POLICY FORUM: NUCLEAR RESEARCH

The Past and Future of University Research Reactors

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On 20 December 1951, the Experimental Breeder Reactor at the Department of Energy's Idaho National Engineering and Environmental Laboratory generated the first electricity produced by a nuclear fission reactor in the world. A totally new technology for the commercial production of electricity had arrived, which would require many highly trained engineers capable of designing and building future nuclear power plants. Federal funding flowed, and universities established nuclear research reactors as an important teaching tool for nuclear engineering and science students, with benefits even for liberal arts students. At North Carolina State University, on 5 September 1953, the first university-based "openly operated" nuclear reactor went critical.

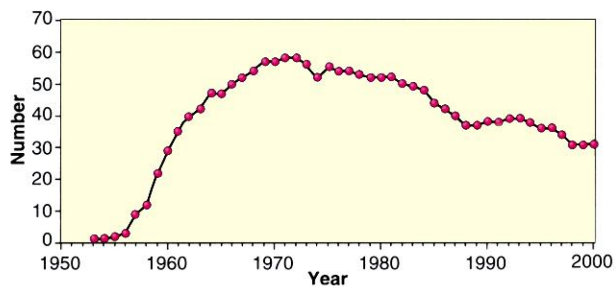
By the late 1960s, there were 58 University research reactors (URRs). However, URRs have steadily declined in numbers from the early 1970s (*1*) to the 28 of today. This decline, which has not been planned or coordinated, has implications for education and training and for a wide variety of research activities. Today, URRs are on a path to extinction. Partly because of the breadth of their possible applications, no single federal entity has been charged by the Congress with maintaining them. They appear to have suffered unduly from the vicissitudes of the nuclear power industry. Here, I discuss the causes of this decline and what role URRs can and should play in the future.

URRs and Education

All URRs operate under Nuclear Regulatory Commission licenses, which must either terminate or be renewed after 20 years. These licenses limit the steady-state power rating of URRs to no more than 10 megawatts (MW). Half of the extant URRs are rated at 500 kilowatts (kW) or higher. Nuclear materials at URRs are subject to Nuclear Regulatory Commission security requirements (now under review), which consider theft, diversion, and sabotage. All the URRs are used in varying degrees for both research and training.

Universities having an on-campus reactor have been in the strongest position to compete for scarce new faculty talent. University administrators regarded their research reactors as valuable, although costly, assets.

However, in the late 1960s and early 1970s, the projected growth of electricity demand failed to materialize, while costs of nuclear power plants under construction soared. Power reactor projects were canceled, from 4 in 1974 to a peak of 10 cancellations in 1980 alone. Prospective engineering students immediately interpreted these cutbacks as signs that nuclear engineering was an unpromising field, so that undergraduate and master's degree enrollments began a steady decline of about 3% per year for the next 10 years until 1992, when the decline abruptly increased to more than 15% per year. Ph.D. enrollments were hit much less hard (*2*).



Numbers of University Research Reactors, 1950–2000.

Beginning in the late 1960s, many universities decided to close their nuclear engineering departments and to shut down their reactors.

Nevertheless, URRs are important, perhaps critical, for successful nuclear engineering and science programs (*3*). URRs provide an opportunity for young faculty and students to hone their research skills in preparation for entering the competitive arena of large multiuser research reactors. Furthermore, when such facilities are down, URRs provide possible back-up laboratories for work that does not require a large reactor.

URRs have advanced research in fields other than nuclear science and engineering and have provided for science education (*4*). The 1994 Nobel Prizes in physics were awarded to two individuals for work carried out at URRs. Applications of reactor-generated radiation (principally neutrons) to academic research have continued to grow. URRs have had an impact on research in radiopharmaceuticals, diagnosis of cancers and arthritis, and neutron-capture cancer therapy; development of new high-technology materials—metals, semiconductors, ceramics, and polymers; analysis of works of art; geochronology and geochemistry; and basic physics studies, such as the charge neutrality of the neutron and the linearity of wave mechanics.

Funding

Federal government sources of funding for most of these studies, such as the National Institutes of Health (NIH) and the National Science Foundation (NSF), do not provide URR maintenance and operational costs. The URR host university has had to cover operating costs from its general funds. Because academic researchers must pay for use time, technical assistance, and the special equipment their research requires at a URR, they often prefer to use national laboratory reactors, where neutrons and technical assistance are provided at no cost. But this means that they have to travel to an often-distant national laboratory and to compete with other researchers for scarce user time and that their own home URRs are underutilized.

Early support for URRs came mostly from the Atomic Energy Commission (later the Department of Energy) with some state, other federal agency, and industrial funding. The NSF at one time provided support for some of the "at reactor" costs of research, but that eventually disappeared. DOE support for URRs gradually became based largely on their relevance to the nuclear engineering and the nuclear power infrastructure rather than to basic science or other academic research and training. DOE funding for URRs now comes entirely from the Office of Nuclear Energy Science and Technology, with none emanating from the Basic Energy Sciences Division.

