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The Scientist as God

by

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Introduction

Good morning to all of you. Thank you for the opportunity to address this bright and talented assembly. I have long been an admirer of the Pingry School tradition of academic excellence– as well as your strong and commendable emphasis on honor and personal integrity. Given my own background in education as a professor of physics at Rutgers University, and especially now that I will be heading back into academia as the President of Renssalaer Polytechnic Institute, I give particular attention to innovative, results-oriented approaches to education. Here at The Pingry School, with your solid blend of scholastic training, ethical development, and extracurricular opportunities, you certainly merit that attention.

I have been asked to speak today on the rather odd-sounding topic of “The Scientist as God.” I should reassure you all, from the outset, that I do not intend to deliver a theological dissertation, and that I have no intentions of arguing that science has replaced God, or that scientists are god-like, or any similar contention. Those kinds of debates are best left to philosophers, and, as you know from my introduction, I am a physicist by trade.

Instead, I would like to approach “The Scientist as God” from a series of three perspectives that do lie within my field of expertise. First, I would like to consider the work of physicists, in this century, in uncovering and unleashing the powers of Nature on a scale that previously would have been unimaginable–in the form of nuclear energy and the atomic bomb. Second, I will examine briefly the scientist as icon–individuals like Albert Einstein who represent, for some, the pinnacle of evolutionary achievement, the human as pure intellect. And finally, I will discuss the way in which our society has placed great stock in science itself, as a sort of abundant fountain from which modern civilization flows–whether in the form of nuclear energy, advancements in medicine, genetic engineering, information technology, or hundreds of other fields of continuous research and development. I will use this last perspective as the platform from which to speak briefly on the role of the government regulator–and specifically that of the U.S. Nuclear Regulatory Commission, in ensuring that scientific developments are used in a safe and responsible manner.

The Scientist as God: Unleashing the Power of Nature

The development of the atomic bomb is one of the most pivotal scientific events of this century–and, perhaps, of this millennium. In 1939, operating in the fear that Germany under Hitler was developing a weapon that would use atomic energy, U.S. scientists began to urge President Roosevelt to begin preparations for atomic bomb research in this country. Not long thereafter, the Manhattan Project was born.

In December 1942, the first self-sustaining nuclear chain reaction was achieved under the direction of Enrico Fermi. Under the stands of Stagg Field at the University of Chicago, Fermi used 400 tons of purified graphite and 22,000 pseudo-spheres of uranium, stacked in 57 layers of cadmium sheets, to construct the first crude atomic reactor, known thereafter as the "Chicago Pile."

The actual development of the bomb was placed under the direction of another theoretical physicist, J. Robert Oppenheimer. In 1943, Oppenheimer selected Los Alamos, New Mexico, as the site for this work. On July 16, 1945, the first nuclear test explosion took place in the desert near Alamogordo, New Mexico, using a plutonium device. Interestingly enough, Oppenheimer code-named this first test bomb "Trinity."

The descriptions of the physicists and military leaders who witnessed the explosion of Trinity are revealing. From a distance of ten miles, physicist Otto Frisch recorded it this way: "Without a sound, the sun was shining. Or so it looked. The sand hills at the edge of the desert were shimmering in a very bright light." Enrico Fermi continued the description: "After a few seconds the rising flames lost their brightness and appeared as a huge pillar of smoke with an expanded head like a gigantic mushroom that rose rapidly beyond the clouds probably to a height of the order of 30,000 feet."

But it is Oppenheimer who provided perhaps the most moving account: "We knew the world would not be the same," he wrote. "A few people laughed, a few people cried. Most people were silent. I remembered the line from the Hindu scripture, the Bhagavad Gita. . . . 'I am become Death, the destroyer of worlds.'"

Only 21 days later, on August 6, 1945, the first uranium bomb, nicknamed "Little Boy," was dropped untested on Hiroshima, Japan, instantly killing over 75,000 people and seriously injuring approximately 100,000 more. As a functioning city, Hiroshima ceased to exist. Three days later, a plutonium bomb virtually identical to the Trinity device and known as "Fat Man" was dropped on Nagasaki, wreaking slightly lesser but similar results. Scientists indeed had unleashed the power of Nature in an unprecedented scale. The Atomic Age was born. As Oppenheimer observed, we have not been quite the same since.

