University Research Reactors

A Brief Overview

Presented to

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Presented by

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URR Introduction

1. U.S. Federal Law recognizes three types of reactors: power-production, test, and research. Research reactors are limited to:

    - Power levels of 10 MW or less.
    - No fueled loops with forced circulation of coolant.
    - In-core experiments of less than 16 square inches in cross-sectional area.

    Research reactors have low inventories of fission products and lack the thermal hydraulic energy to disperse fission products in the event of an accident. They are suited for siting on university campuses.

2. Sixty-four university research reactors (URRs) were licensed and built. Twenty-seven remain in operation. Closures averaged two per year for the last two decades.

3. URR power levels range from a few watts to 10 MW. (See table for list of operating U.S. research and test reactors.)

URRs Are a Unique National Resource

1. URRs are valuable sources of neutrons providing multidisciplinary research and educational opportunities involving:

    - Boron Neutron Capture Therapy to treat brain cancer and metastasized melanoma.
    - Cold Neutron Scattering for performing fundamental physics and materials analysis.
    - Neutron Radiography / Tomography / Radioscopy of materials and components.
    - Radiation Effects on materials.
    - Neutron Activation Analysis to qualify and quantify trace elements in: environmental pollutants, geological samples, biomedical tracers, forensic samples, etc.
    - Radiopharmaceutical development.
    - Digital Monitoring and Control of reactors.

URRs Need Base Support

1. URRs receive inadequate support for replacing and upgrading reactor operations instrumentation, controls, and equipment.

2. URRs receive no base support for a scientific infrastructure (staff/instruments).

3. URRs receive no base support for reactor operations.

4. Many URRs offset operating costs by charging for neutrons. Thus, most researchers conduct experiments at DOE Labs where neutrons are free.

5. The net result is a self-reinforcing negative spiral.

   - URRs receive little research income and that income is not steady from year to year.
   - URRs cannot hire technical staff to assist potential faculty users.
   - URRs cannot equip their facilities with state-of-the-art instruments.
   - URRs become less and less attractive to researchers.

Operating U.S. Research and Test Reactors

U.S. Nuclear Regulatory Commission Licensees		
Facility	**Reactor Type**	**Power (kW)**
Aerotest Operations	TRIGA Conversion	250.0
Armed Forces Radiobiological Research Institute	TRIGA Mark II	1000.0
Cornell University*	TRIGA Mark II	500.0
Dow Chemical Company	TRIGA Mark I	300.0
General Electric Co.	Tank	100.0
Idaho State University*	AGN-201	0.005
Kansas State University*	TRIGA Mark II	250.0
Massachusetts Institute of Technology*	Tank, LW Moderated, HW Reflector	5000.0
U. C. Davis Nuclear Radiation Center*	TRIGA Mark II	2000.0
National Institute of Standards and Technology (Test Reactor)	Heavy Water	20,000.0
North Carolina State University*	PULSTAR	1000.0
Ohio State University*	Pool, LW Moderated	500.0
Oregon State University*	TRIGA Mark II	1100.0
Pennsylvania State University*	TRIGA Conversion Mark III	1000.0
Purdue University*	Pool, LW Moderated, Plate Fuel	1.0
Reed College*	TRIGA Mark I	250.0
Rensselaer Polytechnic Institute*	Critical Facility, LW Moderated	Critical
Rhode Island Nuclear Science Center	Pool, LW Moderated	2000.0
Texas A&M University*	TRIGA Conversion	1000.0
	AGN-201M	0.005
University of Arizona*	TRIGA Mark I	100.0
University of California - Irvine*	TRIGA Mark I	250.0
University of Florida*	Argonaut	100.0
University of Massachusetts (Lowell)*	Pool, LW Moderated, Graphite Reflector	1000.0
University of Michigan*	Pool, LW Moderated	2000.0

