Uranium Enrichment and Nuclear Weapon Proliferation

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Preface

In the years following World War II, when gaseous diffusion was the only practical means of enriching uranium, the potential contribution of uranium enrichment to weapon proliferation seemed small. It was assumed that gaseous diffusion plants were so technically complex and costly that only the most wealthy, industrialized countries could afford them. The potential for the diversion of plutonium to weapon use seemed far more dangerous and received far more attention from people concerned about weapon proliferation.

However, during the past 20 years there has been a steadily accelerating technological advance across the broad spectrum of enrichment technology. These developments have made the enrichment route to proliferation more accessible to smaller, poorer and less technically advanced countries. This has in no way reduced the danger associated with plutonium, but has instead added a new set of dangers and problems for those who would attempt to stop and reverse the spread of nuclear weapons.

This book presents a comprehensive review of the state of the art of enrichment technology and attempts to evaluate the impact of this technology on the proliferation problem. It places the technical development into the context of the economic and institutional environment within which the enrichment industry has evolved to its present state, and it suggests some measures which might be taken to reduce the proliferation dangers inherent in this industry.

Part of this book was prepared in Sweden and part in the Netherlands. The total work was co-ordinated at SIPRI in Stockholm by Allan Krass, who is Professor of Physics and Science Policy at Hampshire College (Amherst, Massachusetts, USA). Dr Peter Boskma holds the chair of Philosophy of Science and Technology and Dr Wim A. Smit is Director of 'de Boerderij' Centre for Studies on Problems of Science and Society, both at Twente University of Technology (Enschede, the Netherlands). Mr Boelie Elzen is a research fellow at 'de Boerderij' Centre and holds a university degree in electrotechnical engineering. Special gratitude is extended to Mr Gerard W.M. Tiemessen, who is also a research fellow at 'de Boerderij' Centre, and who has made substantial contributions to parts of this book; he holds a university degree in physical engineering.

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Frank Blackaby
Director

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Introduction

This book is concerned with the connections between uranium enrichment technology and the horizontal proliferation of nuclear weapons. It is intended to provide journalists, policy analysts, diplomats, students, and political and bureaucratic decision-makers with detailed and complete descriptions and analyses of a large number of important developments, which during the past decade have greatly increased the role which enrichment is playing and will continue to play in the proliferation problem.

Uranium enrichment is one of two methods which have been developed to produce nuclear explosive material. The other is the production of plutonium. Although plutonium production and its attendant proliferation problems are not dealt with in this book, this should in no way be interpreted as a denigration of their importance. Any successful non-proliferation strategy will have to deal with the problems presented by both paths, but a complete study of both is beyond the capabilities of the present authors.

For many years uranium enrichment was carried out by means of one technique, gaseous diffusion, and predominantly in one country, the USA. China, France, the UK and the USSR had by far the largest capacity and for many years held the dominant position in the world enrichment market. However, starting in the mid-1970s this dominant position began to decline slowly as other countries entered the market and as new techniques became more competitive with gaseous diffusion.

It was the anticipation in the 1960s of a large and growing world market for enrichment services which stimulated the research and development (R&D) programmes which led to the new techniques. Most people believed at that time that nuclear energy would spread throughout the world and that the dominant power reactor design would be based on the light-water moderator and coolant, a design which requires enriched uranium for its fuel. The combination of prospects for a growing enrichment market and a growing desire for energy independence led many countries to invest significant resources in an attempt to acquire an indigenous enrichment capability. It is not unreasonable to assume that some portion of this effort was also motivated by a desire to keep an option to produce nuclear weapons.

During this same period concern over weapon proliferation relaxed somewhat. The signing of the Non-Proliferation Treaty (NPT) and the establishment of an international safeguards system led many to believe that this problem could be brought under control. Of course, it was recognized that many of the features which made such new enrichment techniques as the gas centrifuge and the jet nozzle processes commercially attractive also made them vulnerable to acquisition or misuse by states wanting to acquire nuclear weapons, but concern over the problem was muted by optimism that adequate safeguards arrangements could be worked out.

