United States Nuclear Regulatory Commission
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No. S-97-05

"A PHYSICIST'S PATH: FROM MULTIPERIPHERAL MODELS AND SUPERLATTICES TO THE U.S. NUCLEAR REGULATORY COMMISSION"

BY

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BEFORE THE
NATIONAL CONFERENCE OF BLACK PHYSICS STUDENTS
AT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS
FEBRUARY 28, 1997

INTRODUCTION

It is a great honor to be invited here to address this 1997 National Conference of Black Physics students. It gives me great pleasure to look out on a room filled with 250 African-American faculty and students, gathered together to talk about their own present and future careers in physics. To see you and to interact with you is particularly gratifying given the recent College Fund report (Washington Post, 2/27/97, p. A22) on the status of African-Americans in American higher education. That report, in addition to revealing a huge gender gap in college attendance and college graduation among African-Americans, shows how much African-Americans lag the majority in receipt of bachelor's degrees (21% white for ages 25-60 vs 14% Black). In addition, the choice of studies for African-Americans is not in the sciences. At the graduate level, Black men tend to study education and Black women tend to concentrate in public administration. Only three percent of the recipients of doctorates are Black, and only five percent of university faculties are Black. It goes without saying then that I am very pleased -- as a physicist, an African-American, an MIT alumna and MIT Life Trustee -- to be here with you tonight.

The letter of invitation asked me to address the track of my career to this point, and to talk about my responsibilities in my

present position, as Chairman of the United States Nuclear Regulatory Commission.

CAREER EXPERIENCES

I would like to start by talking about my schooling, because that is where all our careers have their beginnings. I was born in Washington, D.C., and entered public school there just three years before the Supreme Court's epochal decision in Brown v. Board of Education.

It is hard to overstate the impact of that decision on the generation of African-Americans who were of school age in 1954. We had all grown up with segregation as a fact of life. We needed no court to tell us that it was morally wrong; we already knew that. But the Brown decision was the official declaration that segregation was also legally wrong: indeed, that it was repugnant to the Constitution.

The practical effects of Brown, in terms of changing the composition of the various public schools I myself attended, were interesting. Initially, the schools were integrated by law, but later became de facto re-segregated, as the racial composition of school-age children in Washington, DC, changed to being increasingly African-American. The moral and psychological effects, however, were enormous. ...
If discrimination was wrong in the schools, then logically it could not be right in any other aspect of American life. Even children, then, could sense that great changes were in the making; that the door of opportunity would be open a little wider for us than it had been for earlier generations; and that accordingly, we had all the more reason to "aim for the stars," which had always been my father's advice to me.

There was a second event in that period that helped to shape my school career. In 1957, the country was shaken by the news that the Soviet Union had beaten us into space by putting the first earth satellite into orbit. At the time, Sputnik seemed to suggest that the Soviets had surged ahead of us in science and technology, and that the American educational system was to blame. The result was that money poured into the schools to improve the quality of education in mathematics and the sciences, and there was a great deal of encouragement to students to pursue careers in these areas.

I also would like to say something about the instruction we received in the public schools of that era. Our teachers were demanding -- extremely demanding. They felt they had to be. They had experienced both discrimination and the Great Depression, and they were determined that we would acquire the knowledge and skills to enable us to compete successfully in the

job market, even in economic hard times. Our teachers' attitude was that if we were going to succeed in life, we would have to be not only as good as the next person, but probably even better. Therefore, they asked for excellence -- nothing less -- and they had no tolerance for excuses for second-rate performance.

That, then, was my schooling: rigorous, achievement-oriented teaching, in the era of opportunity opened by the Brown decision, with the special impetus given to scientific education by Sputnik. For some of us, it was a very fortunate combination. In my case, I graduated from Roosevelt High School in Washington, D.C. as valedictorian, and entered MIT as a freshman in the fall of 1964. There were 43 women and five African-Americans in an entering class of 900 that year. The number of African-American women was two. That compares with 451 women and 76 African-Americans, including 27 women, in this year's entering class of around 1100.

A friend of mine (Dr. Jennifer Rudd) and I were the first African-American women to graduate from MIT, in 1968. She went to medical school and is now a physician. I remained at MIT as a graduate student and received my Ph.D in theoretical elementary particle physics in 1973. I am happy to say that since that day, a number of African-American women have been awarded doctorates by MIT, but at that time, it was a first.

From 1973 to 1974, and again from 1975 to 1976, I was a research associate in the Theoretical Physics Department of the Fermi National Accelerator Laboratory in Batavia, Illinois. The year in between was spent as a visiting scientist in the Theoretical Division of the European Organization for Nuclear Research in Geneva, Switzerland. In both places, my work related to theoretical particle physics.