Facility	Reactor Type	Power (kW)
University of Maryland*	TRIGA	250.0
University of Missouri - Columbia*	PWR, Open Pool, LW Moderated &Cooled	10,000.0
University of Missouri – Rolla*	Pool, LW Moderated	200.0
University of New Mexico*	AGN-201	0.005
University of Texas - Austin*	TRIGA Mark II	1100.0
University of Utah*	TRIGA Mark I	100.0
University of Wisconsin*	TRIGA Conversion	1000.0
U.S. Geological Survey	TRIGA Mark I	1000.0
U.S. Veterans Administration	TRIGA Mark I	20.0
Washington State University*	TRIGA Conversion	1000.0
Worcester Polytechnic Institute*	Pool, LW Moderated	10.0

*University Research Reactor

U.S. Department of Energy & Army Reactors

Facility	Reactor Type	Power (kW)
Aberdeen Proving Grounds	APRFR, Fast Burst	10.0
Argonne National Laboratory – West	NRAD, TRIGA Mark II	250.0
Hanford (Test Reactor)	FFTF	400,000.0
Lockheed Martin Idaho Technologies	Advanced Test Reactor	250,000.0
	Advanced Test Reactor Critical Facility	5.0
Los Alamos National Lab.	Godiva, Fast Burst Flattop Comet Planet SKUA, Fast Burst	Critical Assembly
Oak Ridge National Lab. (Test Reactor)	HFIR, Tank	85,000.0
Sandia National Laboratories	ACRR	4000.0
White Sands Missile Range	FBR, Fast Burst	10.0

Source: Brian Dodd, Research Reactor Specialist, IAEA, and the National Organization of Test, Research, and Training Reactors.

Administrative Organization

1. Most URRs were initially constructed for nuclear engineering and radiological science research and education.

    - Teach reactor design, core physics, nuclear safety, radiological protection.

    - Support research in reactor physics, cross-section measurements, and reactor component development.

2. The mission of the most URRs (100 kW or >) eventually expanded to encompass the activities of other academic departments:

    - Trace element identification (Earth and Planetary, Nutrition, Civil (air pollution)).

    - Neutron scattering (Materials, Biology).

    - Neutron Physics (Physics).

    - Bulk Irradiation Damage (Materials Science).

    - Nuclear medicine.

3. As a result of the changing mission, some universities separated their URR from their Nuclear Engineering Department. Thus, two administrative relations are found:

    - Reactor Manager/Director → Department Head (NED) → Dean of Engineering.

    - Reactor Manager/Director → Laboratory Director→ Provost/Vice-President of Research.

Political Organization

1. Nuclear Engineering Departments are represented by NEDHO, the Nuclear Engineering Department Heads Organization. It meets twice a year rotating between American Nuclear Society and ASEE conferences. NEDHO focuses on the Department of Energy (DOE) in an effort to promote funding for nuclear engineering education.

2. University research reactors are represented by TRTR, the Test, Research, and Training Reactor Organization. It is formally incorporated, and meets annually usually at the location of its chairman. TRTR focuses on the U.S. Nuclear Regulatory Commission (NRC) in an effort to rationalize URR regulation. TRTR has a subcommittee that interacts with DOE.

Conflict of Interest: NEDHO and TRTR

1. NEDHO and TRTR sometimes disagree on the desired DOE policy because each has different goals:

    - Some members of NEDHO want DOE dollars solely for the support of academic programs. NEDHO priorities are research funding. Nuclear Engineering Education Research (NEER) first, then Nuclear Energy Research Initiative (NERI), NED graduate fellowships, and NED matching grants.

    - TRTR wants DOE dollars for the direct support of URRs (fuel assistance, instrumentation upgrades). Very little of the funding received by an academic department ever "trickles down" to a URR. (See URR Funding Mechanisms.)

2. DOE normally focuses its attention on NEDHO's requests rather than those of TRTR because:

    - NEDHO consists of tenured senior faculty whereas TRTR is mostly non-tenured staff.

    - URR mangers who work for a Department Head are often explicitly directed not to interact with DOE.

