Introduction

Figure 1. Stanley Kubrick on the set of *Dr. Strangelove*. Courtesy the estate of Stanley Kubrick.

In the early 1960s I spent parts of a year interviewing Stanley Kubrick for what eventually became a *New Yorker* profile that was published in December 1966.[1] During my interviews he was in the process of making *2001* but, inevitably, we talked about *Dr. Strangelove* and the general subject of nuclear weapons. The Cuban missile crisis had very recently occurred. Kubrick told me an anecdote that I did not put in the profile. At the time of the crisis he decided that he and his family would move to somewhere he deterined would have the least fallout in case Washington or New York was atom-bombed. He decided that Australia would do. Since he did not fly – he thought that the odds against crashing were not small enough – he had booked passage on a boat. He had also ordered 140-odd Boy Scout camp trunks, which he was going to number and load with the family goods. He then discovered that the bathroom of the cabin that he was going to occupy with his wife was to be shared with an adjoining cabin containing people he did not know. He canceled the trip and decided to take his chances with the bomb.

[1] It was published in the December 11, 1966, issue under the title "How About a Little Game?" Part of the interviews were tape-recorded and can be found in the Stanley Kubrick Archives, Taschen, Berlin, 2005, as a CD.

What struck Kubrick, when we talked a few years after this incident, was how little interest there was among the general public about nuclear weapons. He thought that people had even less interest in them than they did in city government. He attributed this to the fact that, to most people, nuclear weapons are an abstraction. Almost no one had ever seen a nuclear explosion. The United States and Russia had stopped testing aboveground in 1962, so even the professionals who worked on the design of nuclear weapons in these countries no longer actually saw them explode. He said that people seemed to look on the absence of a nuclear conflict as they would money growing in a savings account. The longer there was no nuclear event, the safer we were. The whole premise of *Dr. Strangelove* was to show just how fragile all of this is.

The last aboveground test was conducted by the Chinese in 1980. So it has been close to thirty years since anyone has actually seen an atomic explosion. On the one hand we should be grateful and, on the other, concerned because people have so little understanding of what these weapons can do, or how they work. Most people seem to think that we are discussing explosions that are just a somewhat larger version of the car bombs in Baghdad. To put the matter in perspective, the Ryder truck that Timothy McVeigh used on April 17, 1995, to blow up the Murrah Building in Oklahoma City contained about five thousand pounds of high explosives. It killed 168 people. The *one* bomb that was dropped on Hiroshima on August, 6, 1945, had an explosive yield equivalent to about *thirty-two million* pounds of TNT. By comparison, on March 9 and 10, 1945, 334 B-29 bombers dropped two million pounds of incendiary bombs on Tokyo, killing perhaps 100,000 people. By December 15, 1945, it was estimated that 90,000[2] people had died in Hiroshima because of

[2] There is a good deal of uncertainty with respect to this number, but 90,000 seems to be the best conservative estimate.

the effects of *one* atomic bomb. The Oklahoma City bomb partially destroyed one building. The Hiroshima bomb destroyed 90 percent of the infrastructure of the entire city, and totally destroyed everything within a radius of one mile of where the bomb exploded. It may not be generally realized – I will explain more fully later – that this bomb was of a rather primitive design. Its design was considered to be so rudimentary that it had never been tested. The Hiroshima bombing was the test. The design resembled one that a country, or a group, that had acquired the explosive materials but had a limited technology would adopt. The bombs that make up our "portfolio" now typically have the equivalent explosive power of one *billion* pounds of TNT, and we have tested bombs that are a hundred times more powerful. As I will explain, their design requires a good deal of very sophisticated work. Some of these designs have been stolen and sold. This too I will discuss later.

For a while I thought that Kubrick might have been too pessimistic. In 1957, the United Nations established the International Atomic Energy Agency (IAEA) and, in 1968, a Nuclear Non-Proliferation Treaty (NPT) was drawn up. It was eventually signed by 190 countries. Israel, India, and Pakistan did not sign, and each of them constitutes a special case. For many years Israel maintained the fiction that it did not have nuclear weapons. But in 1985, a Moroccan-born Jew named Mordechai Vanunu, who had been fired from his job working at the plutonium-producing reactor in the Negev, defected and sold his story, with photographs, to the *London Sunday Times*. He was captured by the Mossad in Rome and, after serving seventeen years in prison, is living under tight security in Israel. We have gotten used to the idea that the Israelis have the bomb, and I doubt that many people in this country are kept up at night worrying about it. In 1974, the Indians tested their first nuclear weapon and, in 1998, the Pakistanis did the same. For a

