Non-proliferation and advances in nuclear science

P. K. Iyengar

The issue of nuclear non-proliferation has been with us for the last four decades. Initial attempts at the globalization of nuclear technology, through the Baruch plan and the Atoms for Peace initiative, did not succeed. The Non-Proliferation Treaty (NPT) initiative lead to a global divide, with five weapons countries ever increasing their arsenal, but not sharing with the rest of the world peaceful applications of nuclear energy Over a period of time other countries have developed the requisite science and technology, demonstrating the universality of science and the capability inherent in all societies in the world. The emergence of the so-called *threshold states* points to the failure of the NPT in its objective of universal nuclear disarmament. The collapse of communism and the end of the Cold War era have triggered the need for a reappraisal of the objectives of the NPT, and the preconditions necessary for its universal acceptance.

While global politics will always play an important role in determining the framework of such treaties, many of the core issues involved are technical in nature, and are not readily understood by administrators and power-brokers. So far the NPT has concentrated on safeguard regimes based on technologies relating to the production of uranium and plutonium in nuclear reactors, and on their potential diversion for use in nuclear weapons. As nuclear science advances, however, nuclear technology (both peaceful and for weapons) will change, and for the NPT to remain relevant it must reflect these changes. At this juncture, when the NPT is coming up for review in a year's time, it is important for physicists to take a fresh look at recent advances in nuclear science, and inform the policy makers and the public at large about their potential for impacting nuclear technology in the future. Here I would like to highlight a few such advances, and consider their implications for the NPT.

Technical developments

It is an oddity that of all the natural isotopes only ^{235}U is readily fissionable by neutrons, and can thus be used to make a chain-reacting explosive. The discovery of plutonium and other man-made transuranics extended the list of raw-materials that can be fashioned into a nuclear explosive. In the early days different methods for separating ^{235}U were invented. Newer methods have since evolved, such as the use of centrifuges and laser-based isotope separation. Even the efficiency of older methods has been improved, and they have been made less expensive by newer technology. Access and availability of high technology is the only constraint for any nation to produce the small quantities of ^{235}U that are required to make a single explosive. The world has witnessed both open and clandestine efforts to acquire this technology and has seen it used successfully. This has demonstrated the fears of the pioneers that however poor the economic or industrial resource of a country, it may not lack intellectual resources, and in the long run, in spite of disincentives that may be placed in its path, any nation that wants such a device badly enough will get it. Thus, *as long as nuclear non-proliferation initiatives restrict their attention to the spread of nuclear materials and know-how from the 'haves' to the 'have-nots', without taking into account the needs, fears and capabilities of the non-nuclear states, they are doomed to failure.*

In addition to the improvement of existing technology, there are some promising avenues of research that could eventually lead, or have already led, to alternate routes of nuclear technology, and that must therefore be taken note of.

Accelerator-based techniques

The production of plutonium is essentially a slow process, because of the need to supply one neutron per atom for a nuclear transformation. Many competing ideas were floated in the early days, along with that of the production reactors which achieved success in a short time. Of these mention must be made of the accelerator-based neutron source. Lewis of Canada used to argue for producing neutrons 'by the gram' using accelerators and the spallation reaction. These ideas were given up considering the economics and the low efficiency of accelerators of that time. However accelerator technology has now reached a stage where the efficiency from busbar to beam power can be as much as 50% making such schemes technically viable. Indeed, very recently, Carlo Rubbia, the former Director-General of CERN, has come up with a suggestion for a nuclear-energy producing device based on the accelerator, that avoids the dangers of a critical system like that which caused the accident at Chernobyl[1]. The point is that criticality is a concept rather peculiar to fission reactor, nuclear physics simply demands that uranium atoms be exposed to a neutron flux large enough to produce a rate of reaction with the right power-density for commercial exploitation—and not necessarily a self-propagating chain reaction[2]. Even the economics of such a device looks attractive, and if further research shows the scheme to be practicable, it could substitute for the many advanced reactor systems presently being developed worldwide. Suggestions along the same broad lines have also come from a group of American researchers at Los Alamos[3]. It is clear that such a device will make it easy to produce plutonium or ^{233}U. Are we going to restrict the spread of accelerator technology just because it has a potential for proliferation? What happens to the many uses of accelerators for basic research, synchrotron radiation, isotope production for use in the areas of medicine and hygiene, etc.?

Nuclear isomerism

Another idea of interest was published in the monthly journal *Energy & Technology Review*, of the Lawrence Livermore National Laboratory[4]. Nuclear physicists are discovering many nuclear isomers through heavy-ion collisions. To quote the abstract. 'Nuclear isomers, materials with unusual excited nuclear states, can store extremely large amounts of energy, and may prove useful as fuels and explosives. We are identifying the properties of nuclear isomers and developing ways of releasing their energy.' This paper discusses methods of triggering the decay of nuclear isomers, releasing energy instantaneously, as in a nuclear explosive. While the methods are neither simple nor obvious, there remains the possibility of intense energy release from a non-fission, non-fusion, transformation in the nucleus. Does this not indicate that as we understand nucleii more deeply—their structure, their behaviour, and the transformations that they can go through—we will come up with entirely new ways to release nuclear energy? This highlights a shortcoming in the entire approach of the NPT.

