaway view of SNAP-19 RTG	201
Concept of the Viking lander on Mars	202
A lunar seismograph kept warm by radioisotope heaters	203

Illustrations

- Deploying the SNAP-27 RTG on the lunar surface 204
- Concept of a nuclear power plant installed in a lunar crater 207
- Conceptual drawing of a teleoperator-carrying repair-and-maintenance satellite 211
- Experimental nuclear rocket being transported to test stand 213
- Spacecraft configurations utilizing NERVA nuclear rocket engines 217
- Sectional diagram of the NERVA engine 217
- The *NR-1* nuclear-powered submersible 225
- The *Star III* research submersible equipped with teleoperator arms 227
- Whole-body scan of a patient with thyroid cancer 240
- Whole-body counter 241
- Radiation detector locating a brain tumor 242
- Radiotherapy using a cobalt-60 gamma-ray source 246
- High-speed liquid zonal centrifuge 249
- French cardiac pacemaker powered by a small radioisotope power generator 251
- Important components of a nuclear-powered artificial heart 253
- Sketch of the Hardiman man-amplifier 258
- The 200-Bev accelerator at Batavia, Illinois 274
- Radioisotope gauges 288
- Detection of gunpowder residue from muzzle flashback 294
- Gallery of the two-mile-long Stanford Linear Accelerator 333
- Africa and South America as fitted together before continental drift 348
- Uncovering a 14,000-year-old burial site in the Sudan 350
- Activation analysis used to establish the chemical profiles of pottery 355
- X-ray fluorescence equipment used to study a Gauguin painting 358

PART I

ATOMIC TOOLS

