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Preface

This book is a perspective on early attempts to monitor and then to ban atomic weapons tests, as well as on scientific factors leading, instead, to a treaty in 1963 banning tests in all environments except deep underground. The early part of this interval was one in which the great

alliance of powers that won World War II split apart and descended into what became known as the Cold War. The bomb that had ultimately ended the war in the Pacific was a pivotal element in the disagreement between East and West. When the original developers of the bomb—the U.S., the U.K., and Canada—offered in 1945 to give up their monopoly on atomic energy and destroy all weapons in exchange for controls that would ensure that all further uses would be for peaceful purposes, they were rebuffed by the Soviet Union. Instead, the Soviet Union retreated behind an "Iron Curtain" of secrecy following the war. It became imperative for the West to discover if and when the Soviets developed nuclear weapons, necessitating the development of scientific and technical methods to detect nuclear tests at distances of thousands of kilometers.

This perspective on the science and the times is a personal perspective. I was fortunate to be a graduate student in seismology even as the first scientific papers were being published on seismic observations of atomic explosions. Reprints of these and other significant articles are still in my collection; thanks to the small population of seismologists of that day, even lowly graduate students could receive reprints from such eminent seismologists as Beno Gutenberg and Charles Richter (Caltech), Perry Byerly (University of California), Dean Carder (U.S. Coast and Geodetic Survey), Keith Bullen (University of Sydney) and L. Don Leet (Harvard University).

I became involved professionally in developing the science and art of bomb detection in 1949 when the work was highly classified, and through this involvement gained a window into research and development focused on bomb detection years before it was mentioned substantively in the unclassified scientific literature. It was a time when there was virtually everything still to learn about bomb detection. Later, during the years after much of the research became public, I maintained a number of notebooks and collections of unclassified papers that have

been a fruitful resource for this work. More recently, I have been able to obtain or view a number of declassified documents pertaining to my subject. I have used and given a number of references to books and journal articles, in most cases to identify either a source of more information or a key stepping-stone in our thinking about the various subjects to be described here. A few references, mostly post-1960, have helped me to remember and describe the international political background of the era in which these developments took place. However, the main themes and events of this work are those in which I was personally involved. Thus, it remains as a perspective from my own point of view, and I make no claim for completeness.

One focus for this book is the early development of the seismic component of the U.S. Atomic Energy Detection System (AEDS), our then-secret system for detecting and determining the characteristics of foreign atomic explosions. This has guided my selection of events and research results to include here, especially in the years before 1958. While working with the consulting firm of Beers and Heroy, I was instrumental in the design of an experimental seismic system for long range detection. In 1951, together with our sponsoring agency, now known as the Air Force Technical Applications Center (AFTAC), we validated the system during the GREENHOUSE nuclear test operations. AFTAC then rapidly deployed seismic stations in countries surrounding the U.S.S.R., and in August 1953, the still-evolving seismic system detected and accurately located the fourth Soviet nuclear test. However, this book is not intended as a history of the seismic system of the AEDS, but rather a disclosure of seismological research and development that impacted the AEDS, as well as early test ban treaty negotiations.

I have included, very selectively, some of the political circumstances and events within the U.S. and internationally that led to the creation of, and influenced the early years of, the AEDS and its creator and operating agency, AFTAC. In selecting which of the earliest events to include here,

I have been guided by the "folk lore" I absorbed from those directly involved in the two years before my time, especially the late Doyle L. Northrup, Technical Director of AFTAC during most of the years of my close association. I gratefully acknowledge major help from three other sources in placing accurate dates, names, and sometimes context on material of this sort. These sources are: AFTAC (1997), Ziegler and Jacobson (1995) and Welch (1996, 1997); I highly recommend these references to those interested in the history of the AEDS.

A second focus is on the influence of atomic explosions on seismology in general. Sensitive detection and reliable discrimination between explosions and earthquakes required addressing fundamental aspects of classical seismology -- the nature of microseismic "noise" in the earth, the mechanisms of earthquakes and how they excite seismic waves, the effect on seismic waves of propagation through the heterogeneous earth, to mention a few. The atomic explosions themselves became an invaluable part of many investigations of these fundamental problems. For the first time sources of seismic waves with precisely known locations, times and energies—and large enough to be recorded at great distances—became available. These led to fundamental discoveries in the science, and to improved knowledge of the structure of the earth itself.