In 1976, I joined AT&T Bell Laboratories in Murray Hill, New Jersey, and for the next 15 years, conducted research in theoretical physics, solid state and quantum physics, and optical physics. The principal focus of my work was condensed matter theory specializing in the electronic and optical properties of low-dimensional systems. I worked on transition metal dichalcogenides; the electronic and optical properties of electrons on the surface of liquid helium films; and the electronic and optical properties of semi-magnetic semiconductor strained-layer superlattices. In 1986, I was elected a Fellow of the American Physical Society for my research accomplishments.

In 1991, I joined Rutgers University as a Professor of Physics, while remaining a consultant to AT&T Bell Laboratories in semiconductor theory. That same year, I was elected a Fellow of the American Academy of Arts and Sciences. In my scientific career I have had the opportunity to travel extensively, both in

the U.S. and abroad, to participate in conferences, and to lecture, including at the NATO Advanced Study Institute in Antwerp, Belgium, on "Polarons and Excitons in Polar Semiconductors and Ionic Crystals," in 1983, and the Bouchet Conference in Accra, Ghana in 1990. In New Jersey, I had a number of concurrent professional involvements. I served on the New Jersey Commission on Science and Technology under three Governors, Thomas Kean, Jim Florio and Christine Todd Whitman. I also was appointed to the Department of Energy's Advisory Board Task Force on Alternative Futures for the DOE Multipurpose National Laboratories, and to the Boards of Directors of several corporations. There were other appointments as well; I do not want to list them all, because I think you understand my point, which is to say how far, and in what varied directions, a degree in physics can take you.

In late 1994, President Clinton nominated me to the U.S. Nuclear Regulatory Commission, and stated his intention to name me as Chairman. After confirmation by the U.S. Senate, I took office as a Commissioner in May of 1995, and assumed the Chairmanship two months later.

As some of you may know, the Nuclear Regulatory Commission (NRC) is the independent regulatory agency that is responsible, among other things, for ensuring the safety of the nation's 110 nuclear power plants. The NRC's charter encompasses many other kinds of nuclear uses as well, including, for example, industrial radiography, nuclear medicine, and licensing the nation's first-of-a-kind high-level waste repository.

Originally, all aspects of nuclear energy, military and civilian, were the responsibility of the Atomic Energy Commission, which was founded in 1946. The NRC was created in 1975, after Congress decided that the nuclear power industry had reached a point where the same agency should not be promoting the use of nuclear energy and regulating its use. The AEC was abolished. The promotional and developmental duties were given to what is now the Department of Energy, and the NRC was given an exclusively regulatory mandate.

Having served at the NRC for almost two years, I can say that its duties are extraordinarily interesting and also multifaceted. One might imagine that nothing could be more exclusively technical than the task of ensuring the safety of nuclear power plants: setting and enforcing standards, inspecting to ensure compliance, and taking corrective action when needed. In reality, however, many disciplines are involved in the NRC's activities. Ours is an agency where technology, law, economics, public policy, national security, and sometimes even foreign policy considerations intersect.

REGULATORY ISSUES

Economic Deregulation of the Electric Utility Industry

Let me give you a few real-world examples of the intersection of various policy, financial, and technical issues, beginning with the regulation of nuclear power plants. For many decades, America's electric utilities have enjoyed monopoly status in their service areas. They have been regulated by state public utility commissions, which has guaranteed them a fixed rate of return each year, on a given asset base and has allowed them to pass on their prudent business expenses to the consumers of electricity. As a result, the economic performance of these utilities was so predictable and dependable that their stocks and bonds were known as "widows and orphans" securities -- the epitome of safe, conservative investments.

The guarantee of funding meant that if a utility decided to build a nuclear power plant, the NRC did not have to be concerned, once the plant received its license, about the utility's financial condition. The agency could be confident that there would be enough money for the utility to operate the nuclear plant safely, and then to decommission it properly -- that is, take it out of service and clean up the site -- when its useful life was over.

In 1992, Congress passed the Energy Policy Act of 1992, which gave to the Federal Energy Regulatory Commission (FERC) certain authority to initiate competition in the various parts of the energy business. Recent initiatives at the state and Federal levels have set into motion a process by which we will soon see true competition in the generation of electric power. Just as consumers can now choose their long-distance telephone service provider, they soon will be able to choose their supplier of electric power.