URR Federal Funding Mechanisms

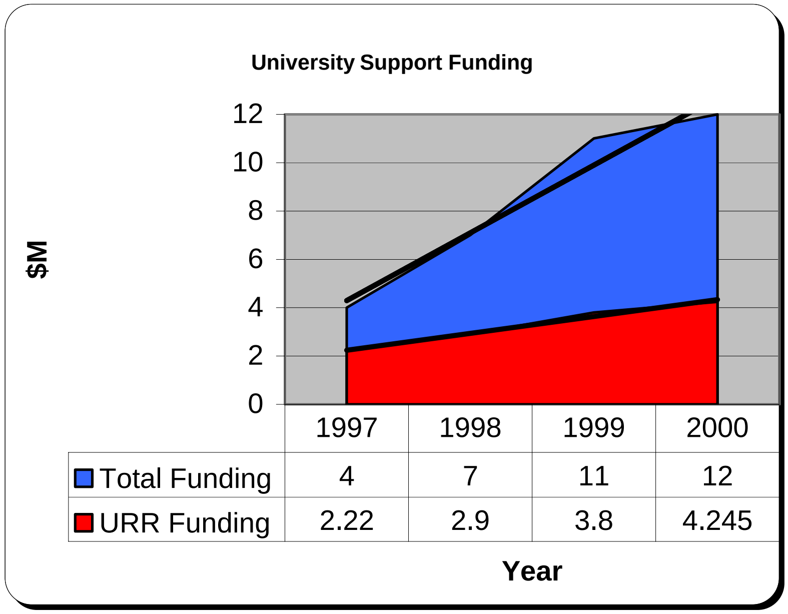
1. DOE provides Fuel Assistance to URRs. These funds cover the entire fuel cycle (front and back end). It is essential for higher power URRs that these funds remain distinct from other nuclear engineering appropriations. If these funds were merged with other programs, the possibility of their being diverted to another program would exist. Any interruption of these funds would force closure of these URRs.

2. DOE provides Reactor Sharing funds on a peer-reviewed basis to URRs. These funds were originally obtained from the surplus (if any) in the fuel assistance budget and were given for the purpose of allowing universities that lacked a URR to use one. More recently, this program has become independent of the fuel assistance budget and 35% of the funds may be spent on the host university.

3. DOE provides Instrument Upgrade funds on a peer-reviewed basis to URRs. There was no funding for this program from 1994 -1998. Of significance is that URR closures decline or stop in years when this program is active.

4. Most URRs offset operating costs by charging users for neutrons. This revenue does not provide for all operational needs. Faculty research grants typically provide little funding for reactor support.

Historical Funding for University Reactor Fuel Assistance and Support under DOE ONEST



- Funding was approximately level from 1994 to 1997.
- NED support consists of Nuclear Engineering Education Research Grants, Industry Matching Grants, Fellowships/Scholarships, other misc. programs.
- URR support consists of Fuel Assistance, Reactor Sharing Grants, Reactor Instrumentation Grants.
- Fuel Assistance funding has been approx. $2-3M/year since 1994. Most of the funding supports new fuel and shipment of spent fuel for high power URRs. Any remaining funds are used for converting URRs from high-enrichment uranium (HEU) fuel to low-enrichment uranium (LEU) fuel.
- For 1999-2000, the average Reactor Instrumentation Grant was $40k, the average Reactor Sharing Grant was $20k

Consequences of Neutron Charges

1. Non-power reactors that are operated by the DOE National Laboratories do not charge for neutrons. Also, the DOE labs often provide technical support to prospective users (equipment setup, instrument calibration, data analysis facilities, low-cost on-site housing, etc.). URRs cannot compete against this.

2. The consequence is that most researchers, including faculty from universities with a URR, prefer to conduct experiments at a DOE National Laboratory Reactor rather than at a URR.

   - URRs receive little research income and that income is not steady from year to year.
   - URRs cannot hire technical staff to assist potential faculty users.
   - URRs cannot equip their facilities with state-of-the-art instruments.

3. URRs are caught in a downward spiral.

URR Staffs

1. The focus at URRs is on reactor safety and not reactor utilization.

2. The available staff usually consists of:

   - Reactor Operators (often undergraduate students)
   - Senior Reactor Operators (often graduate students)
   - Reactor Supervisor/Manager (B.S or M.S.)
   - Reactor Manager/Director (M.S. or Ph.D.)

3. Very few URRs have staff who could take advantage of funding opportunities by developing research programs. In this respect, most URRs are dependent on an associated academic departments. This may explain why very few of the DOE-NERI awards (nuclear energy research initiative) have benefited URRs.