In 1988, a National Research Council report (*5*) recommended that federal funds be provided for base support for the nation's URRs and that the federal government, in partnership with the universities and the national laboratories,

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develop and implement a national research reactor strategy. A single federal agency would be designated to administer support programs and a standing advisory structure would be created to advise, on a continuing basis, on all aspects of the program. The panel further recommended that \$20 million be made available annually for operational support and facility upgrades of university research and educational reactors. In today's dollars that would be more than \$30 million. None of these recommendations were followed, although DOE did provide some funding at a lower level. The URR situation continued to deteriorate.

In a 1994 report to the Senate (*6*), the Secretary of Energy, Hazel O'Leary, stated that the URRs could be sustained by the infusion of a relatively modest but assured base of funding and that the total operating costs of all URRs were equivalent to the cost of operating just one DOE research reactor. She recommended that \$6 million per year for 5 years be provided for the upgrade of the 36 reactors then in operation. She also suggested exploring a network of university reactors that would provide a feeder system to support national and DOE research program requirements. These recommendations, likewise, were never implemented.

In 2000, the Corradini panel (*7*) recommended that DOE continue its University Reactor Fuel Assistance and Support program at the level of \$4.3 million per year, and that it add to this a program under which a university or a group of university collaborators would be able to compete for grants to improve instrumentation and upgrade facilities and training. This was not to cover ordinary operating costs. The recommended programs would rise to \$15 million annually. The panel recognized that not all URRs would be successful in this competition, and that their proposal might not completely stem the continuing demise of URRs.

Recent Funding Recommendations

Three major universities, Cornell, University of Michigan, and MIT, recently announced that they were considering the permanent shutdown of their research reactors. In response, a DOE panel (*8*) recommended that these three universities apply for \$250,000 one-time grants to avert an immediate shutdown. The panel further recommended the establishment of geographically distributed regional facilities: five URRs for reactors operating at a power level of 500 kW or higher and three University Training and Education (T&E) reactor facilities operating at lower power levels. Up to \$20 million of federal funds would be made available annually for the entire group. The final outcomes of the DOE panel report are yet to be clear, but the recommendation of a one-time offer of funds to Cornell, University of Michigan, and MIT was rejected by DOE.

A new DOE program to save the URRs (*9*) is an award of \$100 thousand to \$2 million per year, renewable for up to 4 years, to universities or university collaborators. Under this program, called the Innovations in Nuclear Infrastructure and Education, Research and Education Grants (INIE), creating integrated programs among associations of university research and training reactors is encouraged. Because some URRs or T&E reactors not winning in the first round may lose support from their own administrations and may be slated for elimination, DOE intends to retain the Fuels and Reactor Sharing and the Reactor Upgrade programs and will give priority in these two areas to non-INIE participants.

The INIE program will have to grow rapidly and substantially (by a factor of 10) from its initial funding level if it is to approach the funding levels recommended by earlier panels. The program is not structured to provide base operating funds, so that the problem of prospective users having to pay for their neutrons at the URRs, while getting them free at the national laboratories, remains.

Other Approaches

There are additional possibilities for reversing the central problem of underutilization at URRs: The DOE approach to funding could be broadened, although the DOE Office of Nuclear Energy Science and Technology funding of URR improvements and outreach should continue, but it should be augmented with DOE Basic Energy Science (BES) Division funding for research in fields other than nuclear engineering and science. The BES Division is already the steward of several other types of national multiuser facilities.

Another possibility is to establish formal pairings between URRs or groups of URRs and DOE laboratories with research reactors. I would encourage the National Institutes of Health, National Science Foundation, and Nuclear Regulatory Commission to include support for URR operational and maintenance expenses in their support for projects that plan to use a URR facility.

Although these changes might very well put the URRs on a thoroughly sound footing, they are unlikely to occur unless some new kind of federal mechanism for coordination is created and a transparent evaluation process is established and applied to every URR and T&E reactor. A cooperative stewardship model advocated by a National Research Council Committee on Developing a Federal Materials Facilities Strategy (*10*) could provide a starting point for developing a collective URR model.

A number of URRs serve numerous users beyond their campus and local communities. Taken together they are of considerable importance. URRs will be particularly important in a feeder system when the new National Spallation Neutron Source multiuser facility opens in 2006. It is likely that their continuation requires a totally new approach to assuring base level support. Recent new efforts by the DOE to save them need to be applauded and endorsed by Congress and executive branch leaders and augmented by new interagency agreements and commitments that enable their sustained use for beneficial purposes as first envisioned by the Atoms for Peace Initiative (*11*).

References and Notes

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12. M. Fleishman organized the data for the graph and provided valuable comments.