Let us consider the implications of this. The changes associated with economic deregulation and restructuring of the electric utility industry have operational, economic, and ownership aspects that are important to the NRC. Of course, the NRC is not an economic or rate regulator, but we long have recognized the challenges posed to the nuclear power industry by a changing business environment and by fiscal stringency. They include internal restructuring; ownership changes, including mergers; and a continual effort by utilities to control and reduce costs. These structural changes and economic uncertainties are driven by regulatory and market forces that will determine how, and in what

form, nuclear electric generators will survive in an unregulated, or less regulated, world. The role of the NRC is not to dictate what changes should occur or into what form electric utilities restructure. Our focus is on ensuring that, as the business environment changes, economic pressures do not erode nuclear safety. That means that nuclear electric generators must continue to maintain high safety standards, with sufficient attention and resources devoted to nuclear operations, and with decommissioning funding secure.

I should interject at this point that it is not the NRC's mandate to ensure the economic viability of nuclear power or to jeopardize it, only to ensure that whenever nuclear power is used, it is used safely, and that, when a nuclear plant is shutdown, there is adequate funding to ensure that it can be decommissioned safely. The question now facing the NRC is what deregulation will mean for how we go about meeting these safety objectives. For example, what level of assurance does the NRC have that a particular utility will spend the money required for adequate maintenance and for necessary safety upgrades? What changes do we have to make in our inspection program and other evaluation processes to ensure that we stay ahead of any potential degradation in safety at a plant, so that we can detect adverse trends and correct them. If a nuclear utility is involved in a merger or acquisition, what will the change in ownership mean for the way the plant is operated?

The NRC traditionally has relied on its inspection and plant assessment programs to identify any adverse trends in safety performance. Based on inspection program results, plant performance reviews, and other evaluative mechanisms, the NRC can take action it deems appropriate to protect public health and safety. In the current economic environment, if new business arrangements, competition, or economic constraints result in any impairment of safety, it is imperative that our assessment mechanisms detect such problems early.

The Commission has asked the staff to examine measures to identify plants where economic stress may be impacting safety. The NRC has approved for public comment a paper entitled, "Establishing and Maintaining a Safety Conscious Work Environment." The paper includes as "evidence of an emerging adverse trend" the following example: "cost-cutting measures at the expense of safety considerations."

As I indicated earlier, as electric utility industry deregulation proceeds, the NRC needs to ensure that adequate decommissioning funding is available, whether nuclear plants operate to the end of their license terms or shut down prematurely. Moreover, since deregulation may change the economic umbrella for some licensees,

the NRC may need to monitor their financial qualifications more closely.

In the Fall of 1995, I initiated a reevaluation of NRC policy regarding decommissioning funding. The NRC issued an advance notice of proposed rulemaking (ANPR) in April 1996, seeking additional information on electric utility restructuring. The ANPR also explained that some additional decommissioning funding assurance might be needed for those power reactor licensees no longer subject to rate regulation by FERC or the State regulatory commissions.

We also are examining potential changes in reporting requirements with respect to decommissioning funding.

In short, the NRC is being presented with a host of new challenges, just as a result of utility deregulation, which involve far more than technological issues. A single change in the law -- one that on its face has nothing to do with nuclear regulation -- can have major ramifications for the way we go about ensuring the safety of the public.

High-Level Radioactive Waste

One of the critical issues relating to nuclear power, in this country and worldwide, is the permanent disposal of high-level waste, including spent fuel.

Nuclear waste disposal is both a technical issue and one of public policy. We have seen decades of delay in achieving a demonstrated, workable facility for the permanent disposal of nuclear wastes, and this has had a significant negative effect on public attitudes toward nuclear power. Meanwhile, the volume of spent fuel stored at nuclear plant sites has continued to mount.

Based on what we know today, the NRC believes that safe deep geologic disposal of high level nuclear waste, including spent fuel, is feasible, at least in principle. By law, the U.S. Department of Energy is the responsible Federal agency for designing, developing, and constructing a geologic repository for high-level radioactive waste. DOE has the responsibility to accept spent fuel from commercial power reactors, and high-level radioactive waste from the defense program, and to dispose of that material in a geologic repository. The Nuclear Regulatory Commission has the responsibility of licensing the geologic disposal facility before spent fuel or high-level waste can be accepted at such a repository for disposal.

It will be up to the NRC to determine, once we receive an application from DOE, whether its specific plans for a repository

are satisfactory. It is hard to think of another issue with comparably long-term implications. By long-term, I mean a period measured not just in centuries but in millennia.