As I hinted earlier, I do not intend to comment today on the moral or theological implications of nuclear physics or its applications. However, I certainly find it profound and sobering to understand that in this century, simply by applying the scientific method, our species managed to develop tools that conceivably could be used to destroy themselves en masse. To look at it another way, the scientist, by tapping the secrets of Nature, made it possible for the "doomsday" predicted by Christianity and other religions to be initiated by humans themselves. On the other hand, that same unleashing of Nature, and the fundamental understanding of the atom, its nucleus, and nuclear interactions, has led to enormous beneficial uses–from electrical generation, to agricultural progress, to the treatment of serious illnesses. But more about this later.

One more point I would like to make here is that, with the Manhattan Project and peripheral efforts, we saw the genesis of new societal partnerships that would include the Federal government, the military, private sector industries, and the university community. While these partnerships originated in the defense needs of the country at the time, they paved the way for subsequent joint efforts in other arenas.

The Scientist as God: Einstein and the Embodiment of Mind

Another way in which we can discuss the scientist as God–or, perhaps, as "demi-god"–is in the case of individuals such as Albert Einstein, who represent, for some, the pinnacle of human evolutionary achievement–the embodiment of mind. This is not a new phenomenon. Every civilization has placed great thinkers on a pedestal–sometimes because of their religious stature or reputed mystical powers, but often, as in the case of Aristotle or Isaac Newton, because of their keen thought processes and/or the practical technological achievements that resulted from their work. In some cases, an individual simply becomes associated with a particular movement in science or technology, and by that association becomes a symbol of the entire movement (for example, Bill Gates as a symbol of latter-day information technology).

In the case of Einstein, the foundations he laid in the form of his special and general relativity theories became the basis for an abundance of other achievements by a large number of other brilliant individuals. Nonetheless, he has endured as a singular, stand-out figure–almost an icon of what the rational, scientific human ought to be. I believe this is, in part, because his brilliant rationality was coupled with a conscience and a rigorous ethical standard. As Einstein stated, "Concern for [humankind] must always constitute the chief objective of all technological effort–concern for the big, unsolved problems of how to organize human work and the distribution of commodities in such a manner as to assure that the results of our scientific thinking may be a blessing to mankind, and not a curse."

An Evolution in Judgment: Weighing Both the Benefits and the Risks of Science

This quote from Einstein provides a natural segue into my third perspective. Since the dawn of the industrial revolution, modern society has placed great stock in science itself, as the source from which civilization evolves. At times, it has been easy to idealize scientific achievement by viewing it only in terms of its practical benefits, how the resultant technologies enhance our lives. This evaluation, however, has become more sophisticated over time. Today, we are more aware than ever that scientific and technological advances often are accompanied by risks, and that those risks must be weighed against the benefits.

To illustrate, consider a quote from yet another physicist (you can tell I love physicists), Richard Feynman, speaking at the University of Washington in 1963: "This power to do things carries with it no instructions on how to use it, whether to use it for good or for evil....We are happy with the development of medicine, and then we worry about the number of births and the fact that no one dies from the diseases we have eliminated....We are happy with the development of air transportation and are impressed by the great airplanes, but we are aware also of the severe horrors of air war. We are pleased by the ability to communicate between nations, and then we worry about the fact that we can be snooped upon so easily."

I am sure that you can think of many other examples, fields in which this balance must be struck between the benefits and the risks of scientific advancement. One example is the field in which I currently work, which involves nuclear energy and other civilian uses of radioactive materials. As the Chairman of the U.S. Nuclear Regulatory Commission (NRC), I frequently am faced with making decisions that involve weighing benefits and risks. For the remainder of this discussion, I would like to outline for you a few of these benefits and risks, and describe the role played by the nuclear safety regulator in making risk/benefit evaluations and decisions.

The Role of the Nuclear Safety Regulator

First, a bit of history. The starting point for the commercial use of nuclear energy came with the passage of the Atomic Energy Act in 1954. At that time, the NRC did not exist. The Atomic Energy Commission (AEC), created in 1946, had the dual responsibilities of promoting the growth of nuclear power and regulating its use.