time it looked as if there might be a nuclear war over Kashmir. As horrible as this was to contemplate, considering the teeming cities of both countries and their limited capacity to respond to emergencies, it was to most of us very far away. I think most people in our country naïvely thought of such a nuclear exchange as *their* problem – *they* being the Indians and Pakistanis. In January 2003, North Korea withdrew from the non-proliferation treaty. Things began to look as if they were *our* problem. We had fought a war with North Korea and had troops stationed in the south. Furthermore, North Korea had a missile program that had as its goal the construction of intercontinental ballistic missiles capable of reaching the United States. It seemed very likely that the North Koreans had made at least some nuclear weapons and, indeed, on October 9, 2006, the North Koreans made an underground test of a low-yield nuclear device. Then there was Iran. Now things were getting uncomfortably close to home. Here was a country whose leaders not only appeared to be implacable enemies of ours, but who were also advocating the destruction of Israel. This was also a country that sponsored terrorism. That these people might build an atomic bomb was for many of us impossible to accept. Indeed, the media became replete with discussions of nuclear weapons. Terms like "fission," "enrichment," "centrifuge cascades," and "uranium isotopes" appeared on a daily basis.

What struck me about this was the appalling lack of understanding of any of it that manifested itself in most of these reports. One example, among very many, comes to mind. I was listening one Saturday morning to National Public Radio. An "expert" was being interviewed about the Iranian enrichment program. He referred to it as "distilling." The image came to mind of a large vat in which unenriched uranium was being boiled. The undesirable bits of uranium

would emerge as a vapor, leaving behind just what you needed to make a bomb. The interviewer had absolutely no clue as to the total nonsense of this conception. It stood there unchallenged, adding to the growing budget of misinformation. Here is a more recent example. It comes from an article in the December 2006 *Atlantic* entitled "How to Get a Nuclear Bomb," written by William Langewiesche.[3] The article discusses the very important question of how terrorists might obtain nuclear weapons. Mr. Langewiesche who, whatever his virtues, is not a nuclear physicist, feels obligated to explain how a nuclear weapon works. He focuses on the Hiroshima bomb. He attempts to describe a "critical mass." Here is what he writes: "In relation to its surface area that mass was more than enough to achieve 'criticality' and allow for an uncontrollable chain of fission reactions, releasing further neutrons in a blossoming process of self-destruction." The late Wolfgang Pauli, who was both a great physicist and a scathing critic of nonsense, had a category of physics propositions that he said were not "even" wrong. They were so confused that they were all but devoid of meaning. This sentence is an example.

After having encountered a number of these it occurred to me that I could perform a service. Whereas I do not regard myself as a professional expert on nuclear weapons as compared to people like Freeman Dyson, Richard Garwin, Carey Sublette, Herbert York, or Pete Zimmerman, I have been interested in the subject for many years. I have taught nuclear physics and spent some time assisting Dyson when he was trying to design a nuclear bomb–powered spaceship. I am also one of the vanishing number of people still around who have actually seen the explosion of an atomic bomb – two, in

[3] *The Atlantic*, December 2006, pp. 80–98. The quote can be found on page 80.

fact. This occurred in the summer of 1957, when I was an intern at Los Alamos and went to observe two aboveground nuclear tests in Nevada. I will give my impressions of this experience later. In short, I decided to write a kind of nuclear weapons primer that would explain the basics and prepare people both to understand the news and to read the more complete accounts that can be found, for example, on the websites of Carey Sublette.

Here is how I have set about this task. I first give a history of the basic scientific discoveries, beginning with the discovery of the atomic nucleus just before the First World War and the discovery of the fission of uranium and plutonium just before the Second. I then describe how this science went to war. I also describe how this technology was stolen and the path that led from one country to the next. In the course of this I explain what enrichment is, why it is necessary, how it is done, and what a "critical mass" is. I also describe the hydrogen bomb and its history and how nuclear weapons work. I try to do this with an absolute minimum of technical jargon. I also mix the science with descriptions of the people who did it, something that I have always found fascinating. I hope the reader will be entertained – if this is a word that can be applied to a primer on nuclear weapons – and that, at the end, he or she will come away with a new understanding of the subject.

Let me make a remark in defense of my attempt to write about a subject about which so much has been written, including the two monumental books by Richard Rhodes, *The Making of the Atomic Bomb*, published in 1986,[4] and *Dark Sun*, published in 1995.[5] Whereas these books are extraordinary in their canvas, there are

[4] Simon and Schuster, New York.
[5] Simon and Schuster, New York.

things that have been left out or have come to light since their publication. For example, nowhere in the books does Rhodes discuss the very bizarre chemistry of plutonium and the work of Cyril Smith, the British-born metallurgist who discovered how to make a workable alloy that could be used in making a weapon. Since these books were written the Russians have released some extraordinary new material that casts more light on the role of Klaus Fuchs and the hydrogen bomb. All of this is to say that this is a living subject about which the potential for discussion and discovery seems inexhaustible.