In the meantime, some utilities are running out of space to store spent fuel at their nuclear plants. To address that problem, there are bills now before the Congress under which an interim centralized storage facility would be constructed, also to be licensed by the NRC. This would mean additional responsibilities for the NRC, to license not only such a storage facility, but also certain transportation aspects of the spent fuel movement, including the casks in which the fuel is moved and stored.

EXTERNAL REGULATION OF THE DEPARTMENT OF ENERGY

One potential change for the NRC is the external regulation of U.S. Department of Energy (DOE) nuclear activities. This issue has been identified in our agency-wide Strategic Assessment and Rebaselining as a direction-setting issue for the agency, because of its potential effect on the future operation of the NRC.

In 1995, the DOE created an Advisory Committee on External Regulation. In its December 1995 report, the Committee recommended that DOE nuclear facilities be regulated externally, and named the NRC and the Defense Nuclear Facilities Safety Board as the two potential safety regulators. Last month, Secretary of Energy O'Leary announced that the administration would introduce legislation to give the NRC the responsibility for the regulation of nearly all DOE nuclear facilities, phased in over a ten-year period. This would place such DOE facilities as the Brookhaven, Argonne, and Lawrence Livermore Laboratories under NRC regulatory authority.

Many questions remain to be answered and many issues, both legal and technical, must be resolved about NRC oversight of DOE nuclear facilities. In considering this issue as part of the agency-wide Strategic Assessment and Rebaselining, the Commission is factoring in former Energy Secretary O'Leary's recent announcement and the public comments received on the DOE external regulation direction-setting issue. Those comments overwhelmingly favor NRC oversight of DOE nuclear facilities. This might seem to take us back to the beginning of time, i.e., to the old Atomic Energy Commission. This is not quite so -- this time. We would be the external regulator of DOE, not co-joined in a single agency.

NATIONAL SECURITY AND FOREIGN POLICY

I mentioned that the NRC's duties include questions of national security and foreign policy. Let me explain. As I am sure you know, a major concern for more than two decades has been the

possibility that if a nation is eager enough to have nuclear weapons, it will extract the plutonium from spent nuclear fuel and use it to construct a nuclear device. For that reason, there is a system of international safeguards, administered by the International Atomic Energy Agency, designed to ensure that exports of nuclear fuel and facilities go only to nations willing to accept, among other things, inspection of their facilities.

To ensure that U.S. exports of nuclear reactors and nuclear fuel do not contribute, directly or indirectly, to the proliferation of nuclear weapons, Congress gave the NRC the duty of reviewing all such export proposals and deciding whether they are compatible with U.S. security interests. The law includes a number of specific criteria relating to non-proliferation. If a proposed export has the support of the Executive Branch, it comes to the NRC for review, and if the NRC approves, the export goes forward. If the NRC votes to disapprove, however, the issue is sent to the Congress, which has sixty days in which to vote to block the export. Unless it acts within that period, the Executive Branch view prevails, and the export proceeds.

What that means is that even if the President has decided that a particular export is in the best interests of the United States, we the NRC Commissioners -- all Presidential appointees -- still have the duty of making our own judgment about whether it will serve the national interest, and of bringing that judgment before the Congress, as set forth in the law. That is no small responsibility.

Let me describe another issue with both domestic and international implications. The Department of Energy has a large quantity of surplus nuclear materials from its weapons program. Those materials include plutonium. What should be done with it? Should it be treated as high level waste and disposed of in a repository, or should it be mixed with uranium and used as fuel in nuclear reactors? From the standpoint of maximizing usable resources, the latter course sounds attractive, but for almost two decades, it has been U.S. policy that the dangers of a plutonium fuel cycle are too great -- because of the risk of nuclear proliferation and terrorism -- to justify recycling. Some have called for a re-examination of that policy. But what about U.S. and Russian <u>surplus</u> weapons-grade plutonium? In December 1996, DOE released its plan for excess weapons plutonium disposition, which involves a two-track strategy of vitrification (mixing plutonium with glass, then disposing of it as high-level radioactive waste), <u>and</u> mixing plutonium with uranium to create mixed-oxide fuel (MOX) for use in commercial nuclear reactors. I do not propose to address all these questions tonight, but only to give you an idea of the kinds of issues we face. Any recycling of plutonium in this country, or any use of recycled or

excess weapons plutonium in fuel for commercial reactors, would require NRC approval.

I might add that the downfall of Communism brought a variety of additional responsibilities to the NRC. For one thing, there are a number of newly independent countries that inherited Soviet-built nuclear power plants. Those nations are mindful not only of the design and operational problems that led to the Chernobyl disaster, but also of the inadequate regulation of nuclear energy in the former Soviet Union. Accordingly, these newly independent states are looking to the United States for advice in setting up regulatory bodies of their own, modeled on the NRC. We have been and continue to provide such assistance to these countries, using funds from the U.S. Agency for International Development (U.S. AID) and other sources to strengthen both the authority and capabilities of their regulatory bodies.