URR Utilization

1. URRs are a means of producing neutrons. URR utilization therefore changes with each new application of neutrons.

2. There are six broad areas of application. These are listed below in terms of the required flux level (high to low):

Area	Examples
Neutron Scattering*	Structure of Materials, Neutron Physics
Nuclear Medicine	BNCT, Arthritis, Bone Cancer, Isotopes
Materials Effects Studies	Radiation Damage and Enhancement
Neutron Activation Analysis	Trace Element Identification
Education and Training	Reactor Operation/Lab Courses
Outreach Activities	Tours for Public

*Neutron Scattering in no longer done at URRs. Missouri-Columbia and MIT programs were phased out because of a lack of resources. Cold Neutron Sources are being built at Cornell and Texas - utilization prospects include fundamental physics research and materials analysis.

3. Some URRs engage in commercial work:

- Commercial Neutron Activation Analysis
- Silicon Transmutation Doping
- Gemstone Coloration
- Radiopharmaceuticals production

Why are URRs Valuable?

1. The major argument for a university research reactor is that both research and education benefit when university faculty have state-of-the-art experimental resources in close proximity to their working place.

- Students, especially at the graduate level, learn by doing. On-campus URRs facilitate this.
- Experiments that require iterative runs can be done at URRs where time pressures are not prohibitive.

URR Value (cont.)

2. Activities that are best performed on university reactors include:

   - Researching radiation effects on materials for terrestrial and space applications.
   - Materials and components development using neutron radiography.
   - Applying NAA to novel applications of trace element analysis.
   - Digital control of reactors.
   - Nuclear Medicine.

   The common denominator for these activities is that each is cross-disciplinary using neutron science as a focal point. The best results are obtained when faculty from several departments have input to an experimental program and when multiple trials of a concept are possible.

DOE Definition of Neutron Science

1. DOE defines "neutron science" as "neutron scattering." To this end, facilities such as the Spallation Neutron Source, the former Brookhaven beam reactor and NIST are supported.
2. DOE does not recognize other potential uses of neutrons including materials damage studies, fission research, instrumentation and control, and radiography and imaging facilities.
3. University research reactors do not have the neutron fluxes to compete against national laboratories for neutron scattering research. However, they can excel at other uses of neutrons. Unfortunately, these uses are not recognized under the definition of neutron science and hence not funded.

Comparison of U.S. and European URRs

1. European URRs are far more productive than those in the United States. Mainly due to the availability of large scientific staff.
2. As an example, the Interfaculty Reactor Institute (IRI) at the Delft University of Technology in the Netherlands operates a 2 MW pool-type reactor, a 3 MeV pulsed electron accelerator, and positron beams. It has research groups in:

- Radiation Chemistry
- Radiation Physics (Materials Studies)
- Radiation Technology (Instrument Design)
- Medical Radiation Physics (Health Physics)
- Radiochemistry (NAA)
- Reactor Physics

3. The IRI Research Reactor operations staff ~18 people and a scientific staff of 141

4. Most URRs have no full-time scientific people.

Challenges to URRs

1. The major challenge is lack of utilization by faculty and researchers.

   - URRs lack adequate and modern research equipment.
   - Faculty who are experimentalists may opt to use a national lab reactor which offers higher fluxes, better equipment, support personnel, and lower costs.
   - Number of faculty who are experimentalists is declining because of cost of equipment and availability of simulations.
   - Faculty who have traditionally used URRs have retired.

3. Other factors that bear on URR closures include:

   - Most URRs were built in the 1960s and licensed for either 20 or 40 years. These licenses are now due for renewal. The effort involved is very substantial.
   - A negative perception by the campus community.

Summary of Previously Proposed Solutions

1. Base Support for Existing URRs

- Idea is to provide a one-time infusion of capital to equip URRs with scientific instruments and to provide on-going funds for both scientific support staff and reactor operations. Cost of upgrade is $30-50 M. Cost of support is probably $20-30 M per year.

  (+) Advocated by TRTR

  (-) Opposed by DOE on grounds that it's too costly and there are too many URRs.