Over the ensuing years, as nuclear power progressed from an experimental technology to an established source of electricity production, concern grew over the conflict of interest inherent in having promotion and regulation vested in the same agency. In the 1960's and early 1970's, the rapid growth in the number of nuclear power plants brought a corresponding increase in concern over nuclear safety, waste disposal, and the role of the regulator. In 1974, the Congress abolished the Atomic Energy Commission and created two new agencies: the Nuclear Regulatory Commission, led by a 5-member Commission, with an exclusively regulatory mandate; and the Energy Research and Development Administration (ERDA), which later became the Department of Energy (DOE).

In the two-and-a-half decades since, many events have added to the complexity involved in evaluating the benefits and risks of nuclear power. For example, several events have emphasized U.S. dependence on foreign energy resources, such as the 1973 Arab oil embargo, the 1978 revolution in Iran, and the 1991 Operation Desert Shield and Desert Storm. These events highlighted the vulnerability of relying too heavily on imported oil. They brought attention to the importance of energy security--the need for strategies that ensure reliable fuel sources--and diversity of supply--the importance of maintaining multiple technologies, as well as developing new technologies and improving user efficiency.

In 1979 came the accident at Three Mile Island–a watershed event that cut across all aspects of nuclear energy and nuclear regulation. This event, together with the multiple investigations that followed, showed the need for profound improvements in analyzing the character and risks of severe accidents, and the need for more clearly spelled-out reactor safety objectives.

A third factor has been the ever-increasing awareness of the environmental consequences of energy use. In the 1970's, the increased U.S. attention on urban smog, acid rain, and other effects of pollution was reflected in public and private efforts to lower emissions. More recently, the focus on greenhouse gases and global warming concerns has prompted ambitious commitments toward additional emission reductions. Some proposed strategies include further development of renewable energy technologies, more efficient use of our existing electricity supply, and the continued operation and optimization of existing nuclear power plants.

As a nuclear safety regulator, the NRC is focused, not on promoting or discouraging the role of nuclear power as part of the U.S. energy mix, but rather on ensuring safety through the implementation of a sound regulatory framework. Such a framework includes several elements: (1) the ongoing development of a set of regulations that places the greatest emphasis in areas of greatest health and safety risk; (2) effective and efficient programs for issuing licenses, inspecting our licensees, evaluating the results, and ensuring that our safety regulations are enforced; (3) measures to involve the public in our decision-making process–as well as public interest groups, the Congress, the industry, and other stakeholders–to ensure that decisions are as informed as possible, and that public confidence is maintained; and (4) continual self-assessment to ensure that, as regulators, we impose only the necessary degree of burden on those we regulate.

The regulation of nuclear safety involves not only operating power reactors, but also other elements of the nuclear fuel cycle, such as gaseous diffusion plants, fuel fabrication facilities, the eventual decommissioning of power reactor facilities, and the storage, transportation, and disposal of low-level and high-level radioactive waste. In addition, we regulate a wide range of more narrowly focused technologies that involve the beneficial uses of radioactive material. Many of these nuclear technologies are less well-known, but have a substantial positive impact on our day-to-day lives. I will give you a few examples.

<u>Medical Uses</u>

As with all beneficial uses of nuclear technology, medical uses of radioactive material introduce accepted risks to patients, medical workers, the public, and the environment. Current medical applications of radioactive materials employ a number of different radioisotopes in a variety of chemical and physical forms that can lead to radiation doses and contamination with varying levels of risk significance. When we accept these technologies, we base our acceptance on an evaluation that the added risk is outweighed sufficiently by the benefit gained.

One type of nuclear medicine employs unsealed radio-labeled compounds, known as radiopharmaceuticals, both for diagnosis and treatment of patients via intravenous injection, oral ingestion, or inhalation. Pictured here is a bone scan, in which the internally deposited radioactive material creates a computerized image of the skeletal structure of a patient. In a similar way, since the element iodine has a natural affinity for the thyroid gland, radioactive iodine can be used to determine whether the organ is functioning properly. Small quantities of radioactive material thus can be used to diagnose disease.