Unfortunately, as the 1980s began, these optimistic assumptions appeared to have been premature. A deep recession in the world nuclear power industry has left many countries with an over-capacity of enrichment capability and large capital investments in research, development, and plant construction which now threaten to be unrecoverable. A number of processes have been developed which clearly make proliferation easier, and these, coupled with the continuing desires of some countries for self-sufficient nuclear fuel cycles and the desires of others to export technology, have produced a highly unstable situation with respect to proliferation.

Given these pressures for the spread of new enrichment techniques, it is then doubly disturbing to discover that the various institutional and technical mechanisms for safeguarding enrichment facilities and for controlling exports of sensitive components and know-how are seriously inadequate. Very little experience exists in applying the usual safeguards to enrichment facilities, and both technical and institutional obstacles must be overcome before genuine confidence can exist that enrichment facilities and their product can be monitored with confidence.

All of this leads to the conclusion that the proliferation implications of uranium enrichment technology must be understood much better and taken much more seriously than they have been in the past. The purpose of this book is to gather together in one place the material necessary for such an in-depth analysis.

The book is divided into three parts. In Part One the connections between enrichment and nuclear weapon proliferation are explored and analysed. The argument is presented without technical detail or extensive data on enrichment demands and capabilities. These are supplied in Parts Two and Three.

The argument of Part One proceeds from a brief description of the basic physical principles of uranium enrichment (chapter 1) to a comparative analysis of the proliferation potentials of various processes and the capabilities and intentions of the many nations that have demonstrated interest in enrichment (chapter 2). The problems of control raised by enrichment developments are explored in chapter 3 both from technological and institutional points of view. Then in chapter 4 we outline the conclusions of our analysis and make a number of policy recommendations whose aim is to retard the further proliferation of nuclear weapons, at least until the incentives to acquire them can be reduced or eliminated.

Part Two is intended for a more technically oriented audience. It describes the scientific and technological aspects of enrichment in sufficient detail to allow independent analysis and evaluation of both present and future technological developments. The significant parameters of the various processes are summarized, and a framework is provided for understanding the proliferation implications of these parameters. Part Two presents all of the technical data necessary to support the arguments of Part One.

Part Three begins with a brief history of efforts to control nuclear weapon proliferation with an emphasis on the role played by enrichment (chapter 7). It is shown that the enrichment industry has played a dual role in both facilitating proliferation and providing mechanisms by which proliferation might be discouraged or retarded. This is followed by a detailed picture of the world enrichment industry and market — past, present and future. A country-by-country summary of enrichment capabilities, intentions and non-proliferation attitudes is presented and summarized in a number of tables and appendices. As with Part Two, these data provide the basis for many of the assessments and conclusions made in Part One.

NOTES ON CONVENTIONS

The following general conventions are used in the tables:

. . Information not available
( ) Uncertain data or SIPRI estimate
– Nil or not applicable

'Billion' in all cases is used to mean thousand million.

All dollar prices are US dollars.

Metric units generally apply:
1 tonne (metric ton) = 1 000 kilograms = 2 205 pounds = 1.1 short tons
1 megawatt (MW) = 10^6 watts
1 gigawatt (GW) = 10^9 watts

Erratum

Uranium Enrichment and Nuclear Weapon Proliferation

by

Allan S. Krass, Peter Boskma, Boelie Elzen, Wim A. Smit

Page xv The third paragraph of this page should read as follows (owing to a printing error the underlined words were omitted):

For many years uranium enrichment was carried out by means of one technique, gaseous diffusion, and predominantly in one country, the USA. China, France, the UK and the USSR all built gaseous diffusion plants of various sizes, but the USA had by far the largest capacity and for many years held the dominant position in the world enrichment market. However, starting in the mid-1970s this dominant position began to decline slowly as other countries entered the market and as new techniques became more competitive with gaseous diffusion.