Other possibilities

It is again as a result of intense nuclear research that a possible island of nuclear stability has been identified in the high-mass region. Efforts to reach this island of stability are on, and will perhaps be achieved by very subtle uses of the properties of nucleii. These stable heavy elements will have properties like ^{239}Pu, but *with extremely small critical masses.* They would therefore be prime candidates for a compact nuclear explosive.

An extension of the principle of the hydrogen bomb to the so-called radiation weapon (or the neutron bomb,) gave a new dimension to the area of nuclear explosives. Small, field-usable tactical weapons which destroy men but not the environment seem to have been devised and deployed. Though these are still secret, it is obvious that considerable work has gone on in the design of fission-trigger free fusion systems, which would eliminate the need for fissionable material.

Implications for non-proliferation

The areas of research indicated above are, of course, as yet far from ending in demonstrable nuclear technology. However, they do indicate that as nuclear science develops, different technologies will develop that have weapons potential—and this cannot be wished away. It would be difficult to anticipate the various scientific advances, and even if that were possible it would not be feasible to exercise control over all the technological developments—as history has already shown. Therefore a non-proliferation regime that is based on controlling the flow of information and technology from the elite few to other nations of the world, simply cannot work. Non-proliferation efforts need to concentrate on methods by which sovereign countries, and humanity at large, will *voluntarily* accept universal abstinence from acquiring and using nuclear weapons by all, irrespective of their economic standing and perceptions toward preserving their military superiority. Just as we have largely succeeded in a total ban on chemical and biological weapons, we should work towards a universal renunciation of nuclear weapons. In order to achieve this, the first step is to accept a non-discriminatory and universal non-proliferation regime—there cannot be 'nuclear' and 'non-nuclear' clubs. The recent trend amongst the erstwhile Soviet states, toward voluntary abstinence, is a beginning in this direction. It needs to be followed by concrete proposals from the nuclear powers for a phased elimination of their nuclear arsenals. Nuclear deterrence capability, if thought necessary, should be maintained by the United Nations, where decision-making is a collective responsibility, and not by individual member-states.

As regards the developing world, we should appreciate the need for expansion in the capability for generating nuclear electricity in these countries, using appropriate new technologies. New efforts in R & D are required to design and test nuclear-power producing devices incorporating safer and user-friendly concepts. The fear of environmental degradation by the use of fossil fuels, and the depletion of fossil fuel resources, lends urgency to these efforts. A genuine desire on the part of the developed countries to help in the process of economic growth in the developing world, as well as restructuring the collapsed system in the former Soviet bloc countries, with a non-discriminatory offer of high technology and technology-transfer for the peaceful uses of nuclear energy, can alone assuage the suspicion in a large part of the world. Having achieved economic gains and prosperity, it should then be possible for developing countries to take a more philosophical stand, that the days of deterrence capability and security concerns are past.

Conclusion

As nuclear science develops, new weapons technologies will emerge that cannot be foreseen or restricted. If rampant nuclear proliferation is to be averted, suspicions amongst the developing countries need to be assuaged, especially regarding the bonafides of the nuclear powers. Non-proliferation strategies must therefore be sensitive to the interests and fears of threshold states and non-weapon countries. Constructive nuclear technology, such as for generating electricity, must be globalized. Ultimately, only economic progress will give developing countries the requisite confidence to accept military constraints.

At the dawn of the nuclear era, proposals to establish an international 'Atomic Development Authority', to control all nuclear materials and to take the lead in R & D on the peaceful uses of atomic energy, were put forward at the United Nations—the Baruch Plán. Then the proposals sank due to the mutual suspicions of the Big Powers. Now, in the post-Cold War era, we have another opportunity to usher in a truly global world order, by ensuring that similar proposals are universally adopted and implemented. This time we must act swiftly and seize the opportunity.

1. *An Energy Amplifier for Cleaner and Inexhaustible Nuclear Energy Production Driven by a Particle Beam Accelerator* (eds Carminati, F. *et al*), CERN/AT/93-47 (ET).
2. Iyengar, P. K., *Impact of Nuclear Research on the Future Technology of Nuclear Power*, 15th Shri Ram Memorial Lecture, 1979.
3. Bowmann *et al.*, *Nucl. Instr. Methods*, 1992, A320, 336.
4. *Energy & Technology Review*, a publication of the Lawrence Livermore National Laboratory; January–February 1993, p. 101.

P. K. Iyengar, a former Director of the Bhabha Atomic Research Centre, Trombay, and a former Chairman of the Indian Atomic Energy Commission, lives at 33 Saras Baug, Sion–Trombay Road, Deonar, Bombay 400 088, India.