In contrast to these diagnostic studies, therapeutic treatment typically uses much higher levels of radioactivity to deliver larger doses. To correspond to the increased risk of harm from the therapeutic use of radioactive material, we place greater regulatory controls on handling and administering these therapeutic doses.

In addition to nuclear medicine, radiation therapy for cancer and other medical conditions is achieved via teletherapy and brachytherapy. The objective of teletherapy is to focus the radiation from a sealed radiation source into a radiation beam that can deliver a precisely measured radiation dose to a defined volume of cancerous tissue, or tumor. In brachytherapy, a variety of smaller sealed sources can be inserted into the body using an applicator, implanted directly into tissue, or introduced via an implanted catheter. Medical personnel are able to minimize unwanted dose to people other than the patient by inserting sources from a remote shielded location, resulting in a quicker treatment that is safer for the workers and less demanding on the patient.

The complex devices involved with teletherapy and remote brachytherapy depend upon computerized electronic interfaces for planning and delivering treatment at high radiation levels, and are designed to shield the radiation sources when they are not in use. As a result, our regulations require testing the accuracy and reliability of the devices–both to deliver the planned treatment correctly to the patient and to shield against unplanned doses to workers and visitors.

Research

Radioactive materials also are used for a wide variety of research projects. In genetics, radioactive tracers are used as markers in DNA sequencing. High levels of radioactivity can be used to sterilize bacteria, viruses, plants, and animals. Small biological specimens can be irradiated in self-shielded irradiators. As an example, sterilized pests, such as tsetse flies, can be released into the wild to diminish the breeding successes of their wild counterparts. The small irradiator devices used for such activities undergo regulatory review to ensure sufficient protection of the user from direct exposure to the large radioactive sources.

Low-level radioactive tracers can be used in environmental research to identify, for example, the metabolism and/or migration habits of a free ranging endangered animal. Radioisotopes are used to develop new strains of crop foods, to increase the effectiveness of fertilizers, and to analyze environmental pathways and degradation of pesticides. Geological research also may incorporate tracer studies. For example, injecting the ground with radio-labeled steam can be used to map oil fields. Studies like this warrant careful regulatory assessment of the impact on the environment and the risks to humans via food, water, soil, and airborne contamination. Again, as regulators, we focus our decisions on minimizing the risk while maintaining the benefit from radioactive material use.

Industrial Uses

The final area involves the wide range of industrial uses of nuclear technology. In industrial radiography, radiation is used to inspect the internal structure of manufactured parts and metal welds for defects. Typically, a high activity source is placed into a guide tube in the area of interest. Radiation passing through the object to be tested strikes special radiographic film on the other side, producing an image much like a common X-ray image that shows cracks or other flaws.

In construction and manufacturing, nuclear gauges are used as an inexpensive, yet highly reliable and accurate method of measuring thickness or density. Fixed gauges are used in factories to monitor production and to ensure quality–for example, to verify the level of soda in a sealed can. Portable gauges are used in agriculture and civil engineering to measure soil moisture and asphalt density. The food, medical, and manufacturing industries often use large panoramic irradiators to deliver large doses of radiation to sterilize the materials or to change their physical properties. For example, medical supplies such as rubber gloves, cloth bandages, and contact lens solutions are sterilized in this type of irradiator. Wood and plastic composites are sometimes irradiated to increase their resistance to abrasion and to decrease maintenance.

> In each of these industrial applications, the focus of the regulator is to anticipate the risks, to require proper controls, and, by doing so, to ensure the protection of the public health and safety and the environment.

Conclusion

In closing, I hope that my discussion of “The Scientist as God” has broadened your appreciation of science and the scientist, by highlighting factors to consider that go beyond merely the scholarly and technical dimensions of solving a physical problem–factors such as the ethical considerations, the need to balance the benefits and risks of a technology, and the importance of regulatory controls. I hope that you understand a little better the partnerships that must exist, on highly scientific issues, that involve the government, the industrial sector, educational and research institutions, and the public. And I hope that I have stimulated some of you to consider careers in science, engineering, and technical fields.

Thank you for your attention.