The inadequacies of nuclear regulation in the former Soviet Union have heightened awareness, not just in the U.S., but around the world, of how important it is that regulators have the authority, independence, and resources to do their job. Toward that goal, I have proposed the formation of an international body of nuclear regulators to focus specifically on the regulatory agenda. This past January, I was host to the initial meeting of a working group of seven nations -- France, Germany, Spain, Canada, Japan, the United Kingdom, and the U.S. -- to plan for the establishment of a permanent organization.

As some of you may know, one of the potential legacies of Chernobyl has been a large number of cancers, especially in children. We have been helping Ukraine and Belarus as they monitor their children's health, and carry out various childhood thyroid cancer and leukemia protocols. In fact, we are jointly involved in studies in these countries with the National Cancer Institute and the U.S. Department of Energy.

In the last several years, there have been twice-yearly meetings between Vice President Albert Gore and Russian Prime Minister Viktor Chernomyrdin to discuss a range of issues of common interest. These include the safety of Russian reactors, the development of new generating stations to replace potentially dangerous old nuclear plants taken out of service, and, as I mentioned, the disposition of plutonium from dismantled weapons. The Secretary of Energy and I have been a participants in those meetings.

CONCLUSION

You may ask, does a background in physics prepare you for all this? I would answer: indeed it does, and very well. There is one thing that all of us who have ever taken physics examinations

have in common. We are problem- solvers. We have been trained not to procrastinate, or to lose our composure, or to evade the hard issues, but to analyze and to work through each problem presented in a straightforward, matter-of-fact, professional way, and then move on to the next one. Successful students of physics thus acquire an intellectual and personal discipline that will serve them all their lives, and not only as physicists.

It is because of that training that one of my first initiatives upon becoming Chairman of the NRC was to establish (as I have alluded to earlier in my remarks this evening) what we have called a "Strategic Assessment and Rebaselining." This is a process in which we examine the agency's work from the ground up, taking a fresh look at what we do and how we do it. If there are programs that need to be added, or eliminated, or altered, this is an opportunity to address these questions without preconceptions. It is an exercise in problem-solving: we know that we have a particular mission to fulfill, and by a systematic analysis, we determine the optimum means of accomplishing it.

Before I close, I would like to talk briefly about the employment opportunities for graduates with doctorates in physics. Typically, there have been three principal career paths: the academic route -- aiming toward a tenured faculty position in a university, the private sector, and government. The academic path is one many of you already know something about. Within the private sector, the possibilities are quite diverse. There is research and development, of the kind that organizations like AT&T Bell Laboratories (now Lucent Technologies) conduct; there is also corporate management. As you may know, some physicists have wound up working on Wall Street, where their analytical and modeling abilities have made them valuable for their ability to understand the complexities of financial markets.

I wish I could tell you that a doctorate in physics is a ready stepping-stone to an agency head or a senior policy job in the Federal Government, but that is not generally the case. Often, but not always, these positions are filled by lawyers, social scientists, business executives, and political figures.

Nonetheless, physicists have had and continue to have stimulating and significant roles in the Federal Government. Any number of physicists have found -- in laboratories operated by the Department of Energy, the Department of Defense, NASA, and other technical agencies -- the combination of technically challenging work <u>and</u> the opportunity to serve the public. The President's Science Advisor and Head of the Office of Science and Technology Policy (OSTP) is a physicist. Physicists lead some of the Department of Energy national laboratories. I myself have found great personal fulfillment both in the private and the academic sectors; but knowing that one is working for one's country, for

one's fellow citizens, provides a special and unique satisfaction. It is exciting because it is multifaceted -- combining safety policy development, executive management, foreign and national security policy, and science and technology. I hope it is a satisfaction and an excitement that many of you will be able to experience for yourselves in your own careers.

In closing, as we talk tonight about the vistas of professional achievement and advancement that are open to you -- the students of today -- it is appropriate that we also remember, and honor, those who went before us. I am referring to the men and women who, in times not all that long ago, had all the talent, all the ability, all the drive one could ask for -- everything that was needed for success -- except opportunity. It is, in part, to honor their memory, and to be worthy of it, that we, whose opportunities are so much greater, have an obligation to make the most of our talents and to help others as we go along. In these ways, we will make those who went before us proud, and we will provide role models for those who come after us to emulate.