A third, and perhaps the most important, focus is on consequences of the international political thrust in the 1950's toward an agreement banning—or limiting, as it turned out in 1963—nuclear testing. Public concern about radioactive fallout was an important factor in this, and has sometimes been cited as the major one, or even the only one. But I am persuaded that a larger factor in the thinking of the world's leaders was the increasing size of both weapons and arsenals, and genuine fear that they might be used through miscalculation under the tensions engendered by the East-West rivalry. A nuclear test ban seemed a reasonable first step toward abating an unbridled arms race. However,

the stakes were high, and neither side wanted to give the other an advantage in weapons development. In a world where information was tightly controlled from a continental-sized unfriendly region, confidence within the U.S. that adherence to a test ban agreement could be verified would depend on confidence in scientific monitoring capabilities.

At President Eisenhower's direction, an attempt to pave the way for test ban treaty negotiations brought American scientists involved in test detection into intensive contact with their Soviet counterparts. The resulting Conference of Experts in 1958 broke negotiating precedents in a number of ways, and established scientific verification as a cornerstone of test ban treaties and of a number of other treaties to follow. These meetings, held in Geneva, Switzerland, established that substantial agreement existed on methods and capabilities for detecting atmospheric tests, where several methods apply in both overlapping and complementary ways. But significant disagreement between scientists of East and West was revealed on detecting deep underground nuclear tests. For these, seismology is the only means for detection at long ranges; obtaining proof of *nuclear* origin requires the use of other techniques, and can be very difficult. Resolution of these disagreements was not possible with data from the single underground nuclear explosion that had been detonated up to that time.

New data from several additional U.S. underground explosions, acquired only days before treaty negotiations began in 1958, kept the seismological issues prominent. New problems were revealed by the new data, and once again scientists of East and West were unable to resolve differences in their judgments on nuclear test monitoring capabilities. These differences, in the context of profound political differences between East and West, became obstacles that strongly influenced the course of nuclear test ban treaty negotiations for many years to come.

When deficiencies in seismic knowledge were seen by high U.S. national political leaders to create obstacles to a much desired treaty, they greatly increased funding for the science. What followed was an interval in which classical seismology developed in scope from an obscure science, centered mainly in a few universities, into a flourishing and highly sophisticated science also involving industrial, governmental, and federally funded laboratories. Seismographic data recorded photographically (and even on smoked paper) and analyzed visually were rapidly being replaced by magnetic tape recordings, and modern digital computers became available for analyzing the data. At the beginning of this period attendees of the Seismological Society of America's annual meetings were easily accommodated in a small lecture room and were on a first name basis; within a few years, seismologists were multiplying at a rate that made both impossible.

U.S. scientists conducted their research against the backdrop of treaty negotiations, and as early research results emerged—not all of them good news for treaty advocates—U.S. policy-makers and negotiators were forced to struggle at times to adjust to the changing technical picture. To the USSR, however, the treaty was predominantly a political matter, and the US stress on science was vehemently criticized as merely a pretext to undermine the negotiations. To finesse the underlying seismological issues, the negotiators compromised in 1963 on a ban of all but underground tests.

What follows is loosely historical in structure. However, it has seemed logical to me to separate technical and political occurrences in some cases and follow one thread to some milestone before taking up another set of events in the same time frame. This can lead to viewing one set of events from two perspectives: the advent of thermonuclear tests impacted seismology beneficially, but its attendant radioactive fallout strongly impacted the political world in quite a different way.

There is no precise moment of genesis for this book. A number of colleagues have urged that I do something of this sort, starting at least twenty years ago. Somewhat later Mikhail A. Sadovsky, a leader of the Soviet Union's test detection research since its inception, suggested that we write a joint article on subjects discussed and issues argued during and after the Geneva Conference of Experts of 1958, but that was not to be because of his failing health. The main impetus that actually led to putting words on paper came at the end of 1996, when I was asked to consider initiating the Hamilton Visiting Scholars Program at Southern Methodist University. After accepting early in 1997, I began sorting through old files, reprints, notebooks and so on, and collecting and organizing this and other material as the basis for a series of lectures/seminars. Seven lectures were prepared, and delivered at SMU from hand-written notes (my keyboard skills are distinctly minor) during October and November of 1997. Illustrations were in the form of copies of hand-drafted figures from old reports for the most part—a practice also followed here to help illustrate the technology and informal style of that time, well before the advent of computer-aided graphics. What follows has its origins in those lectures.