2. Centers of Excellence

- Idea is to select on the basis of peer-reviewed competition 5-7 URRs that will become centers of excellence for nuclear science and education.

  (-) Opposed by NEDHO and TRTR because facilities that were not selected would almost certainly be closed.

3. Regionalization

- Idea is an alternative to centers of excellence. Object is to increase number of facilities that survive by forming regional centers that pair a high power and a low power facility so as to address needs of all prospective users.

  (-) Lack of consensus for the approach within NEDHO and TRTR.

4. European Feeder Model

- Idea is to pair URRs with national laboratories. The URR and associated academic departments serve to develop ideas and do proof-of-principle testing. Prototype testing and commercialization is done at the national laboratory.

  (+) Appears to work well in Europe (e.g., IRI at Delft).

  (-) Does not appear to be on DOE's radar screen as a possibility.

Summary of Proposed Solutions (Cont.)

5. Corradini Report (NERAC)

- Idea is to create a new program that would provide \$15 M per year to URRs on a peer-reviewed basis for "innovative research, training, or for outreach proposals."

  (+) Would be a valuable new source of funds. Also, encompasses all URRs (high and low flux).

  (-) Ignores the fundamental issue of base support.

Origins of Corradini Report

1. In 1997, DOE-NE (Bill Magwood) and NEDHO established a University Working Group (UWG) to advise DOE on policy initiatives in nuclear engineering. TRTR has only one member on the nine-member UWG.

2. TRTR attempted to focus the UWG on URRs so that DOE understood that:

- URRs served a broader clientele than NEDs.
- The needs of URRs were not the same as those of NEDs.
- URRs were at a serious financial disadvantage because neutrons were free at national laboratories.

3. TRTR asked DOE-NE to redo the 1988 National Research Council study, "University Research Reactors in the United States: Their Role and Value," that had been done under the leadership of Dr. David Shirley. DOE-NE determined that such a study would cost too much and take too long. So, a study by a NERAC Subcommittee was proposed instead. TRTR concurred and provided a list of suggested members. The purpose of the study at this time (Spring 1999) was solely to examine URRs.

4. The mission of the NERAC Subcommittee was subsequently expanded to three goals:

- Future of Nuclear Engineering
- Support for URRs
- Collaborations between DOE laboratories and university laboratories

The membership, with the exception of Commissioner Rogers, was not from the list suggested by TRTR. TRTR was unaware of both the revised mission and the altered membership.

5. The Corradini Committee was originally tasked with prioritizing URRs according to value to the U.S. nuclear engineering infrastructure. The Committee refused to take on this task after strong opposition by TRTR.

TRTR Comments

TRTR supports the Corradini Report recommendation for a $15M annual competitive research and training award program. Certainly, such a program would do much to address the issue of URR under-utilization.

However, TRTR is concerned that the Report recommendations do not address the immediate needs for reactor equipment and scientific instrumentation upgrades at most URRs. Nor does it address the issue of base support for URR operations.

Also, the Report specifically advocates TRTR consultation in developing new "qualification criteria" for the existing grant programs. However, there is concern that there is no specific mention for TRTR consultation in developing award criteria for the competitive research and training program.

TRTR Recommendations

1. Establish recognition that:

    a. URRs are multidisciplinary tools with uses beyond support of nuclear energy/engineering research.

    b. Nuclear science is more than neutron scattering. Other uses of neutrons (medicine, NAA, materials studies) are worthy of support.

    c. NERI-style research programs specific to URRs would increase utilization, but would not fund URR operations since neutron charges are a small fraction of total project costs.

2. Modernize existing URRs through an infusion of adequate funding for new reactor operations instrumentation and equipment, and for new scientific instrumentation to better equip current researchers/educators and attract new researchers/students.

3. Establish Base support for URR operation and base support for technical research groups that will enable faculty/students to use the URRs.

4. Revisit the 1988 National Research Council Study, "University Research Reactors in the United States: Their Role and Value," by Dr. David Shirley, which recommended base support within the context of the European feeder model and a "centers of excellence" program.

5. Study the European "feeder model" that pairs university reactors with national facilities. The former develop concepts and do proof-of-principle testing. The latter do prototyping.